Westwood Global Energy Group

Hydrogen scale-up: what's priming the UK for success?

March 2023

Introduction

As the world began recovering from the coronavirus, the UK saw an opportunity to "build back better". It announced investments to support economic recovery and drive forward its carbon emission reduction target of 78% compared to 1990 levels by 2035 and achieve Net Zero by 2050. The government's Ten Point Plan issued in November 2020 aimed to spur investment in energy, buildings, transport and low-carbon technologies, the latter of which included hydrogen. The government unveiled its national Hydrogen Strategy in August 2021, which set a 5 GW target for low-carbon hydrogen production in the UK by 2030.

Russia's invasion of Ukraine in February 2022 fuelled an energy crisis and stoked concerns over future energy security. This resulted in Europe scrambling to secure alternatives, setting in motion plans to reduce dependency on Russian gas and accelerating the transition to a low-carbon future. The UK was no exception to this – the government reacted by doubling its hydrogen target to 10 GW by 2030.

This target may now appear ambitious given hydrogen is in its infancy. Mechanisms will be required to support the development of a hydrogen economy, including scaling up production, investing in infrastructure and encouraging switching/demand uptake.

This report explores three key factors priming hydrogen for success in the UK market: 1) government support, 2) cost reductions and 3) supply and demand.

1. Government Support

To meet its 10 GW target, the UK government introduced two important measures in its Hydrogen Strategy – the Net Zero Hydrogen Fund (NZHF) and the Hydrogen Business Model (HBM) – to incentivise the production and use of low-carbon hydrogen.

The NZHF seeks to de-risk investment in low-carbon hydrogen production and reduce lifetime costs. It provides £240 million in grant funding to be used towards the upfront costs of development and capital expenditures.

The HBM provides ongoing revenue support to the developer through a Contracts for Difference (CfD) mechanism, which has previously proved successful in supporting the deployment of large-scale renewables projects.

The first joint allocation '2022 HBM/NZHF Electrolytic Allocation Round' ran between July and October 2022 to support 250 MW of green hydrogen production to be operational by the end of 2025 – a shortlist of successful projects is due to be announced in early 2023. A second round is planned for summer 2023 with contracts awarded in 2024.

2. Cost Reductions

Government support is aimed at addressing the high cost of hydrogen relative to other alternatives. Figure 1 from the IEA shows the average levelised cost of hydrogen (LCOH) for blue (produced from natural gas with CCUS) and green (produced from renewable energy) remaining uncompetitive versus grey (using natural gas, and the dominant form of current production) until 2030 (IEA, 2022).

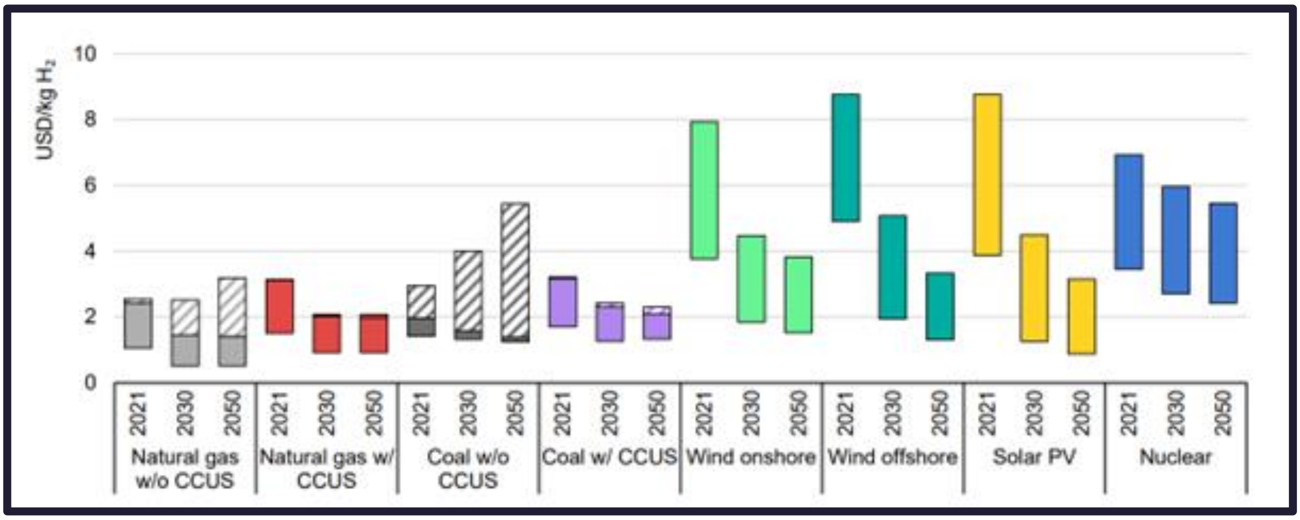

Figure 1: LCOH by technology in 2021, 2030 and 2050 (IEA, 2022)

Russia's invasion of Ukraine led to a surge in energy prices and temporarily made green hydrogen competitive with grey and more attractive than blue; however, natural gas prices have since significantly declined back down to pre-invasion levels, once again reducing green hydrogen's competitiveness.

Until hydrogen scales and costs decline, government support will be instrumental in making low-carbon (blue and green) hydrogen competitive, which is essential for incentivising uptake. Developers are simultaneously attempting to strengthen their business cases for hydrogen by leveraging advantages such as feedstocks and infrastructure that could deliver further cost reductions.

2.1 Feedstock Selection

The UK government is taking a twin-track approach, supporting both blue and green hydrogen production since it has advantages in both.

UK's advantages in blue hydrogen

Although not carbon-neutral, blue hydrogen can scale faster relative to green because 1) grey hydrogen production technology (SMR and ATR) is already well-established, as is carbon capture which is required for blue hydrogen production, although the latter has not been proven at scale and 2) it is currently produced from refineries and, hence, there is an existing demand base and can benefit from large economies of scale. Blue hydrogen can, therefore, provide the UK with a route to decarbonisation in the short-to-medium term until green hydrogen is more readily available and cost-competitive.

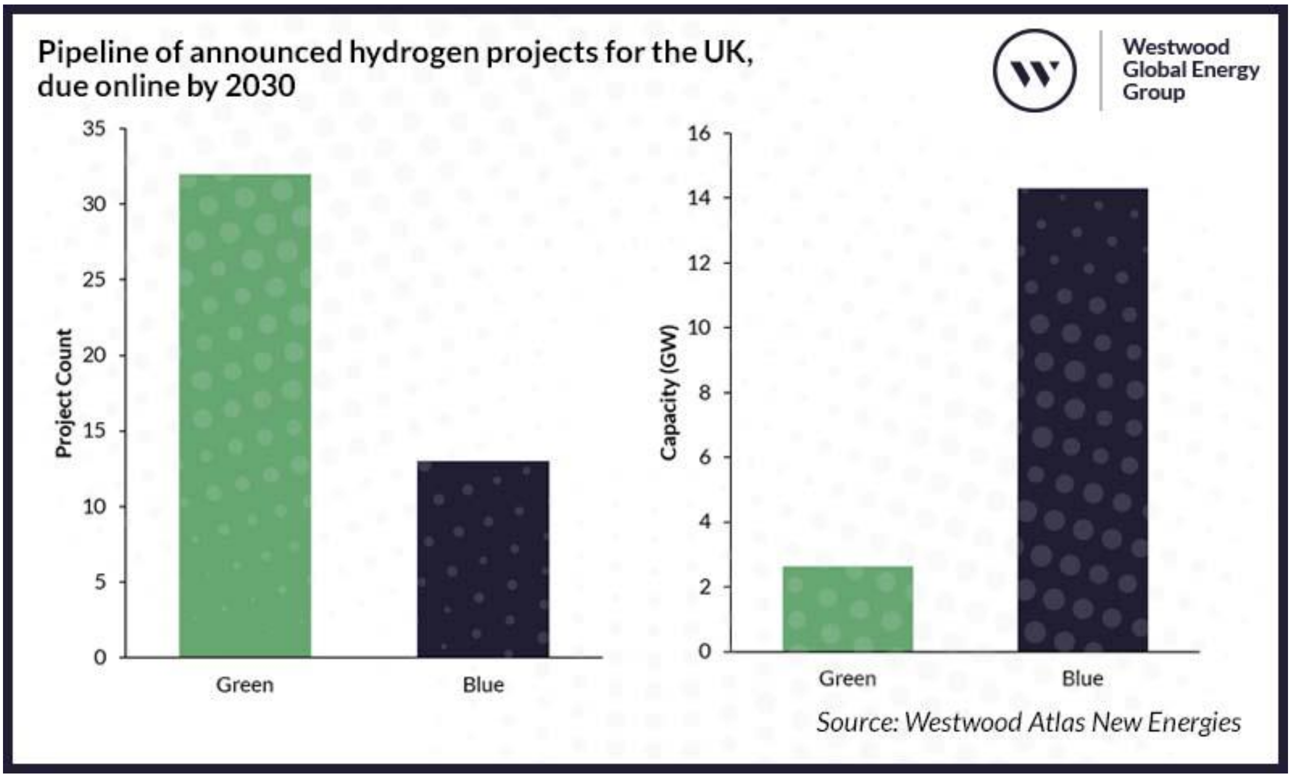

Figure 2: Pipeline of announced hydrogen projects for the UK, due online by 2030 (Westwood Atlas New Energies, 2023)

Westwood's Atlas New Energies solution currently tracks 45 low-carbon hydrogen projects in the UK. Blue hydrogen makes up 29% of the total project count and 84% (or 14.3 GW) of the 17 GW of total low-carbon hydrogen capacity announced for start-up by 2030.

If all the capacity starts up as planned, this would surpass the UK's target; however only a small number of demonstration-sized green hydrogen projects have thus far reached final investment decision (FID).

Natural gas is the feedstock for blue hydrogen production. The UK has access to abundant natural gas reserves in the North Sea – 240 oil and gas fields are in operation, supplying 40% of the UK's gas needs (Westwood, 2023). The UK is highly dependent on natural gas use in critical applications such as power and heat for industry and homes; thus, not only is natural gas important for the UK's energy security but it also represents a significant opportunity for decarbonisation.

Project development is being led by the large traditional oil and gas players, which demonstrates the importance of their role in the initial scale-up of blue hydrogen. These companies have access to existing hydrogen production (at refineries), natural gas supply and pipelines. They are also able to leverage their wealth of technical, geological and regulatory expertise needed to progress these projects.

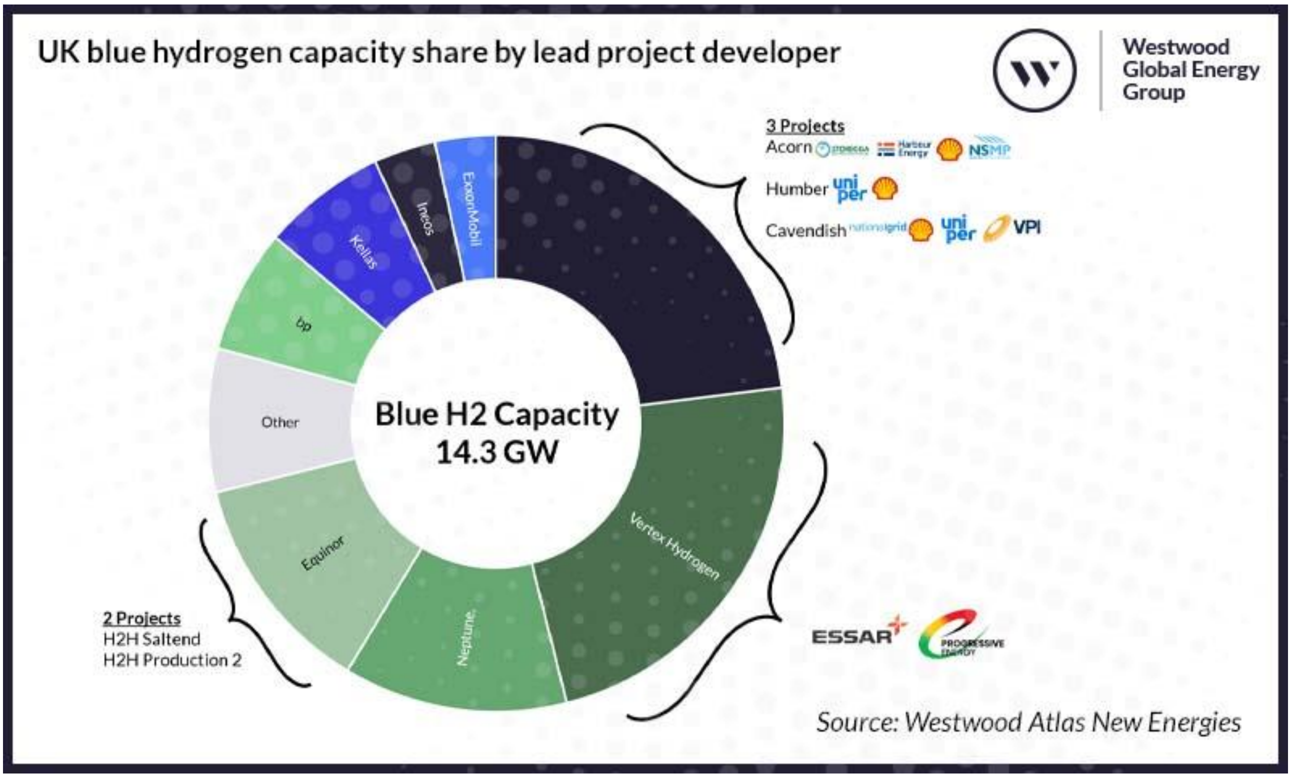

Figure 3: UK blue hydrogen capacity share by lead project developer (Westwood Atlas New Energies, 2023)

Shell is the largest participant in the development of blue hydrogen projects in the UK; it is involved in three projects that will develop 3.3 GW. Vertex Hydrogen (a joint venture between Essar and Progressive Energy) is developing 3.3 GW through its Hynet project. Equinor is involved in two projects that together add 1.8 GW of blue hydrogen capacity. All the proposed blue hydrogen projects are coastal, which provides easier access to the necessary natural gas supply and CO_2 storage.

UK's advantages in green hydrogen

Green hydrogen production can achieve carbon-neutrality when paired with a 100% renewable electricity source, such as wind or solar, which is required to power the electrolyser.

The UK is surrounded by seas that boast some of the world's best wind conditions. Its shallow seabed along its coastline makes offshore wind relatively accessible and cheaper to construct. Because of these geographic benefits and strong regulatory support, the UK has the largest pipeline of offshore wind projects globally. Currently, offshore wind accounts for nearly 14% of the UK's power generation (National Grid, 2023).

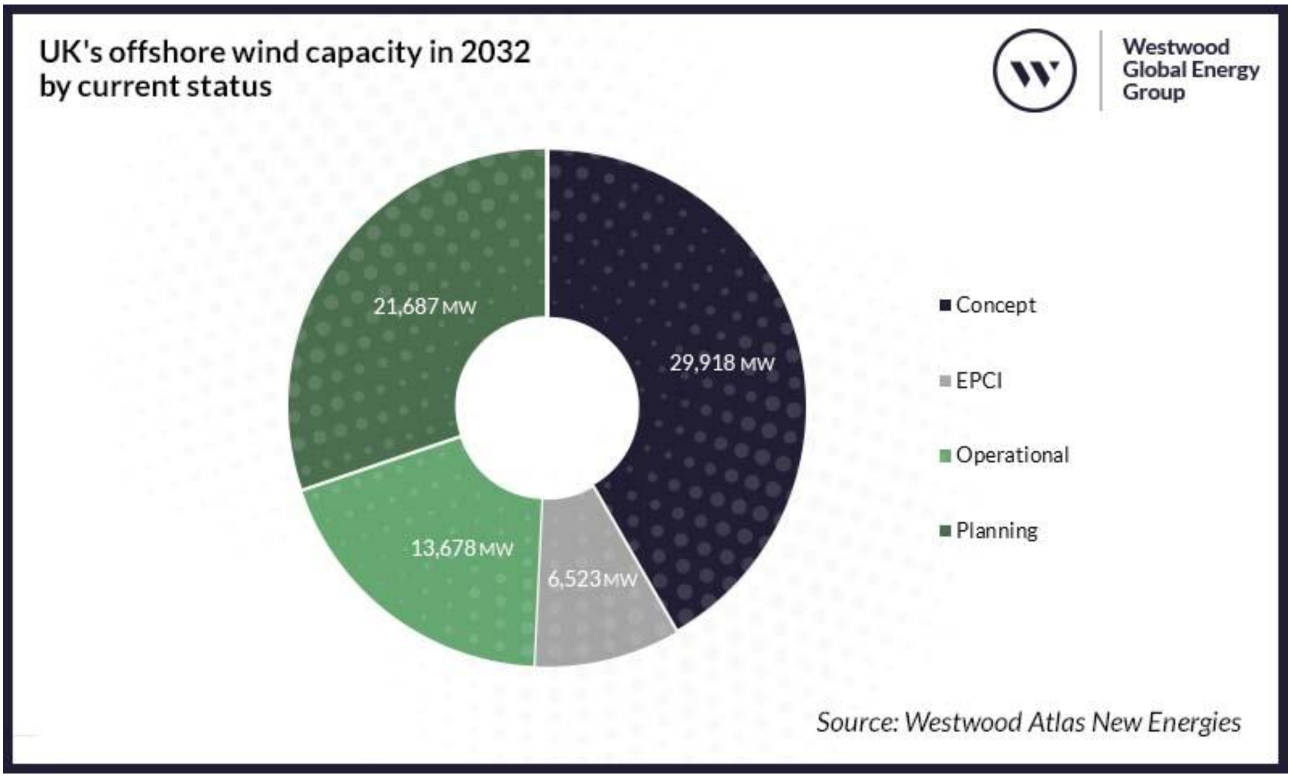

Figure 4: UK's offshore wind capacity in 2032 by current status (Westwood Atlas New Energies, 2023)

At the end of 2022, the UK had installed 13.7 GW of offshore wind capacity, which is second only to Mainland China at 29.4 GW. This is set to grow significantly with the ambition to quintuple offshore wind capacity to 50 GW by 2030.

Westwood's WindLogix solution currently tracks 70 offshore wind projects in concept, planning or engineering, planning, construction and installation (EPCI) stage. If these all come to fruition, total offshore wind capacity could far surpass the target and reach 71.8 GW by 2032.

Some green hydrogen projects coupled with wind farms are starting to emerge. In the North Sea, there is an extensive subsea gas network that can transport hydrogen to shore, as well as an established offshore wind supply chain and platforms that can be repurposed to house electrolysers.

In contrast to blue hydrogen's large project pipeline, announced capacity for green hydrogen in the UK only totals 2.6 GW. As Figure 5 shows, green hydrogen capacity is much more fragmented, with smaller project sizes and a higher number of developers.

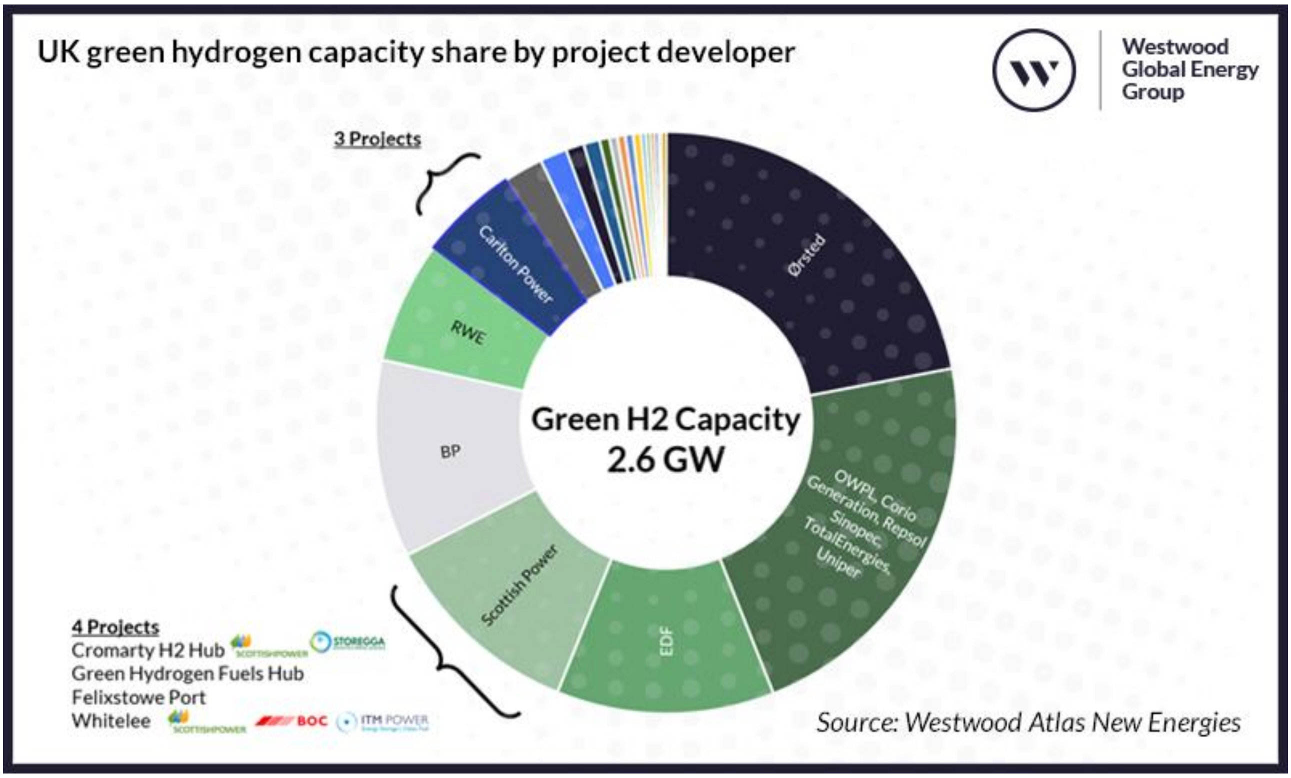

Figure 5: UK green hydrogen capacity share by project developer (Westwood Atlas New Energies, 2023)

The largest of these projects is Gigastack, the UK's flagship green hydrogen project led by Ørsted, Phillips 66, ITM Power and Element Energy. The 571 MW project, located in South Killingholme, intends to demonstrate the deployment of large-scale green hydrogen production powered by renewable electricity from Hornsea Two – the world's largest offshore wind farm. Phillips 66 will offtake the hydrogen as fuel gas for its Humber refinery. ITM Power will supply a 5 MW electrolyser for the demonstration, which aims to scale up to a 100 MW electrolyser system.

This leads onto another significant UK advantage in green hydrogen – electrolyser manufacturing. The UK is home to ITM Power, one of the world's largest proton exchange membrane (PEM) electrolyser manufacturers. It opened its gigafactory in January 2021 in Sheffield, now one of the world's largest electrolyser production facilities. Gigafactories will be crucial for scaling green hydrogen since major constraints are currently around electrolyser size and cost. The gigafactory will allow ITM to reduce electrolyser stack costs by 40% over the next three years (BEIS, 2021). ITM is also participating in the largest PEM electrolyser deployment globally, signing two contracts with Linde in January 2023 for 100 MW PEM electrolysers to be installed by RWE in Lingen, Germany and powered by offshore wind from the North Sea.

2.2 Storage

As the UK energy mix and infrastructure evolves, the storage of hydrogen can play an important role in creating a more secure energy system:

1. **It can balance the intermittency of renewables and create value from power that would otherwise have been curtailed.** Hydrogen can be stored during periods of high renewable electricity generation and used during periods of low generation, helping to smooth variability from renewables. Curtailment of the offshore wind farms as a result of grid constraints and lack of storage cost the UK over £500 million in 2021 (Lempriere, 2022).

2. **It can balance seasonal fluctuations in demand.** Grid-scale hydrogen storage can meet large fluctuations in seasonal heating demand.

3. **It can be used for grid balancing.** Hydrogen-fuelled combined cycle gas turbines can be a source of fast dispatchable power when required.

In the case of blue hydrogen, storage for CO_2 removed during the production process will also be required. The UK's geological formations are a significant advantage as they can be used for the storage of both hydrogen and carbon.

Hydrogen storage

There are two main types of geological hydrogen storage options in the UK – salt caverns and depleted oil and gas reservoirs.

Salt caverns' large and open chambers can facilitate high discharge rates, making them suitable for fast-response applications. It also has lower operational expenditure when compared to depleted oil and gas reservoirs because the rock salt is inert, reducing contamination risk and the need for purification.

Converting depleted oil and gas fields for hydrogen storage is more challenging. Its porous nature impedes gas flow, making them suitable for seasonal storage, but salinity and temperature need consideration as these may encourage the growth of hydrogen-metabolising bacteria. Costs are typically higher as hydrocarbon remnants could require purification, and cushion gas is needed to maintain pressure and withdrawal rates. However, the UK benefits from decades of experience in the production, distribution, storage, use and regulation of gas, which it can apply in this area.

Due to the advantages of salt caverns over depleted oil and gas reservoirs, demand for salt caverns for hydrogen storage is expected to take off ahead of reservoirs, although lead-time development for both options can take 5-10 years (IEA, 2022).

The UK is home to one of the four salt caverns globally currently being used for hydrogen storage. The site in Teesside has a capacity of 25 GWh H. However, there is potential to convert more salt caverns currently used for natural gas into hydrogen storage. Figure 6 shows the location of the UK's operational and planned salt cavern storage sites.

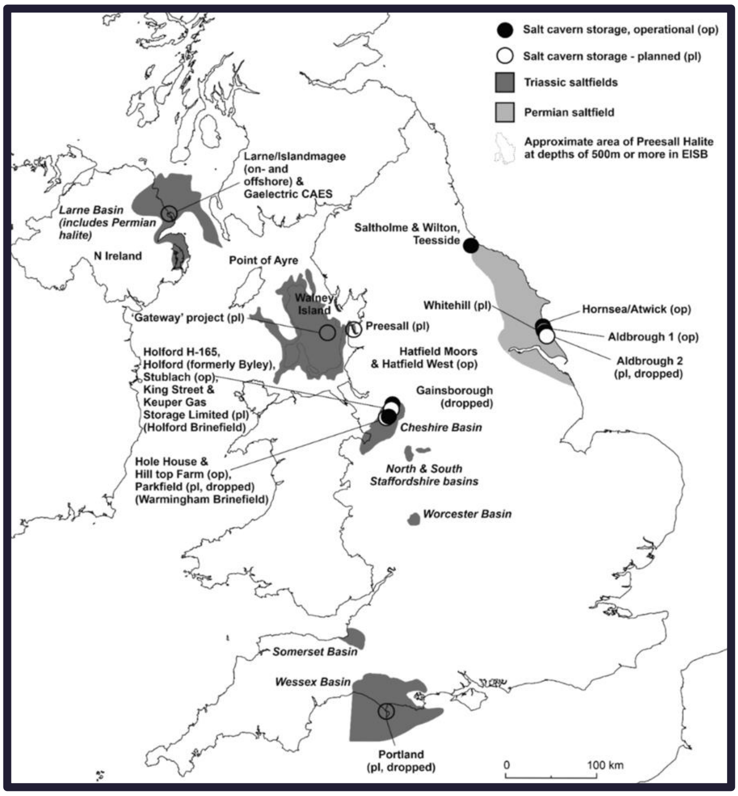

Figure 6: UK salt caverns (Evans and Parkes, 2021)

Some notable UK conversion projects include:

- **HySecure:** A partnership between Storengy, INOVYN and Element Energy, demonstrating grid-scale hydrogen storage can be deployed at a salt cavern in Stublach – the UK's largest natural gas storage facility. It is 10 times larger than Teeside and expected to be online mid-2020s.

- **SSE Thermal and Equinor:** Converting natural gas storage in nine underground salt caverns at Aldbrough by 2030. It will be part of the East Coast Cluster and store hydrogen for the Humber region. With a capacity of 320 GWh H2, it would be one of the world's largest storage facilities. It is expected to be online by 2028.

- **Keuper Gas Storage Limited:** A subsidiary of INOVYN, planning to use 19 new underground cavities to store 1.3 TWh H2 in Holford Brinefield and expected to be online by 2030.

Carbon storage

Carbon storage (CS) will be important to achieving industry decarbonisation and for the scale-up of blue hydrogen. Figure 7 shows the blue hydrogen projects along the UK's east coast. The business case for these projects is strengthened by the fact that carbon storage is located relatively nearby, as the carbon captured during production can be easily transported and stored securely and cost-effectively. Aggregating CO_2 from a number of emitters and transporting the CO_2 to a central location for sequestration is one way to achieve cost-effectiveness.

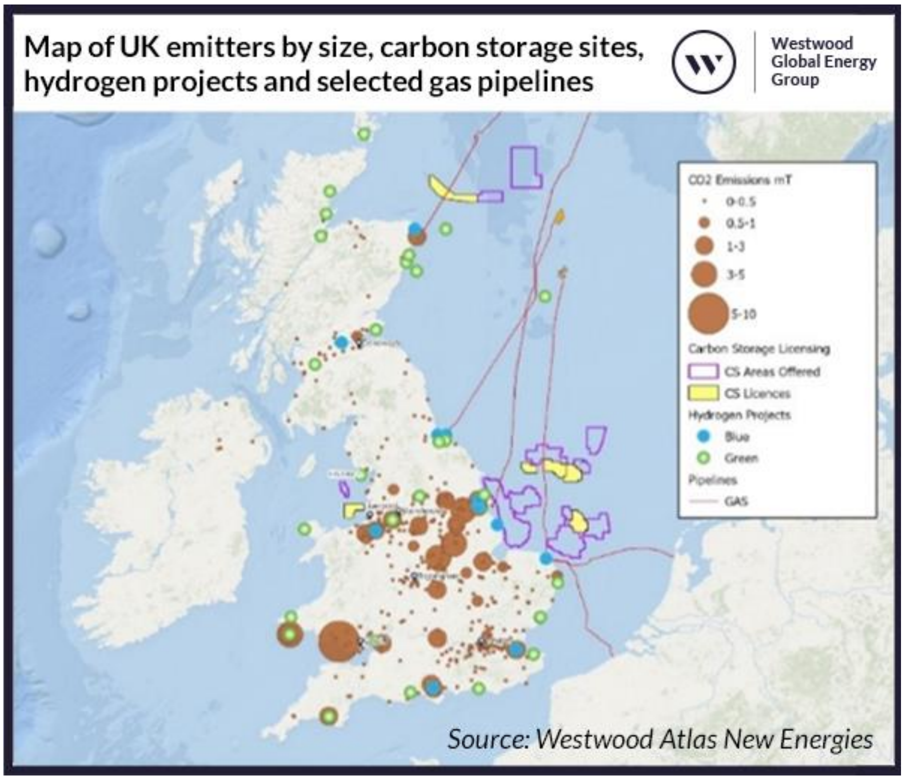

Figure 7: Map of UK emitters by size, carbon storage sites, hydrogen projects and selected gas pipelines (Westwood Atlas New Energies, 2023)

The location and size of the UK emitters are identified in the map. This shows a high concentration of large emitters around central England. Carbon from this area has the potential to be stored offshore in the Southern North Sea off the UK's east coast and in Liverpool Bay in the west coast.

To develop offshore carbon storage, a storage licence needs to be awarded. In the UK there are currently six active CS licences that have been awarded. The UK ran its first competitive CS licence round in the summer of 2022. In total 26 bids from 19 companies were received, with the award expected in 1Q 2023. The locations of the 13 carbon storage areas offered, and the existing licenses are shown on the map.

The UK will require 104 MTPA of CO_2 storage by 2050 according to the Balanced Net Zero Pathway, which sets out what is required to meet the 6th carbon budget and reach net zero by 2050. The UK is estimated to have at least 70 GT of offshore CO_2 storage capacity – one of the largest in Europe. This is spread across 600 storage sites, 61 GT in saline aquifers and 9 GT in depleted hydrocarbon fields. Over half of this storage potential is located in the Central North Sea (Energy Technologies Institute, 2011).

2.3 Pipelines – Repurposing vs. Newbuild

Hydrogen is difficult to transport over long distances as it requires costly compression or liquefaction; hence, hydrogen has historically been consumed on the site it is produced.

To help reduce costs, hydrogen projects are being constructed close to demand centres, which in the case of the UK is in the industrial heartlands. This is the easiest way to connect supply with demand as there is often a complex, established pipeline system linking several businesses that are in close proximity to one other.

Pipelines, especially repurposed, offer the cheapest method of transport in the immediate term. Repurposing existing gas pipelines for hydrogen is up to five times more cost effective than building from new (National Gas, 2022). It can also significantly reduce construction time.

Eventually, demand will move further away from supply, resulting in the need for a more extensive pipeline distribution network. Project Union is one such project aimed at achieving this.

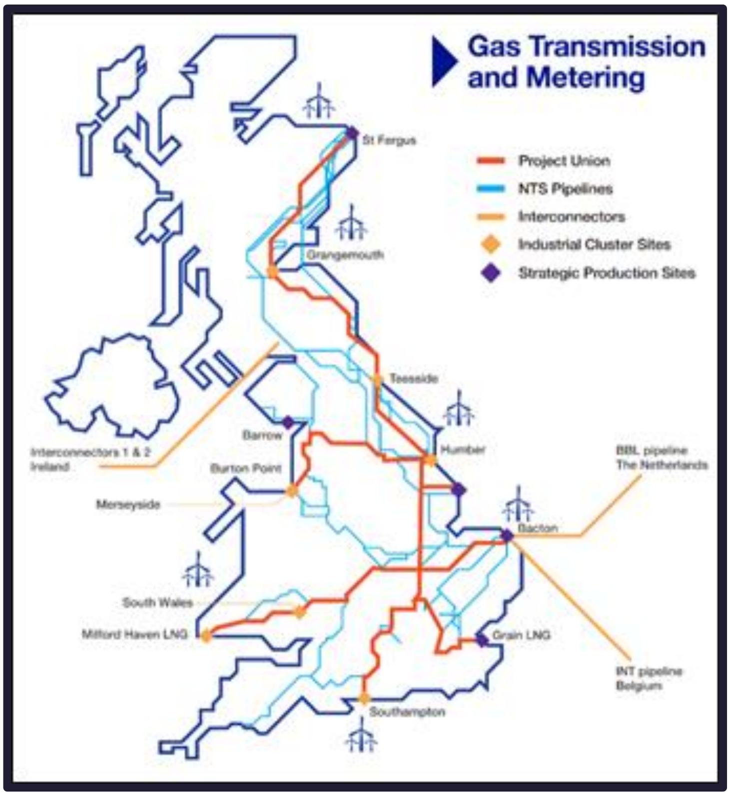

Figure 8: Project Union's proposed hydrogen backbone overlaid on national transmission network (National Gas, 2023)

Project Union is the largest hydrogen pipeline project planned in the UK. Spearheaded by National Gas (formerly National Grid), the project aims to create a hydrogen backbone for the UK by repurposing 2,000 km of pipeline (25% of the UK's natural gas transmission pipeline) to hydrogen. It will be done in phases starting from 2027 with the initial backbone to be completed by the early 2030s.

The backbone will initially link the industrial East Coast clusters of Teesside and Humber. The project also explores the potential to link into the natural gas transmission network and connect hydrogen production to demand beyond this area. It will also look at connecting to existing interconnectors in the Bacton gas terminal in Norfolk, which could open up hydrogen trade with Europe.

Elsewhere, in the northwest, 125 km of new pipeline is being planned as part of the Hynet cluster and will deliver hydrogen that is either produced by Vertex Hydrogen at the Stanlow Refinery or stored at INOVYN's storage site to industrial customers and/or be blended into the gas network near Manchester.

These projects support the UK government's target to decarbonise the national gas grid by 2035.

3. Supply and Demand

For hydrogen projects to move forward, it is crucial that suppliers secure offtake agreements. This implies demand must scale up in tandem, which is easier said than done in a nascent market with many uncertainties. One way the government is overcoming this issue is through the use of clusters as they help mitigate significant risk and provide greater certainty for early adopters and investors.

3.1 The Clusters

Clusters integrate supply with demand and have several efficiency and cost benefits:

- Shares infrastructure (i.e. pipelines and storage).
- Minimises hydrogen transport, which over long distances is very costly.
- Quickly achieves economies of scale from large industrial demand.
- Connects multiple revenue sources and balances stable industrial demand with variable power demand.
- Builds in redundancies, as new technology carries higher risk of unexpected operational issues.
- Promotes liquidity in a burgeoning sector where there are few market participants.

The UK government plans to establish four industrial clusters by 2030. These clusters will be instrumental in the initial uptake of hydrogen because the projects within these clusters will receive the funding support required to make low-carbon hydrogen affordable. In October 2021, the Eni-led HyNet North West Cluster and the BP-led East Coast Cluster were selected as 'Track 1' Clusters and are expected to be online in the second half of the decade. In total the two Track 1 Clusters are responsible for approximately 18 MTPA of CO_2.

In January 2022, 41 projects applied for Phase 2 of the Cluster Sequencing process; of these, 20 were selected to proceed to the due diligence stage. Figure 9 shows the breakdown by sector of CO_2 which will be captured from the shortlisted 20 projects. Within the Track 1 Phase 2 projects, four blue hydrogen projects have currently been shortlisted with a total potential online hydrogen capacity of 5.9 GW, contributing 60% of the UK's 10 GW target. The government also launched its first transport hub in Tees Valley (near the East Coast Cluster), which will enable green hydrogen to develop for transport alongside blue hydrogen in industry; this will serve as a blueprint for the creation of other green hydrogen transport hubs across the UK.

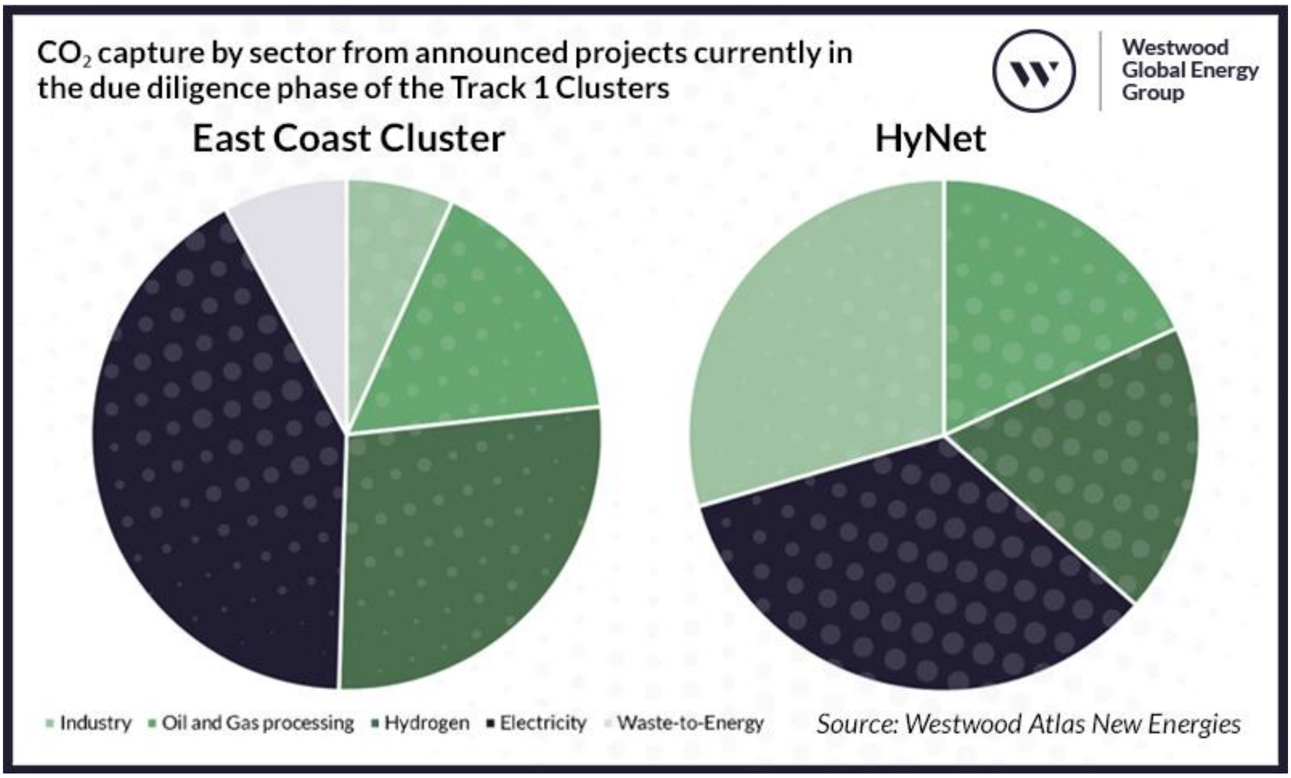

Figure 9: CO_2 capture by sector from announced projects currently in the due diligence phase of the Track 1 Clusters (Westwood Atlas New Energies, 2023)

The UK has six official clusters and five strategic production sites as shown in Figure 8. Each of these clusters is centred around key assets or infrastructure. For example, Acorn in Scotland, which was selected as a Track 1 reserve is close to Grangemouth – Scotland's sole refinery, while Southampton is the location of ExxonMobil's Fawley refinery. Grain and Bacton are two important locations for natural gas – Grain has one of the UK's three LNG terminals while Bacton has one of the country's three interconnectors linking gas supply between the UK and Europe (Belgium and the Netherlands).

Clusters play an instrumental role in the UK's decarbonisation plan. As yet, there have been no announcements on timings for 'Track 2' clusters nor which clusters will be included.

3.2 Moving Beyond the Initial Clusters

The next phase of development extends beyond these clusters, and it is this phase that needs further attention and government support.

There are other demand centres that exist outside of these clusters that are more distributed but still need to find a route to decarbonisation. These businesses are currently exploring whether they should or could link in with hydrogen production and how. Will they have access to a hydrogen pipeline? Can hydrogen be trucked? What will it cost? How secure will supply be? Will storage be required? These are just a few of the many questions they are grappling with.

Similarly, on the supply side, hydrogen producers want to know the next most attractive projects to invest in, where their next largest pool of hydrogen customers will come from, and how demand in other sectors, such as marine and aviation, will materialise – all of which depends on how policy in both the UK and abroad will evolve.

This next tranche of distributed hubs will also be looking for government support and require cost reduction initiatives and partnerships to succeed. However, it is hoped that they will be able to benefit with learnings gained from the initial clusters.

Risks and Uncertainties

While the UK is primed for success, much of this is down to the government. Undoubtably, it has made great strides towards laying the foundations for a hydrogen economy, but there is additional work to be done and uncertainties to be overcome. The timeline in Figure 10 from the UK's Department of Energy Security and Net Zero shows some of the upcoming hydrogen milestones.

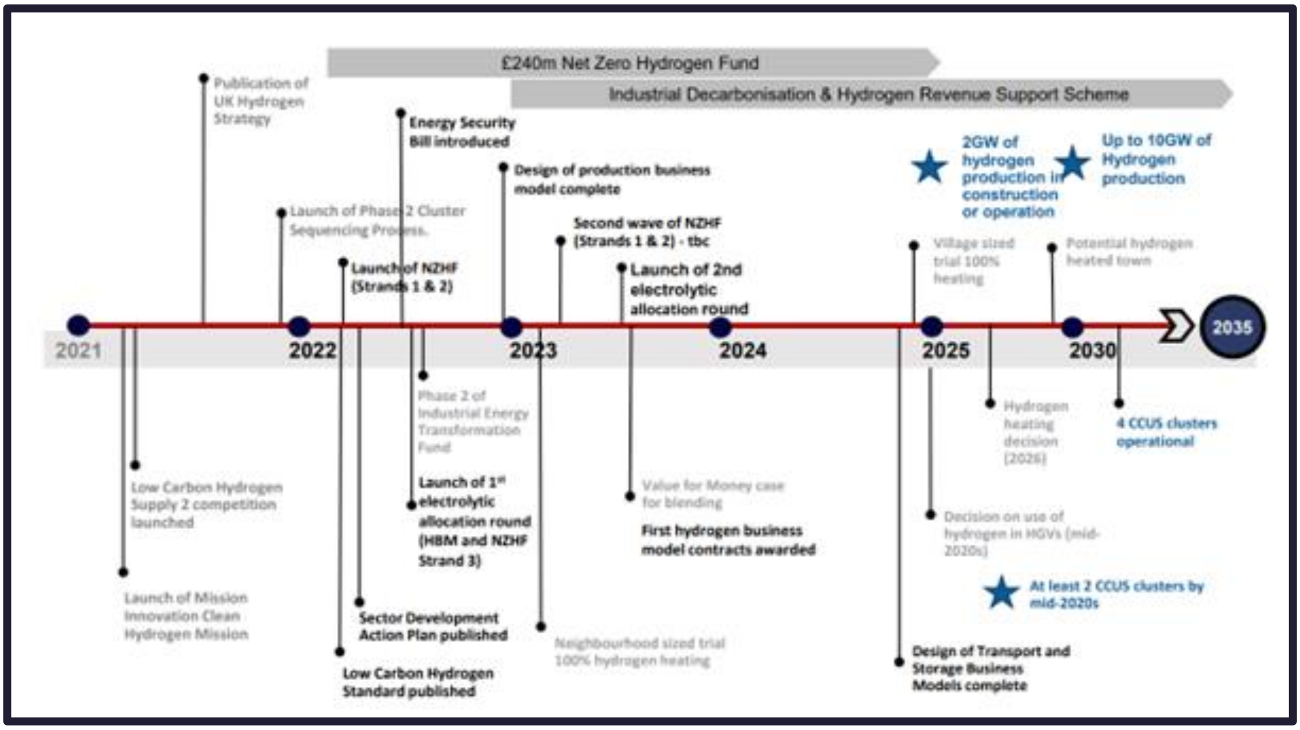

Figure 10: Upcoming UK hydrogen milestones (Ostheimer, 2023)

Within this framework there are still risks and uncertainties that need to be addressed. A few of the key ones have been identified below:

- **Political uncertainty.** The UK has undergone a series of government leadership changes over the past 18 months. The disruption has resulted in fiscal instability, policy uncertainty and some delays.

- **Competition.** The policies and tax incentives of other countries (i.e. the US' Inflation Reduction Act and Europe's Green Deal Industrial Policy) could threaten hydrogen production and investment in the UK.

- **Unfinalised definitions.** Countries are announcing different low-carbon hydrogen definitions, and there is a need for mutual recognition of international standards and certification to promote cross-border trade. The UK started consultation for its hydrogen certification scheme, which it intends to launch by 2025.

- **Lack of clarity around future government support.** The timing and scope of future HBM/NZHF allocation rounds and Track 2 Cluster sequencing activities have not yet been defined.

- **Approval of business models.** The Low Carbon Hydrogen Agreement terms for inclusion in the HBM is still in draft and not expected to be available until later this year, delayed from 2022. Business models for hydrogen in transport and storage infrastructure are being developed for 2025.

- **Timing of hydrogen and CCS business models.** Blue hydrogen projects and carbon capture and storage projects need to move together, but timing misalignments between the two business models makes reaching a final investment decision difficult.

- **Unfinalised demand views.** The government has not yet agreed on hydrogen's role in blending and heating – decisions that will be made in 2023 and 2025, respectively. These decisions have the potential to significantly impact hydrogen demand.

To qualify for government support blue hydrogen projects need to come online by 2027, which means projects must take FID in 2024. Few are willing to assume the risk of a binding 'Take or Pay' contract that is usually required before FID takes place without further guarantees. The question is how to overcome the 'chicken and egg' problem? One way could be for the government to offer non-binding initiatives to provide more certainty and encourage projects to move forward to the next stage (front-end engineering and design). Clarity, as well as a simplified, streamlined process is needed such that all players along the entire value chain can move in tandem at the pace needed to meet the targets.

Conclusion

As this report highlights, the UK can boast of numerous advantages that could see it become a leader in the creation of a highly competitive and successful hydrogen economy. Whilst risks and uncertainties abound, these can be mitigated to secure investment – strong, clear, streamlined and timely government policies will be key. At the same time the incentives must permeate through all parts of an incredibly complex value chain. Competition is quickly heating up around the world and any delay or lack of clarity in the government's steer could have adverse consequences for the UK's hydrogen ambitions should investors believe they can obtain greater certainty and higher returns elsewhere.

Joyce Grigorey, *Director – Hydrogen*
jgrigorey@westwoodenergy.com

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About Westwood

Westwood's New Energies solutions provide insight into the technologies and themes driving the future of energy markets. We provide focused and in-depth coverage of the source of the problem – climate and emissions – as well as key solutions: carbon capture and storage, hydrogen and offshore wind. Atlas New Energies is a highly intuitive, integrated market intelligence solution covering energy clusters, offshore wind, hydrogen, CCS and related oil and gas infrastructure in the UK and Norway. It empowers clients to make better decisions in a fast-changing, interconnected world.

Drawing on Westwood's New Energies sector knowledge, our Commercial Advisory Services relating to the Energy Transition include bespoke market research, analysis of key commercial drivers and dynamics, transaction support, business planning and strategy formulation and feasibility studies. cater to both corporate strategy and transaction support. In addition, we provide independent analysis and insights to industry bodies and government agencies to help shape specific policies for the upstream energy sector.

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Published 07 March 2023

Contact: enquiries@westwoodenergy.com