Hydrogen Energy Association

The Role For Transport And Storage In Delivering The Hydrogen Transition

October 2023

Introduction

As we move towards a decarbonised future, hydrogen has emerged as a potential energy carrier with a vital role to play in facilitating the transition to net zero. This Paper explores the various aspects related to the wide-scale implementation of hydrogen in our energy system, specifically focusing on the challenges and opportunities tied to its transportation and storage.

This paper has been developed against the background of the Department for Energy Security and Net Zero's evolving position as articulated in its 'minded to positions' on Transport and Storage business models published in August 2023.

The first section of this Paper presents an analysis of the considerations inherent in the development of a transportation network for hydrogen. It considers both pipeline and non-pipeline options and highlights how a combination of the two will deliver a network with the greatest reach, lowest cost and best flexibility to meet user needs.

In the second section, the Paper addresses hydrogen storage, an under-explored component of renewable energy integration, and key to hydrogen's future role. It outlines how strategic hydrogen storage can aid in managing periods of excess renewable electricity production and the potential cost savings it could deliver for the energy system. Furthermore, it explores both short-term and long-term storage solutions and the infrastructure required to support them, emphasising the need for timely planning and investment.

Finally, the paper delves into the crucial aspect of strategic planning, offering a comprehensive view of how a future-oriented, coordinated approach to hydrogen network development can ensure optimum resource allocation and maximise the impact of investments.

By integrating these threads, the paper aims to shed light on the multi-faceted challenges and potential solutions tied to hydrogen's role in our de-carbonised future. It draws attention to the urgency of coordinated strategic planning and policy-making to ensure that we capitalise on the opportunities that hydrogen presents, and to ensure the UK's energy system is prepared for the demands of the coming decades.

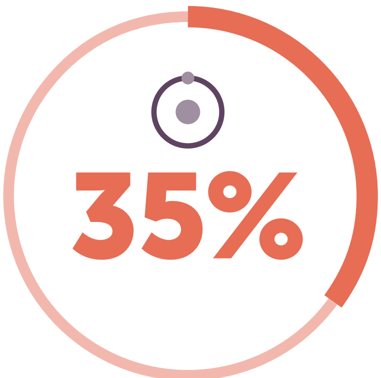
Transportation of Hydrogen

Introduction

The UK's transition to net zero requires significant changes to our energy infrastructure, including those to accommodate energy carriers such as hydrogen.

Hydrogen is a vital component of our decarbonisation journey, expected to account for up to 35% of final energy demand by 2050[1]. It is a versatile energy vector that can be used in various sectors, including power generation and transportation. A functioning infrastructure for hydrogen will include low carbon production, use in various sectors, and transportation and storage to connect the two.

This section explores and compares pipeline and non-pipeline methods for the transportation of hydrogen and considers the options for non-pipeline transportation, including road, rail, and sea.



Hydrogen is a vital component of our decarbonisation journey, expected to account for up to 35% of final energy demand by 2050

Pipeline Transportation of Hydrogen

Whilst pipeline transportation of hydrogen will undoubtedly form part of our long-term infrastructure, it requires a significant capital investment, takes time to build, and is limited in coverage. According to a report by the Committee on Climate Change, the UK's hydrogen pipeline network won't fully serve industrial clusters until after 2030[2]. This timespan is due to several factors, including the need for significant investment in pipeline infrastructure and regulatory hurdles. Following the recent publication of Government's minded to position, there is more certainty on the investment in infrastructure being made, with the confirmation that pipelines will likely be supported through a Regulated Asset Base (RAB) model.

The RAB model is a well proven funding mechanism which essentially enables investment into infrastructure while an operator is given an "allowed revenue", which is recuperated from the users of such infrastructure. During the initial years, where the user base is growing, an external subsidy mechanism will likely be provided – effectively "topping up" the difference between allowed revenue and the value which can be recuperated through a fair user charge structure.

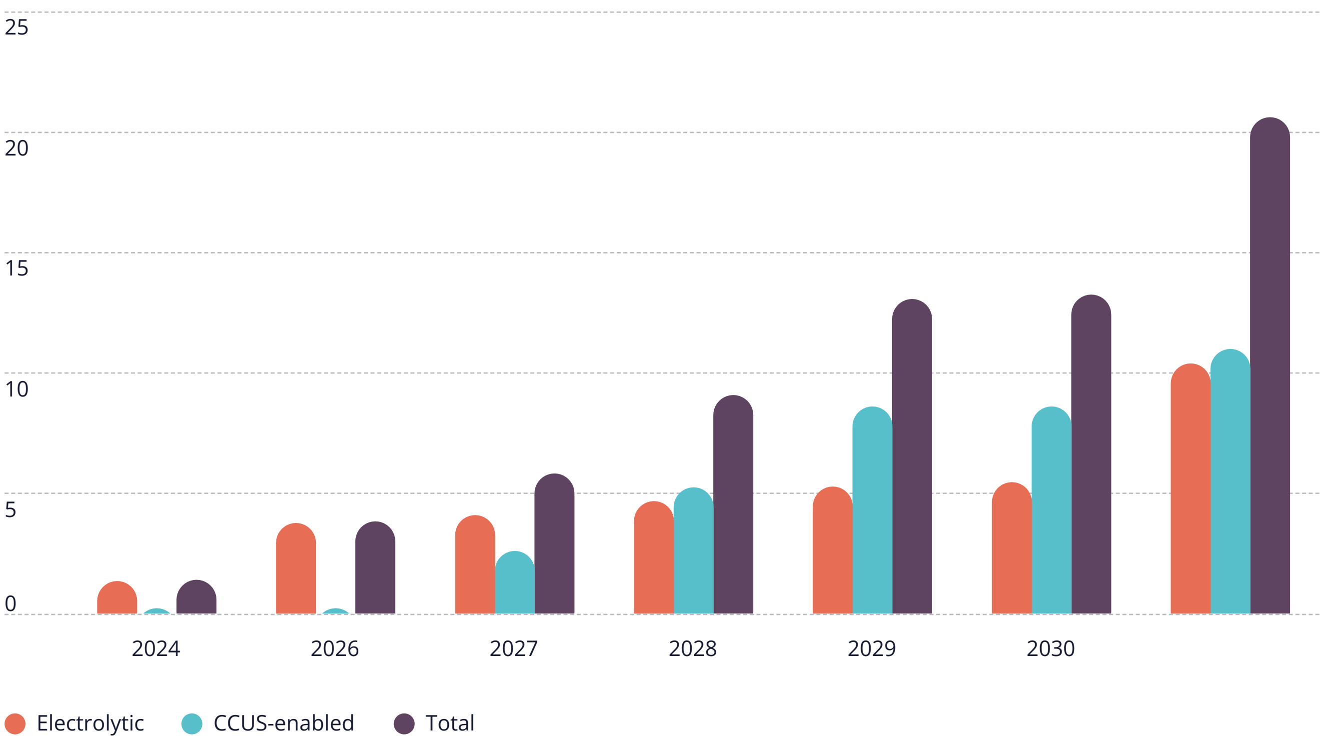
While the clarity on DESNZ's minded to position for subsidising hydrogen pipeline infrastructure is welcome, support becoming available after 2025 is too late considering the UK's ambitious hydrogen production targets.

1 https://www.gov.uk/government/publications/uk-hydrogen-strategy/uk-hydrogen-strategy-accessible-html-version
2 https://www.theccc.org.uk/publication/net-zero-power-and-hydrogen-capacity-requirements-for-flexibility-afry/

The lack of hydrogen pipeline infrastructure to support key demand centres in the short term creates uncertainty for consumers in these centres regarding the availability and cost of supply. These uncertainties are further exacerbated in locations without any form of hydrogen delivery to meet local needs. Pipeline quality hydrogen, for use in non fuel-cell applications, could benefit from significant cost reductions in comparison to pure hydrogen transported via tube trailers. This is particularly true once the hydrogen pipeline networks are as widespread as existing natural gas. A study by the International Energy Agency found that the cost of transporting hydrogen via pipelines is highly dependent on the distance travelled and the volume transported[3]. While the volume and distance of hydrogen that will be transported via pipelines is currently unclear, projects such as Project Union with 'East Coast Hydrogen' are looking to reduce network build out costs through the conversion of the existing natural gas pipelines to hydrogen[4]. These points highlight the importance of carefully planning pipeline networks to minimise costs and ensure efficient transportation of hydrogen.

The UK Government and industry stakeholders must work together to invest in the necessary infrastructure, address technical challenges, and ensure that the first 10GW of Low Carbon Hydrogen can be delivered to off-takers in the absence of hydrogen pipelines. The design and implementation of a business model for hydrogen transportation are crucial enablers for these actions. Without a business model in place, those looking to buy hydrogen in the future might hesitate to switch, as there's no guarantee for a steady supply. While DESNZ's recent announcements move us closer to a solution, if we delay setting these up, we risk not establishing sufficient offtake for the anticipated growth in hydrogen supply between 2025 to 2030 (Figure 1[5]).

Figure 1: The known pipeline of hydrogen projects shows potential for growth and investment



3 https://iea.blob.core.windows.net/assets/9e3a3493-b9a6-4b7d-b499-7ca48e357561/The_Future_of_Hydrogen.pdf
4 https://www.nationalgas.com/document/139641/download
5 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1166666/hydrogen-investment-roadmap.pdf

Non-pipeline transportation

Non-pipeline transportation offers several benefits over pipeline transportation including ease of deployment, the delivery of high purity hydrogen and the ability to reach the full range of locations where hydrogen is needed. These benefits notwithstanding, non-pipeline transport is yet to be accounted for in the Transport and Storage business models.

Non-pipeline methods for hydrogen transportation can be deployed quickly and easily to link all possible combinations of production and use, providing fully flexible solutions to meet customers' needs – wherever they are. As they can be deployed now, and with such flexibility, they provide both a smooth transition to a hydrogen pipeline network, where that is developed, and a complement to such a network through the widespread geographical coverage. A further benefit of this is that hydrogen can be distributed widely across the UK, contributing to the levelling up agenda.

In addition, the established gas industry has a proven track record of utilising non-pipeline routes, such as road transportation, for a substantial portion of gas product transportation. This operating model is familiar to both gas suppliers and their customers, easing the transition to hydrogen delivery via non-pipeline methods. In addition to its role in facilitating a transition to a hydrogen economy, non-pipeline transportation methods can also deliver high-purity hydrogen for transport and other applications without the need for further purification to remove impurities such as odorants from the gas. This ensures that the hydrogen meets the requirements of a range of fuel-cell based applications.

Alongside the road transportation of hydrogen, there are also rail and marine options within the UK region:

Marine: Companies such as Gen 2 Energy are exploring the shipping of hydrogen in Norway[6]. In future, with support, this could be a viable route for the transport of large volumes of hydrogen along the UK coast.

Rail: Examples exist in Canada[7] of Liquified Natural gas being transported via rail to remote regions. In areas without hydrogen pipelines and with suitable rail connections, the possibility exists to transport hydrogen to connect producers and users via rail.

6 https://gen2energy.com/gen2-energy-and-grieg-logistics-sign-a-letter-of-intent-for-cooperation-on-green-hydrogen-in-the-mosjoen-and-helgeland-area/
7 https://www.cer-rec.gc.ca/en/data-analysis/facilities-we-regulate/canadas-pipeline-system/2021/natural-gas-liquids-pipeline-transportation-system.html

Recommendations to Government

To support the development and deployment of non-pipeline transportation methods for hydrogen, the UK Government should consider emulating the current Hydrogen Business Model, adapting it to suit the particular characteristics of this element of the transportation and storage jigsaw. The Business Model has been successful in attracting private investment and providing long-term stability for the industry. By adopting a similar approach for non-pipeline transportation, the Government can help to establish a funding mechanism for the transport of hydrogen which will aid in the servicing a greater variety of regions prior to the commissioning of a functional hydrogen pipeline network. Considering that it will make up the majority of transported hydrogen before 2030, as displayed in Figure 3, the HEA believe the importance of non-pipeline has been underplayed in the minded to Positions for Transport and Storage Business Models[8].

In addition, once a pipeline network is operational, it will offer ongoing access to users not connected to a pipeline as well as those requiring high purity hydrogen. Thus, end users will have access hydrogen in the short term, while distributors can invest in the associated CAPEX and OPEX to enable the system.

To bring forward the technology behind high capacity tube trailers for the transport of hydrogen, the HEA recommends the allocation of funding for R&D to support next generation type 4 tube trailers, such as world leading UK based company Luxfer Gas Cylinder[9].

Summary

In summary, the transportation of hydrogen is a critical component in the transition to a low-carbon economy in the UK. While pipeline transportation offers a long-term solution for some customers, its implementation faces several challenges, including a lengthy build-out process and uncertainties around reliability of supply. Non-pipeline transportation methods offer several benefits over and complementarities to pipelines, including short timeframes for implementation, full geographical flexibility and the ability to deliver high-purity hydrogen. The different modes of non-pipeline transportation, including road, rail, and sea transportation, provide further flexibility and optionality which should be supported through the Government's Transport and Storage Business Models.

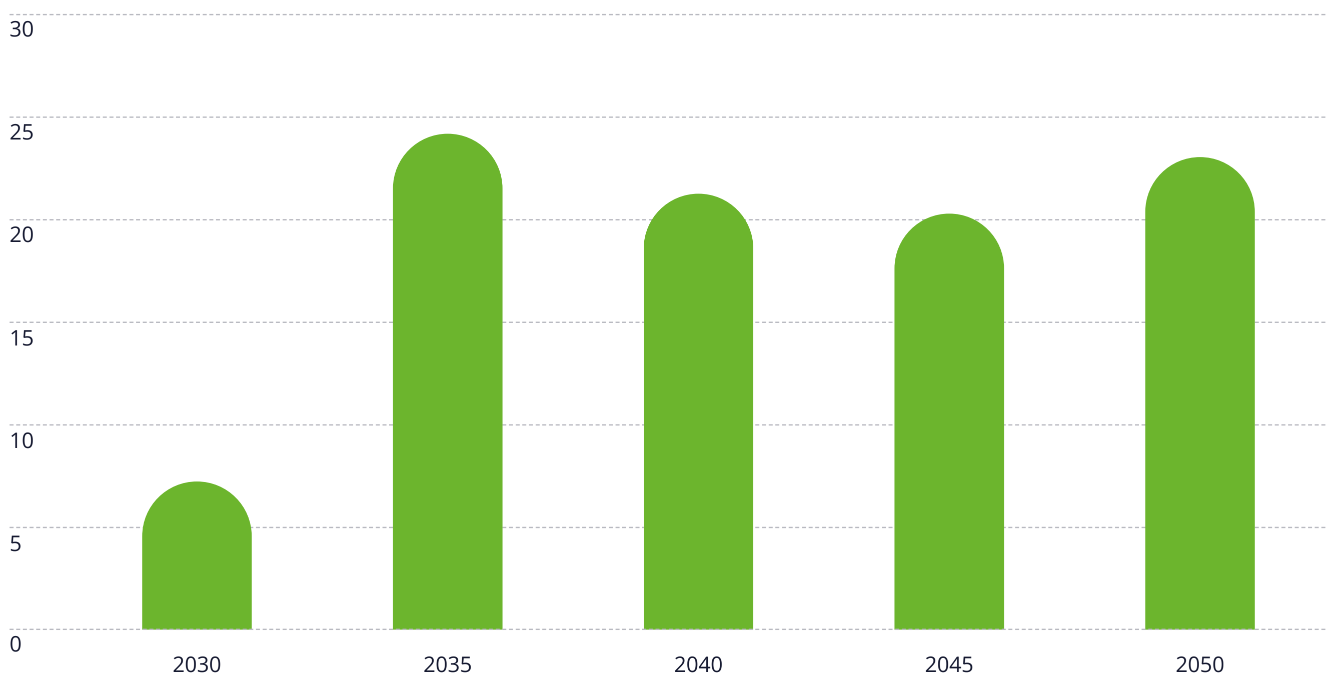
8 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1175804/hydrogen-transport-storage-minded-to-positions.pdf
9 https://www.luxfercylinders.com/products/virtual-gas-pipelines/g-stor-pro-bundle

Hydrogen Storage

Storing hydrogen is an important means of addressing renewable intermittency while helping to bolster the UK's security of supply at least cost. To minimise the curtailment of renewable energy, which will increase in decades to come (Figure 2[10]) and has already cost the UK government £402m across 2020-2021[11], we must take action.

Hydrogen can be produced via electrolysis during periods when supply exceeds demand. It can then be stored to meet future hydrogen demands or reconverted to electricity when needed, building flexibility and efficiency into the UK energy system.

Figure 2: Levels of annual renewable curtailment for all durations (TWh)



Note: 2030 has lower values due to the assumption that network reinforcements currently planned are included in the base network. These levels of curtailment are significantly higher than the current 1-2TWh per year but come at much lower cost due to the assumption that post-subsidy renewables are curtailed at 0£/MWh, as opposed to the opportunity cost of the relevant subsidy.

10 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1095997/benefits-long-duration-electricity-storage.pdf

11 https://www.drax.com/wp-content/uploads/2022/06/Drax-LCP-Renewable-curtailment-report-1.pdf

As well as helping to effectively harness renewable energy, hydrogen storage could also generate further cost savings elsewhere in the energy system. The Hydrogen Transport and Storage Consultation's Analytical Annex anticipates potential savings of £13-24bn to the electricity system from 2030 to 2050, primarily due to reduced fuel costs for power generators[12]. Looking further ahead, hydrogen storage is expected to be a necessity in all net-zero scenarios under the National Grid ESO's Future Energy Scenarios from 2030 onward[13], with an estimated 56 TWh of hydrogen storage required in their System Transformation scenario by 2050[14].

£13-24bn

cost savings to the electricity system from 2030 to 2050 with long term hydrogen storage

This section will consider short-term storage, which caters to the hourly or daily fluctuations in energy demand and supply, and long-term geological storage, which is required to serve sustained periods of supply and demand mis-match (in periods from weeks to seasons). Although these two options differ in storage duration, their purity typically varies as well. Short-term storage might include both high purity and pipeline quality hydrogen, whereas strategic long-term storage is likely to focus on larger amounts of pipeline quality hydrogen. Despite the practical advantages of short-term storage, this paper emphasises recommendations for large scale, long-term storage.

Beyond electricity system optimisation, storage of hydrogen is essential to ensure a reliable and consistent supply of hydrogen to meet demand, particularly during peak periods. By addressing the challenges associated with hydrogen storage, the UK can create a robust and flexible low carbon energy system.

Short-Term Storage

Short-term storage spans from several hours to a few days, and can effectively manage intra-day variations between energy demand and supply by employing surface storage tanks which can provide fast access to stored hydrogen. These systems will serve as a buffer, reducing the impact of intermittent fluctuations thereby ensuring a smooth energy flow. Additionally, their implementation contributes to operational flexibility, enabling efficient usage of renewable energy sources by addressing their inherent variability.

12 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1100705/hydrogen-transport-storage-analytical-annex.pdf (page 7)
13 https://www.nationalgrideso.com/document/263876/download
14 https://www.nationalgrideso.com/document/283101/download

Long-Term Storage

Long-term storage targets the overarching disparity between demand and supply, ranging from weeks to entire seasons. Notably in the UK, this approach will likely involve geological repositories, such as salt caverns and porous rock, to accommodate large-scale, prolonged storage, providing an effective solution for seasonal shortfalls. Looking ahead, it is essential to consider the need for large volumes of storage capacity, which will be required around 2030 in line with the delivery of the UK's first 10GW of low carbon hydrogen. Timely planning and implementation are critical, as the development of significant storage infrastructure requires a long lead-time[15]. As highlighted in the 2022 Future Energy Scenarios, strategic investment is required now to realise the high levels of geological hydrogen storage that is required[16].

In August 2023, Government announced its 'minded to' positions for the support of long duration storage, which will be an adapted "Floor" mechanism. A "Floor" mechanism guarantees a minimum revenue to a facility, irrespective of its actual use. If the facility doesn't generate enough revenue from users, an external subsidy ensures it still receives this minimum revenue.

Operating storage facilities without consistent revenue assurance poses the risk of underinvestment and selective use. Such sporadic use can lead to strategic gaps in storage distribution, potentially leaving some regions underserved and causing others to be saturated. The "Floor" mechanism, by guaranteeing a steady revenue stream, offers protection against these market inconsistencies. This assurance encourages investment in infrastructure and fosters proactive management, ensuring the storage facilities are not just operationally sound, but also cater to the broader needs of the network. It aligns with the strategic vision of achieving optimal storage distribution, preventing any regional disparities and, in turn, fortifying the reliability of the UK hydrogen network.

Recommendations to Government

Short-Term and Modular Storage

While large-scale underground storage is favoured in the preliminary outline of the Transport and Storage Business Models, it is vital to also consider how above-ground storage options will evolve, particularly for the transport sector. Collaborative efforts between Government and industry can encourage research and development to support above-ground storage solutions; their implementation will complement geological and salt cavern storage. By providing a supportive regulatory and policy environment, Government can attract private investments in small and modular storage infrastructure, supporting widespread non-pipeline distribution and pipeline utilisation.

Long-term Storage

The HEA is supportive of a 'Floor' mechanism, and welcomes the clarity on the business model for long-term storage. However, as elsewhere, the proposed timelines are of concern. With the potential for critical delays in infrastructure development and investment. An expedited rollout of storage business models is crucial to ensure we meet the immediate needs of the network and foster investor confidence. We urge the Government to reconsider this timeline, prioritising timely delivery to reinforce the UK's hydrogen storage ambitions.

15 https://www.theccc.org.uk/publication/net-zero-power-and-hydrogen-capacity-requirements-for-flexibility-afry/
16 https://www.nationalgrideso.com/document/264421/download

Summary

Hydrogen storage is a crucial component of a resilient and flexible decarbonised energy system, throughout this section we have highlighted the urgency of accelerating the development of storage business models, emphasising the risk of market failure if strategic planning and adequate resources are not allocated timely. By recognising the need for both short and long duration storage, conducting economic analysis, and implementing supportive policies and subsidies, Government can foster the development of robust storage infrastructure. These measures will enhance energy system resilience, ensure a reliable hydrogen supply, and accelerate the transition to a sustainable and decarbonised future. It is imperative that Government proactively collaborates with industry stakeholders, conducts research and analysis, and provide the necessary support to unlock the full potential of hydrogen storage. By doing so, the UK can ensure the supply of low carbon hydrogen throughout the year, even during times of low renewable generation and high energy demand.

Strategic Planning

Strategic planning for hydrogen transportation and storage will allow the Government to take a holistic and visionary approach to the development of a hydrogen network.

Strategic planning will help facilitate the identification of long-term system goals, define the strategic direction, and ensure coordinated efforts across stakeholders.

Strategic planning should assess existing infrastructure, identifying gaps and formulating a roadmap for infrastructure deployment – aiding in optimum resource allocation and prioritising investments for maximum impact by 2030 onwards (see Timeline below for anticipated infrastructure and policy developments from 2023 to 2033). A clear roadmap will instil confidence in investors, ensuring a conducive environment for the growth of hydrogen-related industries.

While the Government's August publication, outlining its 'minded to' positions was helpful in confirming the development of the "Hydrogen Networks Pathway" prior to the establishment of a Future System Operator, there remains great uncertainty across areas of strategic planning. National distribution by one body, the FSO, is a commendable objective; however, policy has to support development at all levels.

One area of confusion is where the Government has been clear in taking a strong central planning role, with some form of competition for projects where the most strategic are selected. Yet, it remains unclear at what point this role hands over to the FSO. We would welcome confirmation of timings and processes for the transition.

In addition to system level development, there should also be arrangements for private pipe arrangements, recognising them as potential first movers that could foster wider adoption.

Those looking to invest and develop hydrogen storage are venturing into a policy void. It's essential to look beyond just the NPS (National Policy Statement), as highlighted in the Government's 'minded to' positions, but also incorporate National Planning Policy framework (NPPF) and National Planning Policy Guidance (NPPG) content. This comprehensive approach will further encourage local development plans to actively support hydrogen transport and storage.

Virtual Price Discovery

A Virtual Price quantifies hydrogen's value, bridging its current intangibility to a future tangible market worth. The process of discovering a virtual price is a vital progression from the price discovery activity found within the Hydrogen Production Business Model. The virtual price will account for the total cost of hydrogen to the end user, factoring in transport and storage costs. It is an important milestone in the commercial evolution of hydrogen and is the stepping stone from our current shadow market to a mature trading market. Once established, it should accelerate project development and deployment - ensuring the availability of hydrogen energy sources across the UK. The average price and consumption histories of UK low carbon hydrogen are vitally important to business investment decisions and Government policy decisions. At present, pricing data is sparce and not well traded; in future decades we will need a metric similar to the UK's National Balancing Point (NBP)[17] for natural gas. This will require the FSO to go through a process of learning in the years leading up to 2030 to understand what exactly the virtual hydrogen price is, and this should be included in the remit of the FSO.

17 The National Balancing Point (NBP) is a virtual trading location for UK natural gas supplies, where gas across the national transmission system is priced uniformly as NBP gas. This simplifies transactions for buyers and sellers, streamlining the deal-making process.

Timeline

2023

Early production projects supported in the Hydrogen Allocation Round process set to receive localised transport infrastructure support.

Government Begins development of the Hydrogen Networks Pathway.[18]

Government to announce principles of the Transport and storage business model by 2023.

2024

2GW low carbon hydrogen production target reached, no pipeline networks in place all transport via virtual pipelines.

Future System Operator selected and in operation.

2025

Design of Transport and Storage Business Model.

2026

Government Decision on Hydrogen Heating in 2026.

HEA anticipates round 1 of the Transport and Storage Business Models to conclude before the end of 2027.

2027

2030

10GW of production online and transported exclusively via virtual pipeline network.

2033

Pipeline Networks and Long Duration Storage begin to come online. Project Union connects to the European Hydrogen Backbone.[19]

18 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1175804/hydrogen-transport-storage-minded-to-positions.pdf
19 https://www.nationalgas.com/document/139641/download

Conclusion and Recommendations

This paper has explored the dimensions of transportation, storage, and strategic planning in relation to hydrogen, shedding light on the challenges, opportunities, and need for policy. Based on the findings, we put forth the following recommendations for policy considerations and future action.

In terms of the transportation of hydrogen, we stress the importance of non-pipeline transportation methods and suggest the government take inspiration from the current Hydrogen Business Model, adapted to address the characteristics and challenges of this component. To foster innovation and ensure safety, we recommend dedicated funding for research and development, particularly on high-capacity tube trailers, and a comprehensive approach to the development of safety standards and regulations.

Storage solutions for hydrogen present a two-fold challenge of addressing both short-term and long-term storage needs. To support the development of short-term storage, we recommend that Government fosters a supportive environment for the development of above-ground storage facilities, including favourable regulatory frameworks to attract private investments. For long-term storage, we advocate for a Business Model based on a Regulated Asset Base model. Furthermore, we highlight the urgency of accelerating the development of storage business models, emphasising the risk of market failure if strategic planning and adequate resources are not allocated timely.

Strategic planning is the cornerstone of a successful hydrogen economy. The development of a virtual hydrogen price will be key to facilitating the sector's growth and ensure the timely deployment of the hydrogen infrastructure. This shift not only holds significant potential for cost reductions but will also have considerable implications for the wider hydrogen network.

The path to a hydrogen-based energy future is paved with complexities and opportunities alike. Through rigorous strategic planning, forward-thinking policies, and a commitment to innovation, the UK can effectively navigate these challenges, maximising the benefits that hydrogen offers for our energy system and our environment. It is our hope that these recommendations will contribute to the ongoing discussions and policy planning necessary for the successful integration of hydrogen into our energy future.

"To foster innovation and ensure safety, we recommend dedicated funding for research and development, particularly on high-capacity tube trailers, and a comprehensive approach to the development of safety standards and regulations"

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