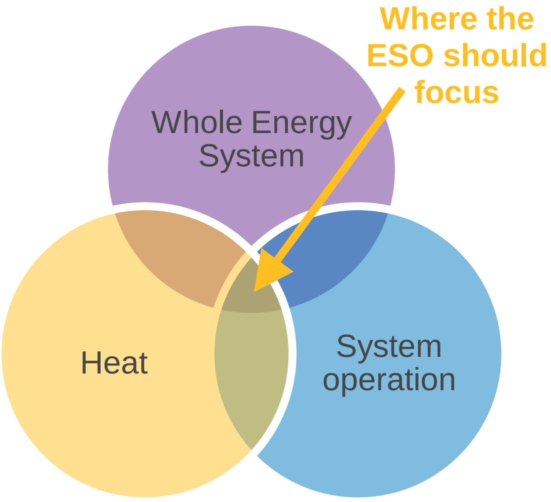
nationalgridESO

Clean heat

Heat decarbonisation and its implications for electricity and gas system operation



In FES 2020 one of our Key Messages is that reaching net zero is achievable but requires immediate action across all key technologies and policy areas. One of these areas is heat decarbonisation, which is identified as requiring urgent policy decisions to drive change across the whole energy system. It is a challenge that cuts across sector boundaries and so needs collaboration and a whole system approach, considering gas and electricity, transmission and distribution, and the users of the systems.

As a nation we need to decide how we will decarbonise heat in the 2020s if we are to achieve a net zero energy system by 2050. As the ESO we want to focus where we have the most expertise and can add the greatest value. We are uniquely placed to comment on decarbonisation of heat from the perspective of the electricity system and, through our collaboration with the GSO in areas such as their Future of Gas work, on gas-electricity interactions and network operation. In this thought piece we will explore the big questions on 'clean heat' from a system operation perspective.

What are the options for the future of heat?

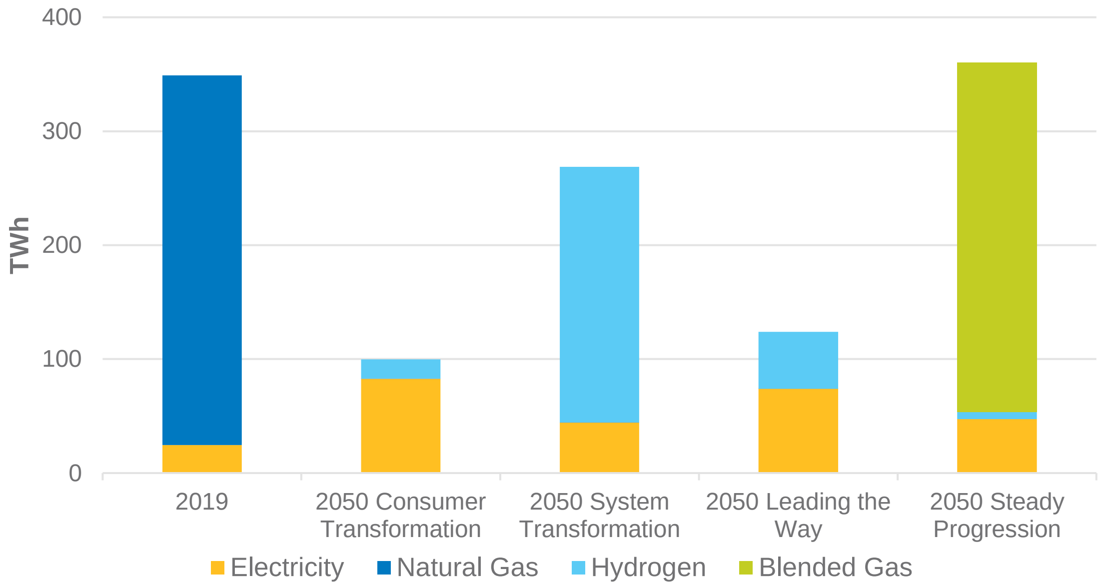
The shift from an 80% carbon reduction target to a net zero target restricts the potential options for heat decarbonisation – we can no longer burn natural gas in boilers to heat people's homes. This leads to the main uncertainty in this area: whether clean heat is predominantly delivered by hydrogen or electricity or through a combination of these. One of the biggest challenges in clean heat from a system operation perspective is that these different future scenarios are all plausible, but they are very far apart in terms of system design.

In our Future Energy Scenarios (FES), we explore a range of outcomes for the future of heat, with the differences driven by the speed of decarbonisation and the level of societal change. Different clean heat solutions require different levels of change from the consumer; replacing gas boilers with hydrogen boilers is likely to be less disruptive to consumers than replacing them with heat pump, as hydrogen boilers operate very similarly to gas boilers and require less disruptive insulation upgrades to operate most efficiently.

Of the net zero scenarios, Consumer Transformation is a highly electrified world in which heat pumps dominate and there are higher levels of insulation, System Transformation relies heavily on hydrogen for heat, while Leading the Way sees a mixture of heat pumps and hybrid heat pump-hydrogen boiler systems. In the Steady Progression scenario, the net zero target is not achieved by 2050 and there is only limited decarbonisation of heat. The impact of these on the fuel flowing through networks to provide heat is shown in Figure 1 below.

The four fully developed whole energy system scenarios within FES capture a wide range of uncertainty but there are other potential further variations in how heat will decarbonise. In scenarios where heat is mostly decarbonised via hydrogen, that hydrogen could come mainly from electrolysis using renewable electricity ('green' hydrogen) or mainly from natural gas reforming with Carbon Capture Use and Storage (CCUS) ('blue' hydrogen). In scenarios where heat is mostly decarbonised via electric heat pumps more electricity system flexibility will be required, that flexibility could mainly come from supply or demand. In scenarios with high take-up of hybrid systems containing both a heat pump and a hydrogen boiler these units could operate in very different ways, potentially alleviating some system operation challenges but causing new ones.

Figure 1: Networked fuel mix for heating homes in 2050 (FES 2020)



Even within these diverse national deployment scenarios there could be variations in the extent of regional differences. Although the thermal efficiency of different home types varies significantly, most regions have a mix of many different homes so at the level of a distribution network some of this variation will average out. Other differences, such as local weather patterns, the presence of a gas network, and proximity to industrial clusters and district heat networks, may cause more significant differences between regions. These regional differences in heating needs improve the benefits of regional approaches to clean heat, but this is in tension with the economies of scale that come with national infrastructure systems and roll out programmes.

How to ensure that the lights stay on and homes stay warm?

To keep electricity and gas flowing year-round there are security standards that the networks are tested against to ensure resilience. These comprise a performance standard and a demand scenario which includes peak demand. The gas and electricity systems have different properties, and these are reflected in their different security standards. The gas system uses a demand scenario with a more extreme winter than the electricity system because gas demand is more sensitive to temperature than electricity demand, so extreme winters dominate security analysis. It would also take much longer to safely recover the gas system after failing to meet demand.

Our current security of supply standards have served the nation well, with the GB gas and electricity networks being some of the most reliable in the world, however changes driven by the shift to clean heat will mean that these also need to change.

While today only 8% of households use electricity for heating, in Consumer Transformation in 2050 this rises to 70% of households, in such a scenario, there will be a greater link between temperature and electricity demand and the demand testing of the electricity standard may need to have more emphasis on demand variability and peak demand in extreme winters.

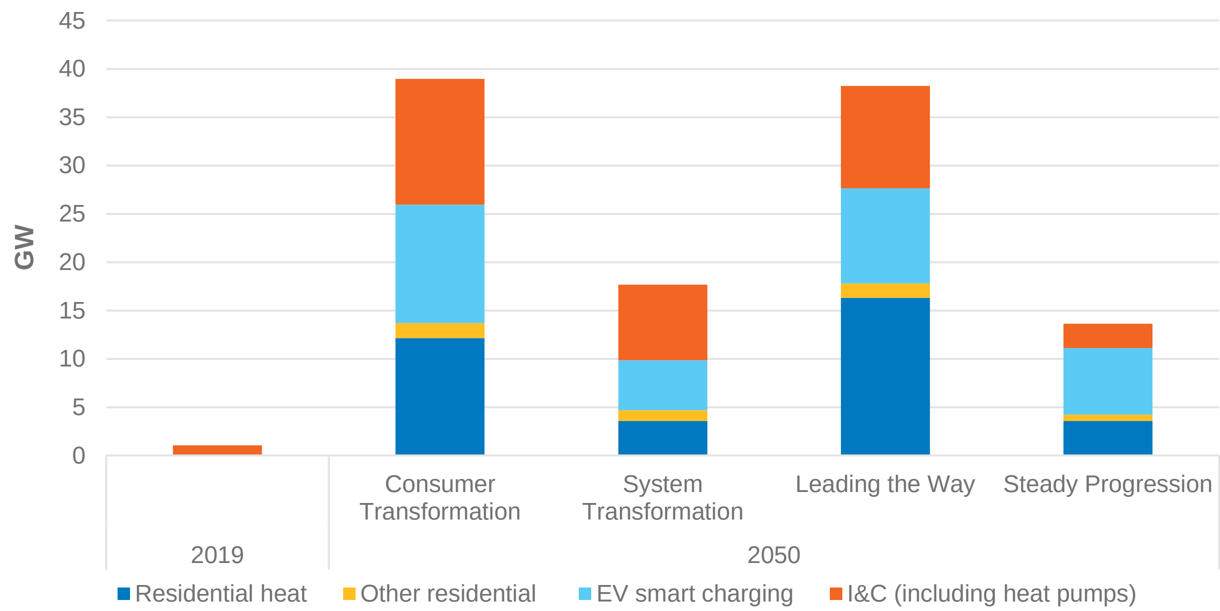
Another potential area of change is on the gas side. In our System Transformation scenario, the gas network carries 100% hydrogen around the country in 2050, but well before this point gas standards may need to change as gas compositions change, with increasing proportions of biogases and hydrogen in the network. This could mean that gas security standards need to have more emphasis on the capability of the network if changing gas compositions reduces network flexibility.

What are the external factors that could affect clean heat pathways?

This thought piece focuses on clean heat, but the energy system is complex with interactions everywhere. Changes in other areas could change the system operation challenges of clean heat. Two areas of interaction are particularly important: demand side electricity system flexibility and the production and use of hydrogen.

Our net zero compliant scenarios in FES 2020 have much more variable renewable generation and so need much more flexibility across the energy system to help manage this. Scenarios with high electric heating demands could see peakier electricity demand which will also require greater flexibility to manage. While today most electricity system flexibility comes from the supply side, in scenarios with high levels of societal change we expect more of this flexibility to come from the demand side, as shown in Figure 2, and so factors that increase demand side participation across other sectors will affect clean heat scenarios.

Figure 2: Demand side response contributions at peak times in 2050 (FES 2020)



In particular, we expect electric vehicles to act as the gateway to consumer engagement in energy flexibility. The addition to a household of an electric vehicle - a major flexible electricity load – and the rise of automation and smart technology could lead to the adoption of time of use tariffs by consumers. This could pave the way for greater DSR participation from heat pumps, particularly when combined with thermal storage. The response from both these technologies should be complementary and able to support each other assuming effective coordination.

For example, an electric vehicle may be able to offer Vehicle-to-Grid (V2G) during peak evening heat demand, reducing the impact of peak heat demand on the system. In Consumer Transformation, while smart control and thermal storage could reduce peak demand by up to 8.2 GW in 2050, vehicle-to-grid could provide 16.9 GW back to the grid over this period.

As highlighted in the FES 2020 key messages, deployment of hydrogen and CCUS technology is essential for net zero, and the two are closely linked; effective CCUS could allow scaling up 'blue' hydrogen production from reformed hydrocarbons with the carbon emissions captured. Hydrogen network assets have large economies of scale and could therefore benefit from stacking demand from multiple sectors, so decisions made in other areas, such as the use of hydrogen in industry, rail or HGVs may affect the availability of hydrogen for heat.

The size and characteristics of a future hydrogen network will depend on all the sources and uses of clean hydrogen, not just heat. Operation of this network will also need to meet differing requirements, for example the higher hydrogen purity levels required for transport end uses compared to heat could add additional operability complexity.

How to collaborate for whole system clean heat solutions?

We know that no one party has a monopoly on the decisions that will enable clean heat or on addressing the challenges that it will bring. The ESO needs to collaborate widely, including with other system operators on issues that affect the operation of multiple energy systems. For example, on system operation issues relating to heat pumps we collaborate with DNOs and for those relating to hydrogen for heat we collaborate with the GSO and GDNs. Close working will also be necessary between the ESO, policy makers, regulators and network users to ensure that the most efficient system operation outcomes can be achieved.

There are likely to be complex interactions between electricity prices and gas demand; feedback channels include gas generation, power to gas, electrolytic hydrogen production, and consumer DSR. Clean heat will impact system operation by changing annual and peak demands for energy, as well as the variability and predictability of demand, and beyond this these effects will vary across different areas of the country, changing the requirements on the transmission networks. This is an area we are exploring in more detail in our Bridging the Gap programme. Last year we discussed how we will manage peak electric heat demand and this year we are investigating how technology, markets and data can help us to manage the peaks and troughs in the future system.

Some impacts will be initially felt by one network, but other networks may be affected by how these impacts are managed. Peak demand from heat pumps in an extreme winter is primarily an electricity system issue, but dispatching flexible turbines connected to a hydrogen network might be part of the solution. Increased operational complexity from changing gas compositions is primarily a gas issue, but that will interact with the operation of power to gas electrolysers to balance the electricity system.

To enable clean heat, system operators will need to manage challenges they have not faced before, using capabilities they have not developed yet. We have been working to understand the impact of clean heat pathways on our current activities, but more work is required to understand the size of potential capability gaps and how to fill them. Of particular importance are two areas where cross-sector collaboration is needed: long term system planning and network operation.

For whole system long-term planning system operators will need to coordinate the investments each network makes to address the challenges they face. To do this they will need to understand the typical and extreme peaks that they have to design for under different clean heat scenarios. These will be underpinned by assumptions about levels of insulation, the effect of flexibility and demand side response and their impact on peak demands. We also need to understand how quickly we can build the required new assets or convert existing network assets and therefore when we need to make key investment decisions.

For future network operation we know that both gas and electricity networks will face unprecedented operability challenges. Stronger links between energy systems will increase the operational complexity but could deliver clean heat at a much lower overall cost to consumers. System operators will need to ensure their networks can work together and support each other to deliver efficient secure operation, both day to day and in more extreme circumstances.

Many of these considerations come back to improvements in data and digitalisation, a key focus area for the ESO and other parties. Increased collaboration and work on interoperability standards between system operators, networks and energy market participants will be key to unlocking many of these future challenges.

What are the next steps needed to deliver clean heat?

There is widespread agreement from bodies involved in the sector that pathways for clean heat need to be decided in the 2020s. In 2018 BEIS committed to "laying the groundwork in this Parliament to prepare for decisions in the first half of the next decade about the long-term future of heat", while the CCC 2020 Progress Report highlights that we will need "Strategic decisions on the future of the natural gas grid and the future balance between hydrogen and electrification for heating" by the mid-2020s.

The future of heat may be uncertain, but there are already things we know today that can help us make the right decisions for the long term. FES 2020 shows that across all three of our net zero scenarios we can expect big changes to have taken place by 2030, with serious deployment of key technologies starting in the late 2020s. Heat pump deployment is projected to accelerate from the early 2020s, hydrogen production from electrolysis is expected to start scaling up from 2026, and methane reformation from 2027 with hydrogen playing a role in home heating from 2030.

To enable these big changes to happen there are several things that need work in the 2020s. We will need to see appropriate investment signals in place by the mid-2020s so that markets work to deliver optimal outcomes for heat. Investment requirements for different clean heat pathways diverge in the late 2020s. We need to have found solutions to the potential system operation challenges presented by different clean heat pathways, and be confident that the pathways are operable, before significant deployment starts. We await the government's energy white paper and the BEIS heat and buildings strategy which are expected imminently and will help provide clarity setting out a path for the future of heat.

We currently chair the whole system strategy workstream of the Open Networks project. This workstream is able to look at both gas and electricity aspects of challenges such as clean heat and was the first ever industry working group looking at whole system issues to include both gas and electricity networks. We are also jointly leading a product within this workstream to develop a whole system cost-benefit analysis tool, evaluating whole system options to help achieve net zero, deliver a secure network and optimal value for money to consumers, and put consumer benefit at the heart of industry decision making. This can be used for asset intervention, investment planning, generation connections, local area energy plans and strategic decision making and will facilitate cross sector funding for whole system solutions.

Within our five-year strategy of our RIIO-2 business plan we have included a number of steps which will support heat decarbonisation, in particular:

- Supporting BEIS on its clean heat strategy, providing key inputs from a whole energy system perspective
- Investing in our capability to undertake more complex system modelling and data exchange to allow us to assess future operability needs and use a whole energy system approach for zero carbon operability
- Supporting a targeted review of the Security and Quality of Supply Standard (SQSS), to ensure it is designed to enable decarbonisation of the electricity system

We are keen to continue working with stakeholders through avenues such as our innovation projects to help answer the system operability questions raised by the future of heat. The 4D Heat project has identified ways for the ESO, DNOs and energy consumers to reap benefits at no additional cost through accessing heat flexibility to manage curtailed wind in Scotland. The Spatial Clean Heat Model project is developing an integrated, cross-vector model of the whole GB heating system. We are currently engaging with stakeholders to shape the modelling and assumptions on heat in our FES 2021 scenarios and will continue to work with stakeholders on demand side response flexibility and the role heat can play in this through avenues such as our Power Responsive forum. We are keen to hear your thoughts on the issues presented in this thought piece and the questions below.

Do you agree:

- with the options we have presented for the future of clean heat? Which do you think is most likely?
- with how we have described the system operation challenges?
- that electricity system flexibility and hydrogen use and production are the most important external factors that could affect the future of clean heat? If not which other external factors would you suggest are most important to consider?
- that collaboration between energy system participants is one of the key steps to enabling heat decarbonisation?

If you are interested in sharing your thoughts, please email us at Box.FES@nationalgrideso.com. This thought piece is to start a conversation; we will also be holding a webinar on Tuesday 8th of Dec on this topic, please register here if you'd like to be involved.