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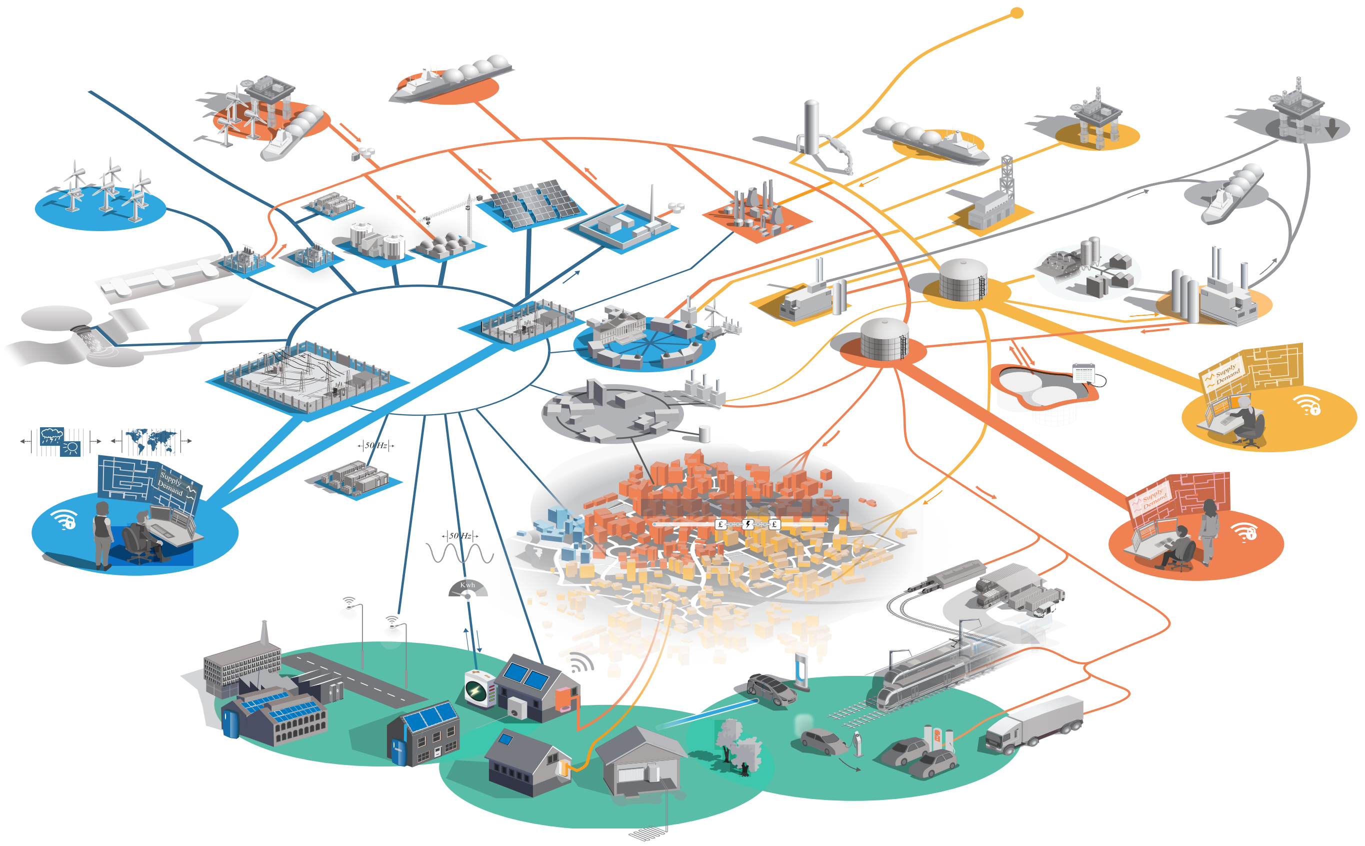
SHAPING A BETTER WORLD

Energy systems: A view from 2035

What will a future energy market look like?



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It is vital that experts like Arup continue to inform the debate about how we as an industry, along with government and other stakeholders can shape a better energy future that is decarbonised, secure and affordable. One thing is clear, as the energy system and market evolves over the coming decades we will continue to see growth and change.

ENERGY SYSTEMS IN 2035

What will a future energy market look like?

The next few decades are expected to be among the most transformative the energy sector has ever seen and the energy industry is at the forefront of this process; investing billions to ensure the system is fit for the future. I welcome this insightful report from Arup in setting out the possibilities for the future energy system.

By 2035 Arup envisages a world with a much more diverse range of heating sources, with significantly lower emissions, and where all new vehicles are electric. Achieving this vision will not be easy and industry is clear that achieving the same success in heat and transport as power generation will require strong leadership from Government, a stable policy framework and for system planners and regulators to take a whole systems approach.

The energy industry will have installed a smart meter in every home and business in the next two years; 53 million meters in all. This will open up new opportunities to manage the energy system in a smarter, more efficient way which will help keep energy bills down. It will also allow households and businesses to play a more active role in their energy management, combined with half hourly settlement, distributed energy and the uptake of electric vehicles could revolutionise how energy is produced and used.

The progress that has already been made is astounding: emissions from energy supply have been cut by 57% since 1990[1] and low carbon energy generation went from making up only 19% of total power production in 2008 to a record 53% between April and June 2017[2]. A mark of this progress is that in April 2017 we had the first day since the industrial revolution with no coal fired power generation on the system.

As Arup's report highlights, the changing system and the decarbonisation imperative will create new roles, interactions and dependencies, bringing with them new opportunities but also creating a number of challenges to overcome. Although significant progress has been made in generation, the report highlights the significant challenges to continue to cut emissions from the power sector, and the heat and transport sectors that have not yet seen progress.

Affordability will of course continue to be a priority beyond 2035 and the most effective way to sustainably reduce energy bills remains through energy efficiency improvements, as highlighted in this report. Recent evidence from the Committee on Climate Change[3] showed how significant bill savings have already been achieved thanks to energy efficiency and it will be important to build on this success into the future system. I strongly believe that a national energy efficiency programme should be a key Government priority to help the most vulnerable in society manage their energy usage and keep their bills down.

Lawrence Slade

LAWRENCE SLADE, ENERGYUK

ENERGY SYSTEMS IN 2035

Picturing the future

Set in 2035 and based around a vision of the future energy system, this thought piece details a conceivable energy system that is helping the UK transition to a low-carbon economy. It sets out the practical steps needed now for the country to move towards this future.

OVERVIEW

Taking the UK as its model, the diagram summarises the 2035 energy system as it transitions towards a resilient, forward-looking, low-carbon economy. It illustrates the combination of major energy solutions required to bring the UK on track to meet its 2050 targets, and reflects broader energy trends influenced by technological and societal factors.

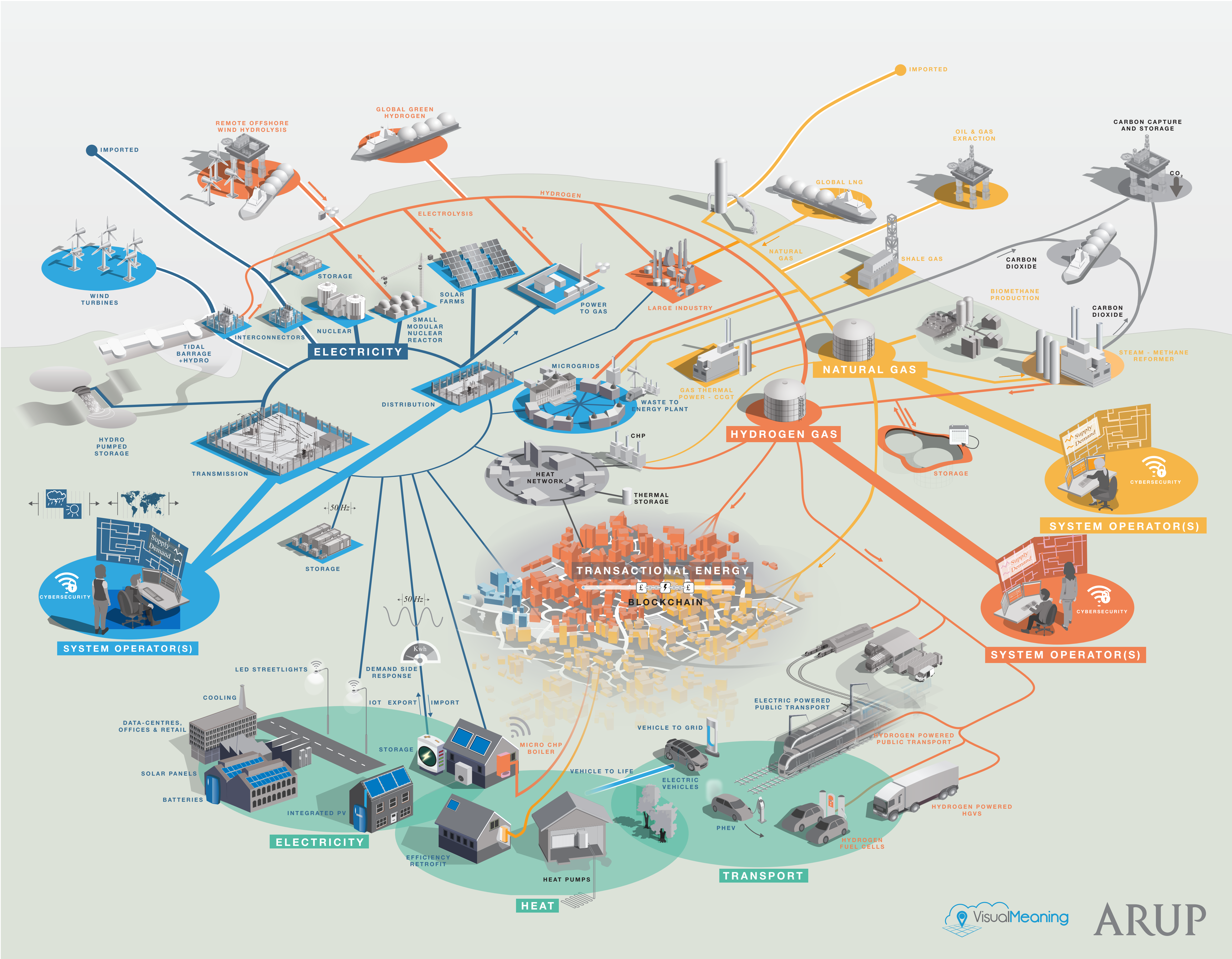
The diagram shows the importance of whole-system thinking and the need for urban, transport and digital systems to be compatible with and complement the energy system. It also shows a plural energy system that will:

- Ensure diversity and market competition
- Avoid abandoning the inherent value of existing infrastructure
- Use the best technology for a particular applications.

In doing so, the diagram focuses on those areas of the system that will change significantly – leaving out, for example, liquid fuels and aviation.

The energy system of 2035 will be more decentralised, disaggregated and multi-vector. There will not be one solution, but many. This will make flexibility (in system architecture, system operation and the regulatory framework) essential to achieving the Government's three objectives of decarbonisation, security and affordability. At the same time, key decisions are required: some solutions will be deployed on a larger scale than others and will require coordination, certainty and support.

The following perspective piece has been written as if it were now the mid-2030s, summarising the energy transition that has occurred over the previous 20 years and the decisions from 2018 onwards that made this possible.



ELECTRICITY

Low-carbon and local, those are now the key words for electricity, with many people no longer relying on the grid.

Most of the generation mix is now low-carbon, with different technologies linked to the grid and decentralised solutions providing power to consumers locally. New nuclear plants became operational in the late 2020s and offshore wind continued to grow rapidly after hitting the 10GW mark in the early 2020s. While combined cycle gas turbines (CCGTs) are still on the grid, they are mostly used to provide flexibility and to balance the system.

Another issue that was not as significant as expected was the intermittent nature of renewable energy.

There is now between 50-77GW of intermittent solar and wind generating capacity on the system, compared to 27GW in 2018.

Intermittency has largely been overcome by different types of storage:

- At the point of generation to enable dispatchable power to be matched to times of demand
- On the grid to enable improved network stability
- In homes and businesses to shift times of demand and enable consumers to benefit from lower real-time tariffs.

	WIND	SOLAR	NUCLEAR	GAS	COAL	OTHER*
TODAY	15%	11%	9%	29%	13%	23%
2035	21-28%	13-22%	5-8%	8-30%	0%	31-38%

*Other = Storage, Biomass, CCS, CHP, Hydro, Interconnectors, Marine, Other thermal, Other renewable
Source: National Grid Future Energy Scenarios

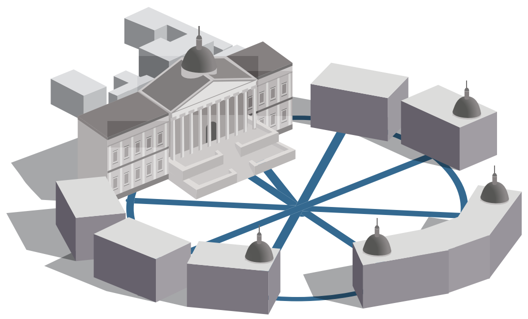
DECENTRALISED ENERGY AND MICROGRIDS

The UK is becoming a nation of energy producers. Between 2020-2030, the electricity system became increasingly decentralised. Now small-scale generation at the distribution level and behind the meter provides close to half the country's generation capacity.

Demand-side response and batteries are widespread in commercial and residential property and have shifted the load profile of demand and generation. Industrial parks, universities, airports and new towns have developed microgrids reducing the load on the national grid – though they still retain a connection to distribution grid.

Special deregulated enterprise zones for large-scale commercial trials promoted innovation that enabled the move to a distributed system operator, and by a review of network charging initiated as part of the RIIO-ED2 price control period (2023-2031). It was fully completed for the new regulatory framework for RIIO-ED3 – called RIIO 3.0, which also covered aspects of the new heat infrastructure.

	DECENTRALISED AND MICRO GENERATION CAPACITY
2016	27%
2035	34-45%



TRANSMISSION

In the age of distributed generation, local networks are more important than ever – although large-scale transmission still has a smaller but vital role to play.

Distribution

Distribution networks are managing their own systems, becoming Distribution System Operators (DSOs).Consequently, investment in reinforcing the network has shifted to integrated distributed solutions.

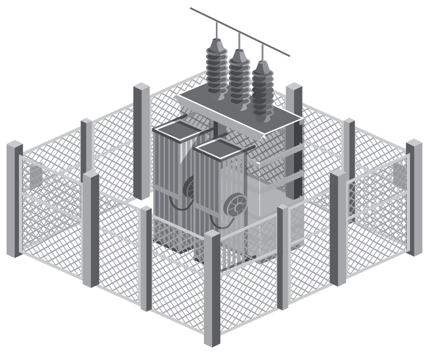
The distribution network has had to be reinforced due to the adoption of electric vehicles (EVs) and heat pumps.

Transmission

Transmission-connected capacity now only makes up 55% - 66% of total installed generation capacity. The need for substantial reinforcement across all networks has been limited by large-scale deployment of batteries and the emergence of distributed solutions such as microgrids.

However, offshore wind and other large-scale investment meant there was still a strong requirements to maintain and invest in the transmission grid. Much of this reinforcement was achieved through smart solutions and system management, but some physical reinforcement was still required.

	2016	2035
ELECTRICITY PEAK DEMAND	60.9 GW	62-71 GW



HEAT

The heat sector is in the midst of a transformation - with heat, cooling and energy production combined efficiently at a local level. The sector has become fragmented, with heat networks in the dense inner cities, electrification in the rural areas and hydrogen replacing natural gas in the suburbs.

By 2030 the heat sector was well on its way from one based primarily on natural gas (methane) to a multi-sourced system varying by location and type of building or customer. Fossil-derived natural gas has also been displaced or supplemented by green gases such as bio-methane and bio-synthetic natural gas.

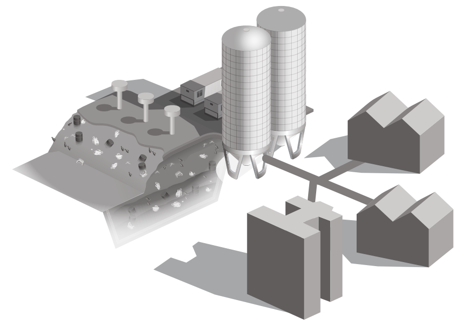
In high-density urban areas, district heating is widely used – mostly for new residential developments and public buildings such as schools and hospitals. Natural gas or hydrogen provides the base load for these systems. In rural and some suburban areas there are electric heating systems with ground-source and air-source heat pumps, as well as space heating. Electric boilers provide hot water and cooking is all-electric.

Most consumers, however, remain on the gas system, using gas-powered boilers for heating, hot water and gas to cook. Some are using gas to generate their own electricity via micro-combined heat and power (CHP) plants, a spin-off from the spare capacity in the internal combustion engine manufacturing sector.

Many customers have switched to hydrogen gas, which offers the same functionality as natural gas but has no CO_2 emissions at the point of use.

Leeds, Sheffield, Newcastle and Glasgow (and surrounding towns and cities) were the first to be converted to hydrogen, being close to the North Sea facilities that store the CO_2 produced by the steam methane reformation process used to produce hydrogen. The conversion to hydrogen was centrally managed and remarkably similar to the UK's conversion to natural gas in the 1960s. None of the technical solutions needed were actually new.

Cooling is also important, particularly in urban office blocks, retail and data centres. During summer months, the heat pumps that have been installed are switched to provide cooling. Industries and buildings with a high demand for cooling have been recruited as providers of waste heat for local district heating projects.



IN 2018:

80% of residential and commercial properties were heated by natural gas in 2018

IN 2035:

70% remain connected to the gas network with many of these converted to hydrogen

20% are using electric heating

10% are connected to district heating network

TRANSPORT

Transport has been transformed, with personal ownership of vehicles dying out and transport-as-a-service (TaaS), using autonomous electric vehicles, now the way the majority of people choose to travel.

A large proportion of pure internal combustion engine vehicles have been replaced. All new vehicles are now either electric, plug-in hybrid or hydrogen-powered.

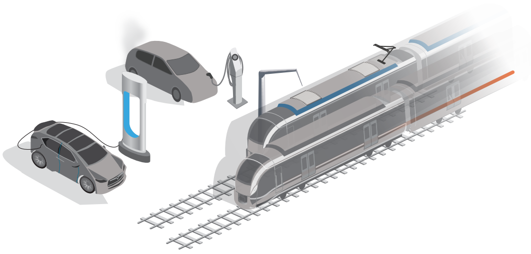
Smaller, purely electric personal vehicles and taxis are used in towns and cities for local travel. Mostly charged at home overnight, they are sometimes topped up at the numerous fast charging points.

A number of journeys, particularly within towns and cities, are by autonomous electric vehicle. Rather than owning these vehicles, consumers pay transport-as-a-service (TaaS) companies for their journeys. As a result, the number of vehicles on UK roads has declined significantly, particularly in towns and cities.

Larger vehicles such as buses and lorries – as well as consumers who make regular long-distance journeys (such as those in more rural areas) – use plug-in hybrid or hydrogen power. Hydrogen is available at a number of filling stations alongside petrol and diesel, which are used less and less each year.

In regions where a hydrogen network has developed, buses have also switched to hydrogen. Other areas use electric and petrol hybrid buses. The rail network, including trams, is fully electrified – other than a few hydrogen trains.

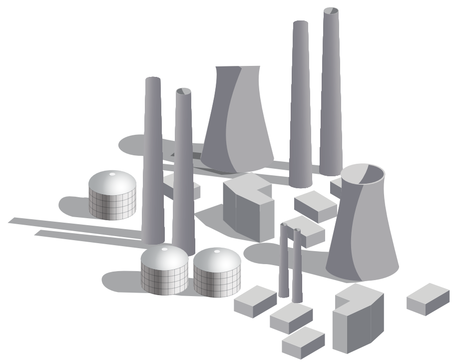
	2016	2035
PEAK DEMAND FROM EV	0.1-0.2	2.4-6.3
PEAK NON-EV DEMAND	30.25	14-30



HEAVY INDUSTRY

Coal has been consigned to the past but natural gas is still powering heavy industry.

Although the sector has started to move away from using gas, it remains the most reliable way to supply the large amounts of energy required by industrial processes such as iron and steel production. Gas is therefore still a major energy source for heavy industry, which remains connected to the gas network.

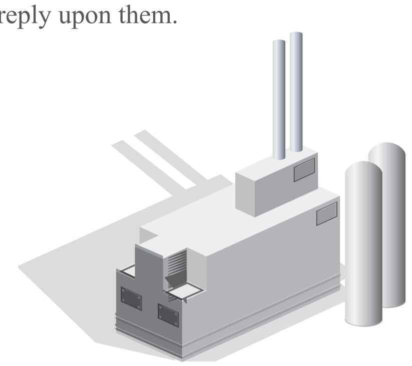


NATURAL GAS

Natural gas plays a smaller but still vital role in the energy system.

While renewables and hydrogen are the rising stars of the energy system, legacy energy infrastructure for natural gas is still operating in parallel. For example, some CCGTs and natural gas networks remain operational and are expected to remain so until the end of their lives.

Existing gas networks are valuable national infrastructure assets with large storage capacities, and heavy industry continues to reply upon them.



HYDROGEN PRODUCTION

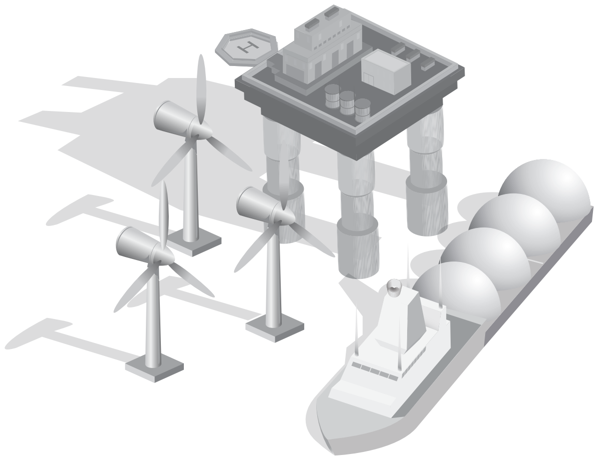
Hydrogen production has become a major industry and an important part of the energy system.

The majority of hydrogen is produced from methane, using steam methane reformers (SMRs) built along the coast. Newly constructed pipelines take waste CO_2 from the SMRs and store it in carbon capture facilities, such as former oil and natural gas extraction sites in the North Sea. Funding previously allocated for North Sea decommissioning was instead used to stimulate investment in these storage facilities.

The gas transmission network has seen significant levels of investment too, as it has had to adapt to the transition to hydrogen while continuing to supply methane. Ofgem appointed a hydrogen network system operator, who managed the competitive process used to build the hydrogen transmission network.

Some hydrogen is also produced from water by electrolysis using low-cost renewable electricity. This approach is expected to play an increasingly important role in the future.

Hydrogen is produced in locations where there are constraints on the network capacity. For example, large onshore wind farms in Scotland and remote offshore wind farms are used to produce hydrogen when there is excess capacity, taking advantage of the low marginal cost of energy of renewable sources.



In other countries with abundant sunshine and large areas of land remote from urban centres of demand, solar PV is being similarly used. Floating windfarms, too far from shore for viable electricity connections, are in the planning phase, with hydrogen storage and terminal locations identified.

The hydrogen produced is fed into the gas network, or transported as liquid hydrogen. There is a growing international market in hydrogen produced from renewables, with shipping and liquefaction facilities under construction.

IN THE 2000s

1,100TWh

is the highest gas demand rate

BY 2050

1,100TWh

will be the annual gas demand

55-65%

of this gas will be converted to hydrogen and used in the gas grid

£125bn

The estimated capex required to convert the majority of the distribution network to hydrogen

SMART HOMES

On average homes are much smarter with their energy, newer homes are virtually energy neutral but the majority of housing stock is old and still energy hungry.

Homes and the appliances within them are much smarter in 2035 thanks to smart meters, small-scale batteries and smart devices connected by the Internet of Things. This has reduced power consumption, particularly at peak times, and enabled consumers to participate in demand-side management. Individual customers can provide balancing and ancillary services via virtual power plants and aggregators.

There are more energy retailers, with local energy co-operatives and municipal suppliers providing a large proportion of energy, particularly for those customers connected to microgrids. This results in a wider variety of products including time-of-use and peer-to-peer tariffs (via blockchain technology).

There is a greater variety of heating solutions: hydrogen (where the network is available), district heating (mostly in urban areas) and electric heating via community heat pumps (largely in rural areas).

	2016	2035
% PEAK DEMAND REDUCTION DUE TO SMART HOME EFFECTS	0 to -0.3	-2 to -17

Source: National Grid Future Energy Scenarios

New properties are energy-neutral. At times they export energy back to the grid (for example from PV generation during the day when sun is shining). At other times they import energy from the grid. Some properties have energy storage allowing them to be self-sufficient in energy throughout the year.

However, with the majority of properties 30 or more years old, an energy-efficiency retrofit programme has been integrated with the deployment of smart appliances and smart systems to homes. These older properties are still largely net consumers of energy, particularly for heating, even with some behind-the-meter generation installed.

ENERGY TIMELINE

Towards a resilient, forward-looking and low-carbon economy

	2017	2018 - 2019	2020	2023	2030
STRATEGY	Industrial strategy Cross-party consensus on industrial strategy Energy Industry Vision	An energy strategy for 2030 - link to air quality, energy costs and changes in transport sector Cross-party consensus on energy strategy	Decision on future heat - policy statement leading to proposal for regulatory and market changes		New planning policies implemented
POLICY - NETWORKS	Start of RIIO 2 - discussion on future of regulation (including future of heat)	Shift to DSO model setting the framework and platform / building blocks (focus on no-regret interventions) Network charging reform How Smart and Flexibility policy changes network regulation for RIIO 2	Start of RIIO 3 discussion - green paper on new heat regulation	New regulations starting for heat solutions including Hydrogen	DSO model live
POLICY - GENERATION		Maintain SMR programme Low carbon generator policy update - future of CfD, carbon prices and capacity market. EMR 2.0 or just evolution?			Decision point on Carbon Capture and Storage
POLICY - RETAIL		Green paper on Data communication, Data protection regulation for energy Retail market regulation and consumer protection			
POLICY - INTERACTION		Research / workstream on new tax revenues Future of EV and other modes of transport - Roadmap			Implement new taxation model
RESEARCH & INNOVATION		Research / innovation on new heat technologies, especially hydrogen (focus on no-regret options and developments) Research on the energy / materials / non-energy commodities nexus Investment in systems engineering - understanding implications of interventions: - national scale - city scale - project scale			

FINAL THOUGHT

The success of transitioning the UK energy market has helped deliver a secure and forward looking industrial strategy for years to come. The transition has enabled technology and digital developments whilst considering application and deployment as well as training, up-skilling and future-proofing jobs. It has also been internationally recognised that the UK has set the bar high for energy development and is an advanced nation delivering against the United Nation's Sustainable Development Goals.

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CONTACT
e: energy@arup.com
w: www.arup.com/energy