Key barriers to the development of hydrogen in the UK energy system

Summary Report

July 2023

Energy Systems Catapult is a partner of the Hydrogen Innovation Initiative. The Hydrogen Innovation Initiative's mission is to accelerate the development of critical technologies and supply chains in the UK for the fast-growing hydrogen economy.

The Hydrogen Innovation Initiative's partners include the Catapult Network, the Advanced Propulsion Centre, the Aerospace Technology Institute, the Net Zero Technology Centre and the National Physical Laboratory.

The Hydrogen Innovation Initiative is supported by Innovate UK.

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1. Summary

As part of the Innovate UK funded Hydrogen Innovation Initiative (HII) Seed project, the Energy Systems Catapult and the University of Birmingham undertook a series of interviews and analysis towards the end of Q1 2023 to identify and collate barriers to using hydrogen in the UK energy system for Net Zero. The interviews took place with 12 organisations representing academia, industry, Government, network operators and regulators. This had a particular focus on the use of hydrogen to provide energy system flexibility.

2. Background to Britain's Energy Systems

Figure 1 provides a sense of the scale of the challenge to reduce Britain's dependency on fossil-fuels as part of the journey to Net Zero. It shows monthly percentages of different fractions of Britain's primary energy supply since 2010, and that Britain is still dependent on between 85% to 90% of its primary energy from fossil fuels.

Even though Figure 1 shows the fraction of natural gas in primary energy ranges between 40% and 60% over monthly timeframes, this underrepresents its importance to the levels of flexibility over timeframes from seconds to seasons and its role in security of supply. The flexibility of the electrical system is currently dependent on the natural gas system to provide energy on demand to gas Combined Cycle Gas Turbines and embedded gas-engines.

As more final demand is electrified, the levels and types of energy system flexibility will change with more input from demand, however, there are limits to demand side response, and thus supply side will remain a critical element of energy system balancing.

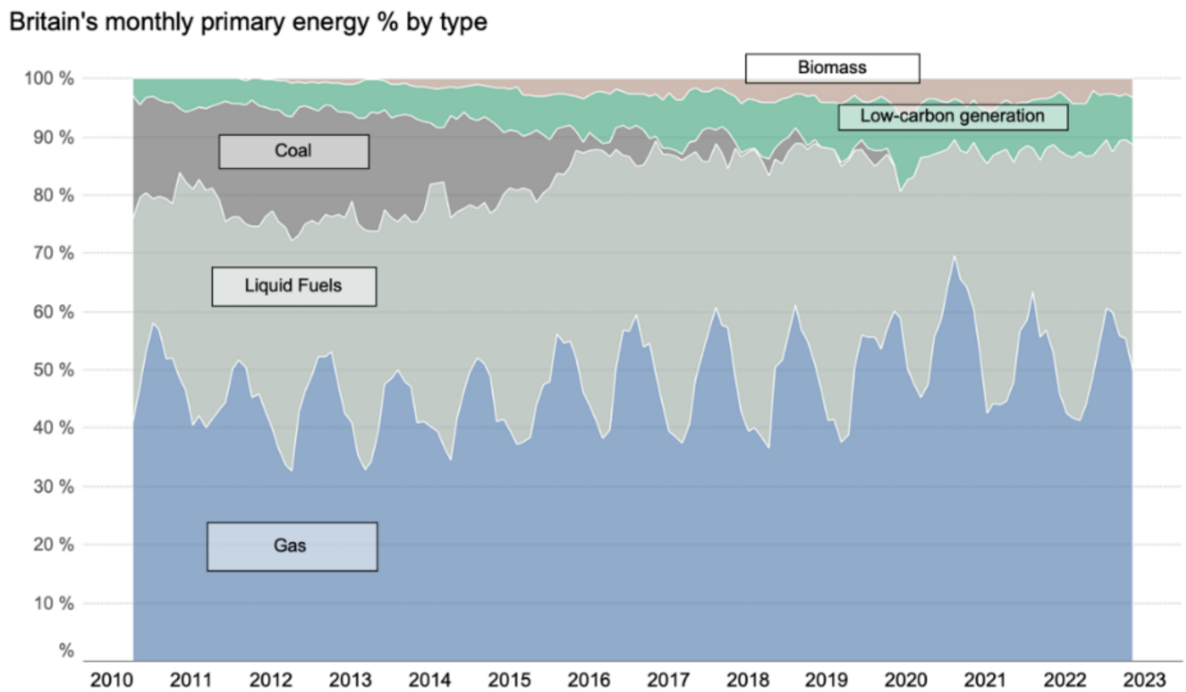

Figure 1 - Monthly percentage sources of Britain's primary energy. (only includes the demand for coal for electrical generation, petroleum products used for transport fuels, and does not include biogas). Data from National Gas, Elexon, National Grid and DESNZ.

Interviewees felt that, as a gaseous vector, hydrogen would be a critical part of a Net Zero energy system, able to provide the 10s of TWhs of energy storage currently largely provided by natural gas, and increasingly needed to provide security of supply covering wind troughs lasting a week or more. Government should therefore "get on with" infrastructure to connect the initial centres of hydrogen supply and demand (the industrial clusters) and the development of hydrogen storage both on and offshore.

There was a great deal of uncertainty surrounding the form of the decision for heating with hydrogen in 2026, but a widespread hope that the decision should increase rather than decrease certainty across the wider energy sector. Although Britain's stocks of coal and gas have significantly reduced, the amount of energy in fossil fuel stores continues to be orders of magnitude greater than the electrical grid-storage of batteries and pumped storage for which it seems economically infeasible to store energy at the TWh scale for longer duration time-frames.

A beneficial characteristic of fossil fuels (or generally of fuels more widely) is that they are comparatively easy to store at scale. This has provided security of supply by storing energy within Great Britain's national boundaries and allows for restocking of stores through bulk deliveries of energy, e.g., Liquified Natural Gas or pipeline gas and petroleum or petroleum products. The seasonal benefit of storage can be seen for natural gas in Figure 2 which uses the daily opening gas stock in "Storage" (caverns and the Rough offshore storage facility) and in LNG facilities from 2011.

The drop in the "in Storage" fraction in the chart from 2015 to 2018 was the winding down and eventual closure of the Rough offshore storage facility. This has been brought back online in 2022, in part due to a changed approach to security of supply influenced by the war in Ukraine and increasing energy demands as the world emerges from the COVID-19 pandemic; the amount of natural gas in storage has been above 13 TWh since the start of 2022.

This highlights the need to continue to have significant storage provision for security of supply at a scale (TWh and above) which makes hydrogen a potential candidate as natural gas is phased out to meet Net Zero.

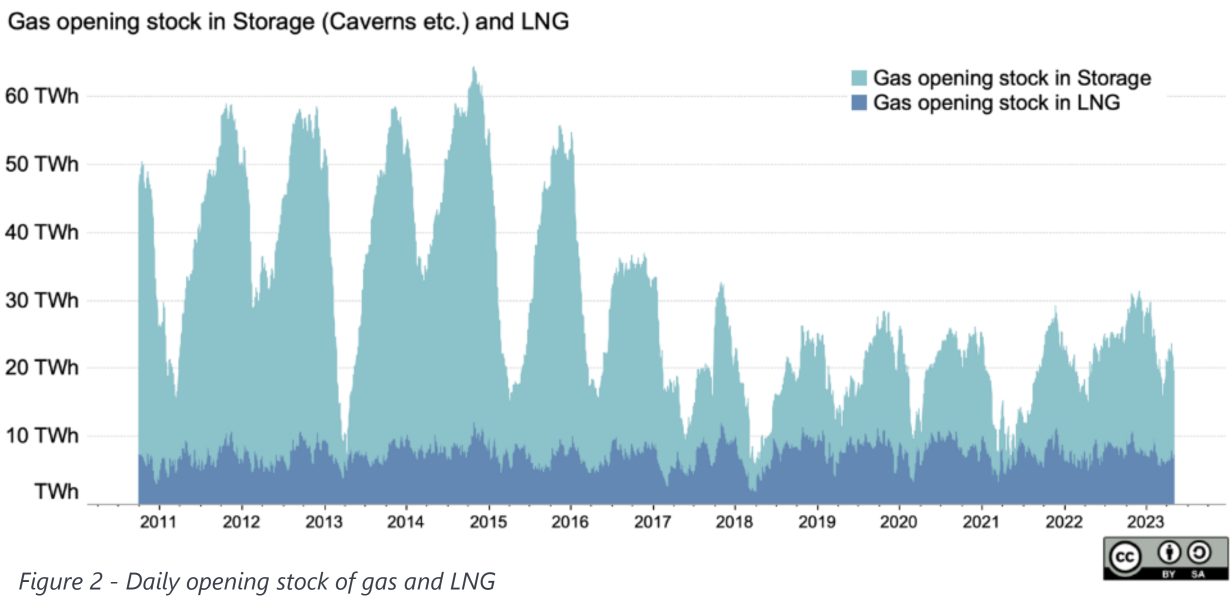

Figure 2 - Daily opening stock of gas and LNG

3. The Key Barriers

Several key barriers to the use of hydrogen for energy system flexibility were highlighted, including the lack of clarity around hydrogen markets and business models, the culture of policy making, market signals around flexibility for the gas system, education and training, meaningful whole energy system approaches at different geographical scales, standards, planning, and increasing pressure on supply chains from international markets. Barriers to the development of hydrogen were felt to be heavily interlinked, and many of the areas highlighted were not thought to be exclusive to hydrogen.

A strong message that resonated with the findings of the UK Hydrogen Champion report is that there needs to be increased coordination across government of the many moving parts that are required to build the hydrogen sector.

It was highlighted that innovation was felt to continue to have an important role not only in technology development and evidencing the safety case of hydrogen transport and storage, but also in whole systems analysis and coordination, planning and business models to underpin timely deployment.

1. **Clear government direction and ambition: A lack of clear government direction on the role of hydrogen in the transition to Net Zero was felt to be a major barrier to early investment.**

   The 2030 hydrogen production ambition of 10 GW was well received, however, delivery of this was dependent on appropriate business models and regulation being progressed.

   There was a clear recognition from interviewees of the policy effort taking place to develop a hydrogen sector in the UK, but that much was still needed to clarify opportunities, scale, and direction. There were growing challenges from supply chains prioritising other international markets that had greater clarity and opportunities.

   Connecting industrial clusters and hydrogen storage seemed to be a low-regrets decision to

   i) increase market scale away from captive local markets,

   ii) enhance security of supply between clusters, and

   iii) develop the foundations of a future system in a timely manner.

   Hydrogen for heat was an example of uncertainty, with the form of the decision itself being unclear. Hydrogen had a critical role in the UKs Net Zero economy to support the integration of greater levels of renewable generation and to support the electrical system. Major infrastructure was recognised as having long lead times, and early certainty on low-regrets approaches was felt to be helpful. The scale of deployment was influenced by the uncertainty about future needs, and that there were risks with over-sizing or under-sizing infrastructure during particular waves of investment.

The wider benefit of over-sizing infrastructure was highlighted in the short to medium term to provide greater levels of resilience to mitigate against reductions from the pace of energy system change.

2. **Culture of decision and policy making: An industry culture of needs driven investment, relatively low risk appetite, risk adverse decision making and failing to convert early innovation to business as usual was identified as a barrier to hydrogen development.**

   A shift of policy to encourage more flexibility in network investment ahead of need under certain conditions. A shift in culture in policy making could be explored, such as in greater sharing / consideration of policy development and collaboration with other countries for hydrogen deployment.

   Regulation may itself need to be radically updated during the decades of profound energy systems change where the pace of deployment is a key determinant of success. A need for an industry level discussion around the benefits of competition vs collaboration and whether the balance of this was suitable, particularly around innovation.

   There was a clear role for Government through the 2020s to coordinate, provide clarity and to develop business models to help enable growth in the sector. Beyond the 2020s, there was an expectation that hydrogen markets would have matured and for government support to play much less of a role.

3. **Market and regulatory innovation for hydrogen storage and flexibility: A lack of meaningful market signals to value flexibility provided by the gas sector was felt to be a barrier.**

   The gas sector is not currently able to fully valorise its contribution to Britain's wider energy system flexibility, resilience, and security of supply due to the regulatory environment. Price signals that were able to flow through to the gas system could provide greater visibility on energy system flexibility.

   Regulatory innovation to fund the eventual construction and operation of strategic levels of energy (10s of TWhs) stores within the UK's national boundaries was highlighted; there are few credible alternatives to using a low-carbon fuel which would likely be hydrogen or its derivatives for this. Stores of energy that can be transformed into TWh levels of electricity will grow in importance as more and more final-use demand is electrified.

   Geological storage needs to be developed soon for availability in the 2030s. GWs of electrolysers can provide demand side balancing. Low-carbon dispatchable electrical generation plant includes hydrogen gas plants; innovation through early deployment of a handful of these is required for wider learning.

4. **Education: The skills needed to scale up the deployment of hydrogen from the planning system, through to manufacture, installation, and end users were felt to be barriers.**

Education is a foundational element for supply chain readiness to support infrastructure delivery at an unprecedented level. Skills for the delivery of hydrogen infrastructure are needed right across the sector, from increasing knowledge in planning, to the design, manufacture and ultimately the installation of infrastructure and end-use technologies.

Industry, SMEs, and domestic end-users would benefit from knowledge on the trade-offs of hydrogen technologies versus other low-carbon forms of end-user service. Increasing whole energy systems knowledge of policy makers at a national, regional, and local level is important to increase the pipeline of people with this experience and skill. To help education and learning in a similar way to hydrogen village trials, locations should be chosen that shift to a mixture of low-carbon heating and also shift completely from gas, e.g., areas of low-carbon heating trials and off-gas trials for villages currently on gas.

5. **Coordination in planning across whole energy systems: Whole systems planning, and co-ordinated delivery was not felt to be happening in any meaningful way. Government and regulation is needed to make this happen.**

A lack of meaningful whole energy systems planning and coordination was felt to be a barrier to hydrogen providing flexibility to the wider energy system. Hydrogen infrastructure was felt able to support the electrical system and integrate greater amounts of renewable generation. Increasing amounts of green hydrogen for Net Zero necessitates a whole systems approach. The Future System Operator was highlighted as an opportunity to bring greater expertise together from the electrical, gas and heat-network sectors.

More focus should be on the frameworks to enable the coordinated planning of infrastructure by increasing the effectiveness of whole systems analysis and on incentives to do so. This will require innovative planning methods and training of people at all levels to deliver. Deeper levels of whole energy systems thinking (electricity, hydrogen, heat, liquid fuels, water, CO_2 transport) need to be embedded across a wider group of stakeholders, and Government needs to take a lead role in making this happen. The current siloed delivery approach for electricity, gas, liquid fuels, and water needs to be targeted with aims, measurable objectives, and resources to encourage greater whole systems interactivity.

Gas Distribution Networks need to plan for the flow of energy through gas infrastructure to be on a downward trajectory. Coordinated planning needs to start between Gas Distribution Networks, Distribution Network Operators and Heat Networks on areas that will no longer have access to natural gas or hydrogen, and how this transition will be managed at a local level. Local authorities / combined authorities should be part of this planning to help to input into this transition.

There is a need to consider how to replace on-site electrical back-up for industry and services with critical requirements for electrical and heat supply. An assessment of the current levels and types of energy system flexibility and security of supply required by different sectors (health, agriculture, industry, transport, etc.) was highlighted as necessary to provide a basis for whole system analysis for future needs. This would reveal the currently hidden sources of high-carbon flexibility, such as backup diesel generators and gas-engines that would have to be replaced, as well as flexibility assets that could be shared versus where exclusivity is required. DESNZ was presumed as a logical place to gather these data, and this could also help to build whole energy systems thinking across different departments and administrations.

6. **Standards and standardisation: A lack of standards can be a barrier to the hydrogen transition, and increasing standardisation can help to drive down costs.**

   Discussion ranged from the need for standards to be further developed through technology and safety trials (funded centrally), to the development of standards for hydrogen markets, to the need for standardisation of approaches as much as possible across Britain for areas such as planning system processes and water abstraction licencing.

   Improving the pace of standards and policy development was seen as important to reduce the risks of these remaining or becoming barriers in the future and forcing delays on deployment. Sharing the development of standards with other countries was seen as a potential way to accelerate some areas.

7. **The planning sector: The capacity within the planning sector to cope with increased levels of applications was felt to be a barrier.**

   The planning system was highlighted throughout many interviews as a potentially systemic risk to meeting targets in a timely manner, particularly under the unprecedented pace of deployment and change right across the energy system from different supply chains. There were therefore suggestions that planning, and education of the wider public needed to take more of a priority to be able to find appropriate balances between local and national priorities.

   The pace of developing infrastructure on land could be a key barrier so more infrastructure might need to be offshore. In addition to the new additions or re-use of gas infrastructure, decommissioning of current natural gas infrastructure was highlighted as an area that needed further attention.

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