THE
ROYAL
SOCIETY

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BEIS select committee inquiry: decarbonising heat in homes

Key Points

- There will be no single solution to decarbonising heat for use in UK homes due to the variability in housing construction and design, as well as geography and climate across the UK. Any meaningful transition towards low-carbon heat will require a mix of technologies.
- There are both significant advantages and disadvantages associated with the leading low-carbon heating technologies.
- Data analytics and digital technologies can also play a major role in driving a switch to low-carbon sustainable behaviours and practice, which will be pivotal in achieving a net zero economy and society.
- A technology strategy is needed to enable these promising technologies to support the transition towards net-zero by 2050. The upcoming energy White Paper and ten-point plan to reach net-zero are ideal opportunities to provide this.

1. Introduction

1.1. The Royal Society is the national academy of science for the UK. Its Fellows include many of the world's most distinguished scientists working across a broad range of disciplines in academia, industry, charities and the public sector. The Society draws on the expertise of the Fellowship to provide independent and authoritative advice to UK, European and international decision makers.

1.2. The Society's fundamental purpose, reflected in its founding Charters of the 1660s, is to recognise, promote, and support excellence in science and to encourage the development and use of science for the benefit of humanity. Our strategic priorities therefore are to promote excellence in science; to support international collaboration; and to demonstrate the importance of science to everyone.

1.3. The Society welcomes the opportunity to highlight relevant work to the Committee's inquiry. The heating of homes and offices is a major contributor to carbon dioxide emissions. In the UK, most homes are currently heated using natural gas. In 2018, this resulted in the emission of 65.9MtCO2, accounting for 18% of all UK carbon dioxide emissions[1].

1.4. There will be no single solution to decarbonising heat for use in UK homes due to the variability in housing construction and design, as well as geography and climate across the UK. Any meaningful transition towards low-carbon heat will require a mix of technologies. There are both significant advantages and disadvantages associated with the leading low-carbon heating technologies. Below we provide an overview and some of the advantages and disadvantages associated with two technologies - low-carbon hydrogen and district heating - and the potential of digital technologies to help promote a shift towards low-carbon ways of living and working.

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[1] Royal Society (2020), Nuclear cogeneration: civil nuclear energy in a low-carbon future

2. Hydrogen

2.1. Hydrogen is the most abundant element in the Universe. On Earth, it is found in many chemical compounds, but as a gas it rarely occurs naturally. When generated as a gas it can be used as an energy carrier, which at the point of use produces no carbon dioxide.

2.2. This means that the large-scale production of low-carbon hydrogen has the potential to play a significant role in decarbonising multiple parts of the energy system including heating buildings. Increased R&D investment is needed to enable the development of the technologies needed to do this, and, if found practical, it is likely that hydrogen would be introduced in a mix with natural gas at first, but this would need to rise to 100% to be a zero-carbon solution. Like all technologies discussed here it is not a cure all and should be seen as one of the possible pathways towards decarbonising heat in homes.

Two principal groups of technologies are most likely to be appropriate for producing hydrogen at scale for use in heating homes in the short to mid-term:

- **Steam methane reforming with carbon capture and storage.** This process has been used to produce hydrogen from natural gas (and other fossil fuels) and steam for decades. The technology is well understood and is operated on an industrial scale around the world. Carbon capture and storage is an essential prerequisite if this method is to be used to produce low-carbon hydrogen, as production methods emit carbon dioxide either from the energy input or as a by-product. However, carbon capture is not 100% efficient and other methods of hydrogen production should be considered if net zero is important.

- **Electrolysis of water.** This process separates hydrogen from water using electricity in an electrolysis cell. Electrolysis produces pure hydrogen which is ideal for fuel cell electric vehicles. It has a high efficiency though many current facilities are small. This technology shows great potential to be scaled up and used as a way of converting excess electrical energy produced by renewables into hydrogen, which enables energy storage flexibility. Economic viability relies in part on the availability of sources of low-carbon, low-cost electricity. Electrolysis has the potential to be deployed to produce low-carbon hydrogen in the near to mid-term alongside steam methane reforming, provided the renewable power is available.

2.3. Benefits of hydrogen:

- Hydrogen can be stored in bulk, for example in underground caverns, for use later. It can also be produced and traded around the world, in a similar way as oil and gas.;
- The existing gas network can be converted to be used to transport hydrogen, which means cost savings and minimal street disruption.
- Steam methane with CCS production uses an energy source not dependent upon renewable electricity.

2.4. Issues and limitations**:**

- Questions exist over the leakage of methane - a greenhouse gas – emitted in the steam methane reforming process.
- High integrity carbon capture and storage (CCS) is required as a prerequisite when using steam methane reforming.

- The conversion of the gas transmission/distribution network and/or replacement of domestic appliances will be required.
- Cost - the costs of steam methane reforming hydrogen production are primarily influenced by the cost of natural gas and the costs and method of carbon capture and storage. Production costs (i.e. not including transportation through pipes, billing costs, taxes and levies) have been estimated to be in the order of 2 to 5 pence per kWh. The cost of production by electrolysis is dependent upon the cost and availability of electricity from renewable sources and is estimated to be between 4 and 9 pence per kWh. Whole system modelling will be necessary to comprehend the value of electrolysers for grid balancing and energy storage.

More detailed information on hydrogen for heating homes can be found in the following Royal Society policy briefing: Options for producing low-carbon hydrogen at scale (2018)

3. District heating

3.1. District heating offers another solution to reducing carbon emissions by providing space and water heating for a group or district of buildings from a large central heating source using insulated pipes. The Government has already identified district heating as an important part of their plan to reduce carbon and cut heating costs.

3.2. In the UK, conventional district heat networks currently provide only 2% of the overall heat demand across residential, public, commercial and industrial sectors; 17,000 networks that supply 500,000 consumers[2]. Recently, the UK Government announced a £320 million Heat Networks Investment Project which aims to increase this coverage to 18% of UK heat demand by 2050[3]. .

3.3. **Nuclear cogeneration** could provide a solution to increasing the UK's ability to maximise the use of district heating without relying on fossil fuels. This is where the heat generated by a nuclear power station is used not only to generate electricity, but to address some of the 'difficult to decarbonise' energy demands such as heating and hydrogen production. It also enables a nuclear plant to be used more flexibly, by switching between electricity generation and cogeneration applications.

3.4. Since the early deployment of civil reactors across the world, heat from the reactor is used in several countries to power district heating networks. To date, there have been around 500 reactor years of experience including:

- The Ågesta reactor, south of Stockholm, produced 10MW of electricity to the grid and between 50-70MW of heat to the suburb 'Farsta' in Stockholm between 1964 and 1974.

- In China, the low-temperature Yanlong reactor, which was completed in 2017, produces 400MW of heat exclusively for district heating. China has now also built a pilot nuclear reactor to provide heat to towns and cities in the colder northern regions.

3.5. Small modular reactors (SMRs) are of particular interest. These are reactors producing 300Mw of energy or less, which can be built in factories and deployed in stages. This should mean lower

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[2] The Association for Decentralised Energy. 2018 Market Report: Heat Networks in the UK. See https://www.theade.co.uk/assets/docs/resources/Heat%20Networks%20in%20the%20UK_v5%20web%20single%20pages.pdf (accessed 23 October 2019).

[3] Heat Networks Investment Project. 2018 Delivering Financial Support for Heat Networks – England & Wales. See https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/748477/hniplaunch.pdf (accessed 16 October 2019).

investment costs and economies of scale in construction. It also gives greater flexibility in locating stations and allows them to be tailored to the energy needs of regional or industrial clusters. A recent Royal Society policy briefing estimated that that SMRs could conceivably be part of the energy grid by 2028[4].

3.6. Recent UK focused studies have considered the potential for district heating in a scenario involving Small Modular Reactors[5]. An analysis of heat demand data suggests there are around 50 conurbations in the UK potentially suitable for hosting SMR-powered district heating networks. The theoretical SMR capacity needed to energise all these networks would be 22 GWe. One UK study identified Hartlepool as a new-build facility with a particularly strong potential for nuclear district heating; using a 7.5km radius, the network potential could include Stockton-on-Tees, Middlesbrough and Hartlepool[6].

3.7. Benefits of district heating:

- District heating is seen as one of the most cost-effective ways of reducing carbon emissions from heating, providing a unique opportunity to exploit larger scale recovered heat sources.
- Nuclear power stations offer one of the largest reliable sources of low-carbon heat, with 'waste' energy being utilised to increase overall efficiency.
- Transmission losses are generally small and nuclear power plants can be sited up to 100km from the demand[7], well within the distance between, for example Hinkley Point (Somerset) and Bristol.
- There is a broad consensus that the required modifications to nuclear power plants for cogeneration represent no specific technical difficulties[8].

3.8. Issues and limitations:

- High cost of installing heat distribution networks. In certain locations existing heating networks may mitigate this cost, however construction costs are lower when part of new housing or commercial development.
- Overall economic benefit yet to be determined, but consensus that district heating is only economically viable in urban areas.
- Questions remain around the efficient utilisation of the network in temperate regions.

More detailed information on district heating can be found in the following Royal Society policy briefing:

Nuclear cogeneration: civil nuclear energy in a low-carbon future (2020)

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[4] Royal Society (2020), Nuclear cogeneration: civil nuclear energy in a low-carbon future. See https://royalsociety.org/-/media/policy/projects/nuclear-cogeneration/2020-10-7-nuclear-cogeneration-policy-briefing.pdf

[5] Mott MacDonald. 2015 Project Summary Report - System Requirements for Alternative Nuclear Technologies. See https://www.eti.co.uk/library/alternative-nuclear-technologies-summary-report-and-peer-review-letters (accessed 16 October 2019).

[6] Jones C. 2013 Utilising Nuclear Energy for Low Carbon Heating Services in the UK. See https://www.research.manchester.ac.uk/portal/files/54537956/FULL_TEXT.PDF (accessed 05 December 2019)

[7] International Atomic Energy Agency. 2017 Opportunities for Cogeneration with Nuclear Energy. See https://www.iaea.org/publications/10877/opportunities-for-cogeneration-with-nuclear-energy (accessed 31 October 2019)

[8] Jasserand F, de Lavergne JGD. 2016 Initial economic appraisal of nuclear district heating in France. EPJ Nuclear Sciences & Technologies, 2, 39. (doi: 10.1051/epjn/2016028).

4. Digital technologies

4.1. Digital technologies can help promote a shift towards low-carbon ways of living and working. Currently 40% of the UK's total emissions come from households, and heating is the biggest contributor to household emissions[9].

4.2. Smart meters are already deployed in many UK homes and the data they collect offers insight into electricity and gas consumption patterns. At present, this information is used to ensure energy bills automatically reflect consumption, or to help suppliers forecast energy usage and better manage supply and demand. Smart home technologies have the potential to support changes in behaviours and significant emission reductions, for example by identifying how to improve home infrastructures.

4.3. Consumer research shows that smart heating controls give users a greater sense of control over their heating, meaning they can adjust their heating to suit their daily routine, heat selective rooms rather than the whole home, and heat rooms to different temperatures for instance to make different occupants feel comfortable[10]. For people to engage effectively with this technology, it will need to present actionable information through clear and engaging user interfaces.

4.4. Digital technologies offer opportunities to optimise patterns of resource use, by enabling better construction and building management, as well as materials re-use. Intelligent building management systems that combine data about the energy use of buildings and other information sources like weather data, to recommend the most sensible heating and cooling patterns, are already available to managers of commercial buildings to reduce energy use and emissions[11].

4.5. Energy loss from existing buildings could be greatly reduced by renovations that add insulation alongside a technological retrofit – combining sensors, technologies such as heat pumps and energy management systems to control energy use while prioritising clean energy. Such combinations would be cheaper than renovating buildings to the highest insulation standard (found for example in 'Passive Houses'), as well as provide control and wellbeing. This approach can enable reductions in energy use and create a better environment for inhabitants, ensuring more comfortable temperatures both in winter and in summer.

4.6. In practice, the existing building stock is very diverse and will require a wide range of interventions. The Greater London Authority has started using a digital twin to monitor, simulate and analyse the whole city's building stock[12]. This can help target interventions depending on built form, age, activity, energy performance, and enables linking with confidential socioeconomic data on occupants. Data and digital technology can also inform the planning and development of new buildings. The sharing of information about buildings' energy performance in their use phase, and the track record of different

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[9] Committee on Climate Change 2016 The Fifth Carbon Budget, How every household can help reduce the UK's carbon footprint. See https://www.theccc.org.uk/wp-content/uploads/2016/07/5CB-Infographic-FINAL-.pdf (accessed 14 October 2020)

[10] Energy Systems Catapult and Department for Business Energy and Industrial Strategy 2020 Using the Living Lab to sell consumer centric heat services that encourage adoption of low carbon heating. See https://es.catapult.org.uk/reports/using-the-living-lab-to-sell-consumer-centric-heat-services-that-encourage-adoption-of-low-carbon-heating/?download=true (accessed 14 October 2020)

[11] International Energy Agency 2019 Case Study: Artificial Intelligence for Building Energy Management Systems. See https://www.iea.org/articles/case-study-artificial-intelligence-for-building-energy-management-systems (accessed 14 October 2020)

[12] Steadman P et al 2020 Building stock energy modelling in the UK: the 3DStock method and the London Building Stock Model. Buildings and Cities, 1(1), 100–119. See https://journal-buildingscities.org/articles/10.5334/bc.52/ (accessed 14 October 2020)

materials, would enable the construction industry to generate better models and design more efficient buildings.

4.7. More detailed information on the role of digital technologies in tackling climate change will be outlined in a Royal Society report that will be published shortly. We will share this with the Committee once available.

5. A technology strategy to enable promising technologies to support the transition towards net-zero by 2050

5.1. Decarbonising the way in which we heat our homes will be crucial to meeting the Government's own target of a transition to net-zero by 2020. Time is running out, and so to achieve this, a technology strategy is needed to enable these promising technologies to support the transition.

5.2. We look forward to the Energy White Paper due to be published by the Government imminently, although no exact date has yet been confirmed. It will, according to Minister for Climate Change Lord Callanan, "consider the overall energy system, including how demand for low-carbon electricity will increase in buildings and transport, and the role of technologies such as hydrogen and nuclear in supporting that transition". Among the areas likely to be addressed are carbon capture and storage, financing for new nuclear, markets for energy efficiency, the decarbonisation of heat, supporting innovation and the development of commercially viable new technologies. This provides an ideal opportunity to provide such a strategy.

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