Surveying the UK's Green Hydrogen Supply Chain Capability

renewableUK

Cover image of an Electrolytic Hydrogen Electrolyser. Courtsey of Protium | www.protium.co.uk.

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Surveying the UK's Green Hydrogen Supply Chain Capability

Foreword

As the world races towards a net zero future, green hydrogen has emerged as a critical element in the transition as an energy source that can reach the parts electrification cannot. The UK is well placed to lead the way. We have unique renewable resources available to us, and, as this paper makes clear, unique world-class engineering and technical capabilities. Delivering the UK's target of over 5GW green hydrogen by 2030 presents an opportunity to develop robust local supply chains that can deliver local growth and jobs, as well as technology export opportunities to a growing global market.

This paper presents the findings from engagement and research RenewableUK has carried out with our members from across the green hydrogen value chain and we set out the UK's strengths and key gaps that must be addressed to build effective supply chains. The message is clear: the UK must deploy large-scale, operational projects as soon as possible to demonstrate we are a viable market for investors and suppliers.

This will require a supportive policy environment that enables mass deployment, including the finalisation and allocation of Hydrogen Business Model contracts, transparent timelines, and other financial instruments, such as tax incentive s, to encourage inward investment. As a first step, it is essential that we bring forward the 2025 date for planned revenue support.

Scaling technology and building an industry requires expertise and innovation, so leveraging our legacy in oil & gas and experience reskilling workers will be critical to deliver projects across the UK. In an already highly competitive market for energy skills, investing in people will be a key priority to develop the green hydrogen industry.

The other cornerstone in building our hydrogen economy is investment in infrastructure. We need to develop the pipelines to transport hydrogen and the underground storage capacity that will support domestic production and wider net zero targets. The UK must take decisive actions to plan and invest in this infrastructure ahead of time to meet the ramp-up in demand to 2030 and beyond.

Integration with our world-leading offshore wind sector that could bring huge advantages to developing the UK's green hydrogen economy. Realising this potential necessitates the implementation of policies that encourage seamless interaction between electrons and hydrogen molecules, in a way that supports decarbonisation and energy security across the system.

The report services as a timely reminder that the UK has the potential to become a global leader in green hydrogen. We stand at a pivotal juncture, where we can cement our position as a leader, but this rests on decisive and strategic action to seize the opportunity.

Dan McGrail

Chief Executive, RenewableUK

Introduction

The UK's green hydrogen economy is gaining momentum as initial investments pour into the growing project pipeline, which has now reached 1.5GW of electrolyser projects.[1] The government's target of 10GW of low carbon hydrogen by 2030, with at least half being green hydrogen, is not only ambitious but underscores the necessity of developing domestic supply chains capable of catering to the required scale of deployment.

Furthermore, National Grid Future Energy Scenarios estimate that hydrogen demand in 2050 could be between 147-474TWh,[2] offering a huge economic opportunity for UK-based companies in this sector.

Wood and Optimat's Supply Chain analysis,[3] a report commissioned by the Department for Energy Security and Net Zero (DESNZ), offers a conceptual framework for comprehending the supply chain necessary to sustain a green hydrogen economy. This includes the feedstock (such as water) and power utilities required for electrolysis; primary equipment such as electrolysers and compressors, as well as ancillary equipment; and the development and construction of hydrogen transport, distribution and storage systems. All of this is underpinned by expertise in research and development, professional services and the installation, commissioning and maintenance of hydrogen production and infrastructure.

Using this framework as a base, RenewableUK has undertaken research and gathered insights from various stakeholders across the green hydrogen value chain to identify gaps in the supply chain and recommend ways to address them. This paper highlights several ongoing themes, including:

- Building multiple large-scale projects complimented by solid policy foundations.
- Plugging the skills gap.
- Preparing the UK's infrastructure for green hydrogen.
- Tapping into the UK's plentiful wind resource.

Together, these highlight the level of policy and financial support that is required to help the green hydrogen economy create a robust, resilient and sustainable supply chain.

Kittybrewster Hydrogen Refuelling Station, Aberdeen | Abermedia / Michael Wachucik

1. EnergyPulse. RenewableUK. https://www.renewableuk.com/page/PIHome

2. Supply Chains to Support a Hydrogen Economy, Wood, Optimat. June 2022. https://www.gov.uk/government/publications/supply-chains-to-support-a-uk-hydrogen-economy

3. Ibid.

Summary of recommendations

Unlocking the UK Green Hydrogen Supply Chain

1 Building large-scale projects complimented by solid policy foundations

Establishing a green hydrogen economy is a global race, in which the UK stands poised to assert itself as a significant contender. To accomplish this, it is essential that the UK focuses on deploying large-scale, operational projects that validate the UK as a viable market and provide predictable utilisation of local supply chains.

Supported by:

- The UK government must meet Hydrogen Business Model completion deadlines, finalise contracts and communicate a transparent timeline for the Energy Bill's passage, including a contingency plan if the Bill's passage is delayed.
- Allocation pots beyond hydrogen allocation round 2 to 2030 should be clarified and the application process streamlined to 6 months, in line with the CfD scheme.
- Review proposal to move Hydrogen Business Model to competitive allocation, considering non-price criteria and the potential to delay if necessary.
- Consult, and explore the potential for a working group, with industry on tax incentives and the use of institutions like the UK Infrastructure Bank that make the UK more competitive internationally, especially in context of the US's Inflation Reduction Act.
- Promote collaboration within the green hydrogen industry and coalesce around industry standards that facilitate highly modular assembly lines for main component manufacturing.

3 Preparing the UK's infrastructure for green hydrogen

The UK will require 3.4TWh of large-scale hydrogen storage by 2030, increasing to 9.8TWh by 2035. Alongside this, it will need to develop transport infrastructure for local distribution and to capitalise on the opportunity to become a major exporter.

Supported by:

- Bringing forward the 2025 date for the Transport & Storage business model support and engaging in bilateral agreements to construct strategically positioned infrastructure in the interim.
- Reviewing future export prospects for international hydrogen trade and investing to build those pipelines ahead of time.

2 Plugging the skills gap

A UK green hydrogen economy relies on a skilled workforce to underpin the supply chain. The UK is well equipped to plug this gap, particularly by leveraging the skills found within legacy industries.

Supported by:

- Build on the North Sea Transition Deal by investing more into dedicated reskilling programs for people within O&G. This requires facilitating the transition of workers from O&G and into green hydrogen by establishing a healthy pipeline of successful projects and an industry that guarantees prospects, particularly for younger generations.
- Investment in education and training, especially in electrochemistry. Structured training and reskilling programs should be put in place through collaboration between industry and academia.

4 Tapping into the UK's plentiful wind resource

The UKs abundant and affordable offshore wind energy will be pivotal in reducing the cost of green hydrogen production. Green hydrogen projects offer promising opportunities for co-location with offshore, which could provide important system balancing services.

Supported by:

- A detailed study of the policy and regulatory changes needed to incentivise the interface between offshore wind and green hydrogen.
- Building on the success and experience of the UKs industrial clusters (e.g. Teesside, Humberside, and South Wales) by consulting on creating hubs targeted at green hydrogen.
- National Grid ESO's Connections Reform should reward technologies that provide system flexibility and stability services, including co-located electrolytic hydrogen. The current process only looks at capacity, not utilisation, and should be reformed to allow electrolysers to provide grid services. Any institutional barriers to this should be communicated to industry.

1. Building large-scale projects complimented by solid policy foundations

Recommendations:

- The UK government should show strict adherence to established deadlines for the completion of the HBM and Net Zero Hydrogen Fund (NZHF), finalise contractual terms for Hydrogen Allocation Round 1 (HAR1) and communicate a clear timeline for the passage of the Energy Bill, which enshrines the HBM into law; including a "Plan B" should the Bill be delayed.
- Looking forward, the allocation pots after HAR2 should be clarified up to 2030, and the application decision-making process should be streamlined to 6 months, in line with the Contracts for Difference (CfD) scheme.
- Conduct an ongoing and comprehensive review of the proposal to move HBM to competitive allocation, considering non-price criteria, and potentially delay this transition if the pipeline of projects and supply chain is not developed enough.
- Consult, and explore the potential for a working group with industry stakeholders, to establish tax incentives that make the UK a more competitive market for investment in the supply chain. Additionally, consider the role of the UK Infrastructure Bank or similar institutions to de-risk investment and unlock private capital.
- Publish a comprehensive roadmap setting out how it will achieve 5GW (or more) of green hydrogen by 2030. The roadmap should outline how the government plans to scale up green hydrogen and foster its uptake in key sectors and industries, as well as ensure green hydrogen is integrated effectively into the wider energy ecosystem for maximum benefit. Industry-government collaboration, such as through an industry taskforce, should be utilised to develop the roadmap.
- Encourage collaboration through establishing a green hydrogen equivalent of the North Sea Transition Authority's Energy Pathway.
- Industry should fulfil ambitious projects at scale and then establish industry-wide standards that encourage local manufacturing through the facilitation of highly modular production

The UK's Low Carbon Hydrogen Strategy has been making strides, boasting ambitious targets and an ongoing design of a comprehensive set of revenue support measures that are first of their kind, such as the HBM, NZHF and Carbon Capture, Utilisation and Storage (CCUS) cluster sequencing scheme.[4] To date, 20 projects have been shortlisted for the first electrolytic HBM allocation round and 15 projects under the NZHF have been allocated a total of £37.9mn, demonstrating the UK's commitment to a hydrogen economy. The UK is also home to world-renowned electrolyser companies like ITM Power and Ceres, whose cutting-edge technology has been licensed globally.

Despite these advancements, sources report that the development of green hydrogen has been hampered by a lack of clear policy direction and investment in comparison to blue hydrogen, and delays in the implementation of key enabling mechanisms, which has slowed the scaling-up of large projects essential for building domestic supply chains and accumulating experience.

Creating a strong UK-based market

The message is clear: the UK must build reference plants to demonstrate the feasibility of green hydrogen production, instead of relying on hypothetical designs and virtual prototyping. For instance, RenewableUK's EnergyPulse reports a pipeline of 1.5GW in development (and many more in pre-development); however, only 4MW is currently operational.[5] Interviewees indicated that real-world projects are crucial to showcase the UK's capabilities globally, but a complex and stop-start policymaking approach has hindered their progress.

To avoid repeating previous errors in the development of both fossil fuels and offshore wind, the UK must recognise that it is part of a "global race." Respondents noted that while the UK has a strong track record of building knowledge, it is deficient in commercialising on this due to short-sighted policies. The UK's failure to fully capitalise on its North Sea reserves provide an example of this, contrasting with Norway's use of much of the profits from

4. UK Hydrogen Strategy. DESNZ. 13 December 2022. https://www.gov.uk/government/publications/uk-hydrogen-strategy

5. EnergyPulse. RenewableUK. https://www.renewableuk.com/page/PIHome

its exploitation of O&G reserves to establish a sovereign wealth fund for investment purposes.[6] This move mitigated the impact of fossil fuel exports on the exchange rate at the time and were reinvested into publicly owned assets for the benefit future generations.

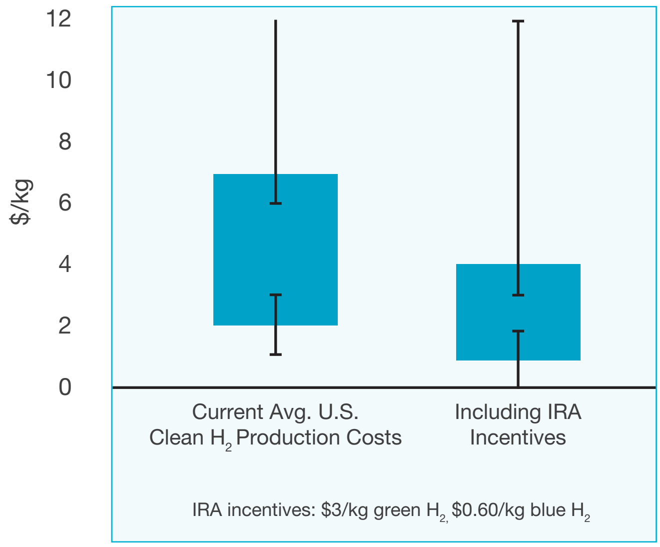
It is undeniable that current planned tax incentives offered internationally are likely to be a force in stimulating investment outside the UK, as evident by efforts of both the US and the European Union (EU). For example, the European Commission recently proposed the Net Zero Industry Act that commits domestic manufacturing for strategic technologies (including electrolysers) to at least 40% of the Union's annual deployment needs by 2030, meaning European electrolyser manufacturing would need to scale up to produce 40GW capacity.[7] This is supplemented by plans to commit €3bn to finance domestic and international hydrogen production via the European Hydrogen Bank.

Additionally, the US has deployed its Inflation Reduction Act (IRA) program to great effect, offering generous tax credits to green hydrogen producers that are proportional to their project's life cycle emissions. This is estimated to result in the reduction in the cost of low carbon hydrogen from $2-7/kg to $0.80-4/kg.[8] Interviewees expressed a strong preference for the simplicity and scale of the IRA program, but in contrast found the UK's HBM overly complex and beset with delays that have undermined private investment for key projects.

The UK therefore finds itself at a critical juncture in its endeavour to establish a hydrogen economy that can compete on a global scale. Its success in this pursuit rests on its unwavering, steadfast commitment to green hydrogen projects that will underpin the business case for supply chains.

The UK government should show strict adherence to established deadlines for the completion of the HBM and NZHF, finalise contractual terms for Hydrogen Allocation Round 1 (HAR1) and communicate a clear timeline for the passage of the Energy Bill, which enshrines the HBM into law; including a "Plan B" should the Bill be delayed. Looking forward, the allocation pots after HAR2 should be clarified up to 2030, and the application decision-making process should be streamlined to 6 months, in line with the CfD scheme. Any ambiguity or delay in policy implementation poses a significant risk to investor confidence and could potentially stifle industry growth.

Figure 1: Estimated clean hydrogen production costs with IRA incentives



Source: Energy Futures Initiative

Building a market framework with sustainable pricing

The UK's plan to shift the HBM from bilateral agreements to competitive auctions by 2025 was also viewed as at risk to the development of local supply chains. According to respondents, a hurried transition to competitive auctions could put green hydrogen developers under intense pressure to cut costs, which could lead to a decline in domestic supply chains as companies seek out cheaper materials and labour overseas. This outcome would be detrimental to the UK's larger economic interests and underscores the importance of proceeding with caution in any changes to subsidies for emerging technologies.

This is evidenced in price-based CfD auctions which have played a crucial role in driving down the cost of offshore wind power by over 60% since the turn of the century.[9] This progress has come at the cost of local supply chains, however, which have struggled to turn a profit and invest in expanding production capacity. Wind turbine manufacturers, for example, have been under pressure to constantly innovate, resulting in shorter product lifecycles which makes it difficult to achieve positive returns on capital.[10]

These developments have since spurred DESNZ to actively consult on adopting non-price criteria in CfD auctions, designed to retrospectively stimulate supply chains, because they implicitly recognise that CfDs alone, based on price and

6. Kevin Albertson, Paul Stepney. 1979 And All That: A 40-year Reassessment of Margaret Thatcher's Legacy on Her Own Terms. Cambridge Journal of Economics. Volume 44, Issue 2. March 2020, Pages 319–342. https://doi.org/10.1093/cje/bez037

7. The Net-Zero Industry Act: Accelerating the Transition to Climate Neutrality. European Commission. https://single-market-economy.ec.europa.eu/industry/sustainability/net-zero-industry-act_en

8. The US Hydrogen Demand Action Plan, Energy Futures Initiative, February 2023, https://energyfuturesinitiative.org/reports/the-u-s-hydrogen-demand-action-plan-

Figure 2: Global wind turbine producers and the % of their product portfolio making a net positive return

	% of Product Portfolio sold at a Net Positive ROC	Additional Unit Sales to Achieve Full Return On Capital Parity
GOLDWIND	52.65%	5,567
Vestas	38.67%	6,540
ENVISION	31.70%	3,707
GE	30.91%	6,701
SIEMENS Gamesa	29.35%	9,497
ENERCON	27.91%	3,963
上海电气 SHANGHAI ELECTRIC	25.32%	3,482
WEG	25.00%	646
NORDEX acciona	24.44%	4,364
MINGYANG WIND POWER	18.46%	3,489
SUZLON	18.18%	1,076
SENVION	16.57%	5,062
HZ windpower	16.55%	5,040
运达风电 WINDEY	12.67%	4,215
IMPSA wind	12.50%	1,578
联合动力 United Power	11.43%	6,740
EWT	10.00%	1,749
VERGNET	10.00%	2,279

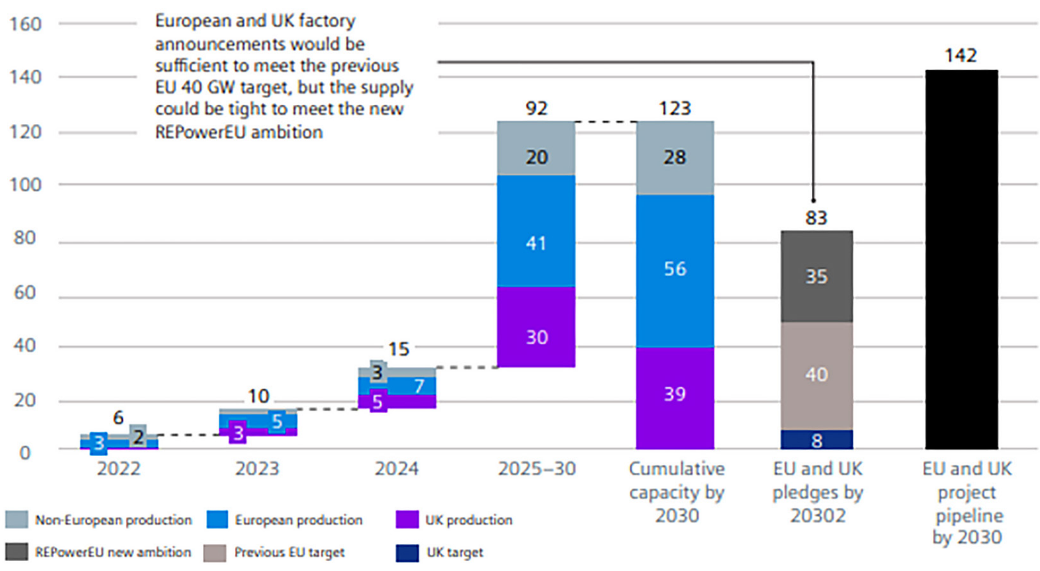
Source: Wind Power Engineering

competition, drive down costs but at the expense of domestic industrial capacity.[11] **These lessons highlight the importance of carefully balancing cost reduction with stimulating local supply chains. It is therefore recommended that the government conducts an ongoing and comprehensive review of its proposal to move HBM to competitive allocation, including a consideration of non-price criteria, and potentially delays the transition if the pipeline of projects and supply chain is not developed enough.**

Incentivising suppliers and assembly hubs to locate in the UK

Soaring global demand for green hydrogen has given rise to significant supply chain bottlenecks, with interviewees stating electrolyser lead times ranging from 9 to 18 months and compressors at 18 to 26 months. Despite Europe doubling its electrolyser manufacturing capacity between 2020 to 2022, Siemens Energy reports that the current planned capacity falls short of what is needed to meet the ambitious targets set by the UK and EU.[12] Compounding this situation, as the US's IRA tax credit system takes effective and major component manufacturers secure contracts with US-based green hydrogen developers, these bottlenecks risk worsening on a global scale.

Figure 3: Cumulative electrolyser manufacturing capacity vs project pipeline in Europe and the UK



Source: Siemens Energy

9. Evans, Simon. Analysis: Record-low price for UK offshore wind cheaper than existing gas plants by 2023. September 2019. https://www.carbonbrief.org/analysis-record-low-uk-offshore-wind-cheaper-than-existing-gas-plants-by-2023/

10. Froese, Michelle. New Analysis May Help Wind-turbine Supply Companies With Poor Capital Returns. February 2019. https://www.windpowerengineering.com/new-analysis-may-help-wind-turbine-supply-companies-with-poor-capital-returns/

11. Introducing Non-price Factors Into The Contracts for Difference Scheme: Call for Evidence. DESNZ. 17 April. https://www.gov.uk/government/consultations/introducing-non-price-factors-into-the-contracts-for-difference-scheme-call-for-evidence

12. A National Endeavour Delivering the supply chain for a net zero GB electricity system by 2035, Siemens Energy, September 2022. https://www.siemens-energy.com/uk/en/offerings-uk/net-zero-2035.html

To successfully achieve the necessary scale of green hydrogen production, it is imperative that the UK embarks on exploring options for incentivising the manufacturing and/or assembly of components domestically. This could be done through the introduction of new financial instruments and tax breaks that support inward investors to locate in the UK, or other policy mechanisms.

If the UK fails to take ambitious steps towards incentivising domestic manufacturing and assembly, it risks losing out on the significant socio-economic benefits associated with the growth of domestic supply chains. Wood and Optimat, for example, report that enhancing supply chains for the manufacture of green hydrogen production equipment and construction has the potential to deliver a turnover of between £3-5mn in 2030 and £7-23mn by 2050.[13]

The government should consult with industry stakeholders, ahead of the autumn statement, and establish a working group to explore the potential for tax incentives that would make the UK a more attractive investment destination. Additionally, it should investigate the potential for the UK Infrastructure Bank or similar institutions to play a role in de-risking investments in the UK. By doing so, the government could help to unlock private investment that is currently unable to reach a financial investment decision.

Incentivising UK-based manufacturing and assembly hubs is also dependent on a clear and long-term view for the deployment of green hydrogen projects. **To this end, the government should publish a comprehensive roadmap setting out how it will achieve 5GW (or more) of green hydrogen by 2030. The roadmap should outline how the government plans to scale up green hydrogen and foster its uptake in key sectors and industries, as well as ensure green hydrogen is integrated effectively into the wider energy ecosystem for maximum benefit. Industry-government collaboration, such as through an industry taskforce, should be utilised to develop the roadmap and ensure that the interests of industry stakeholders are aligned with government policy objectives.**

Stimulating value chain collaboration

In pursuit of a healthy green hydrogen economy, interviewees also viewed collaboration between industry players as key. However, competition in a nascent market can hinder such efforts. To stimulate supply chains, cost-sharing and a consensus on necessary interventions are crucial. An excellent example of this is the Offshore Wind Accelerator, which fostered innovation by having wind developers collaborate, saving £34bn in the first 10 years and reducing LCOE by 15%.

To encourage collaboration, trade associations can serve as a starting point and could aim to establish green hydrogen equivalent of the North Sea Transition Authority's Energy Pathfinder. This platform provides real-time updates on upcoming projects related to O&G, decommissioning, CCUS and energy transition projects; aiding industry players in enhancing their partnerships and coordinating a comprehensive supply chain.

Additionally, once projects are deployed, industry must focus on standardising project designs and technologies. This will enable potential assembly hubs and manufacturers to specialise in specific processes and technologies that can be replicated on an industrial scale with efficiency. Such standardisation will be instrumental in facilitating the mass deployment or assembly of green hydrogen components going forward. **Industry should therefore fulfil ambitious projects at scale to establish industry-wide standards and practices that encourage local manufacturing through the facilitation of highly modular production and assembly lines for the primary components of electrolytic projects.**

13. Supply Chains to Support a Hydrogen Economy, Wood, Optimat. June 2022. https://www.gov.uk/government/publications/supply-chains-to-support-a-uk-hydrogen-economy

2. Plugging the Skills Gap

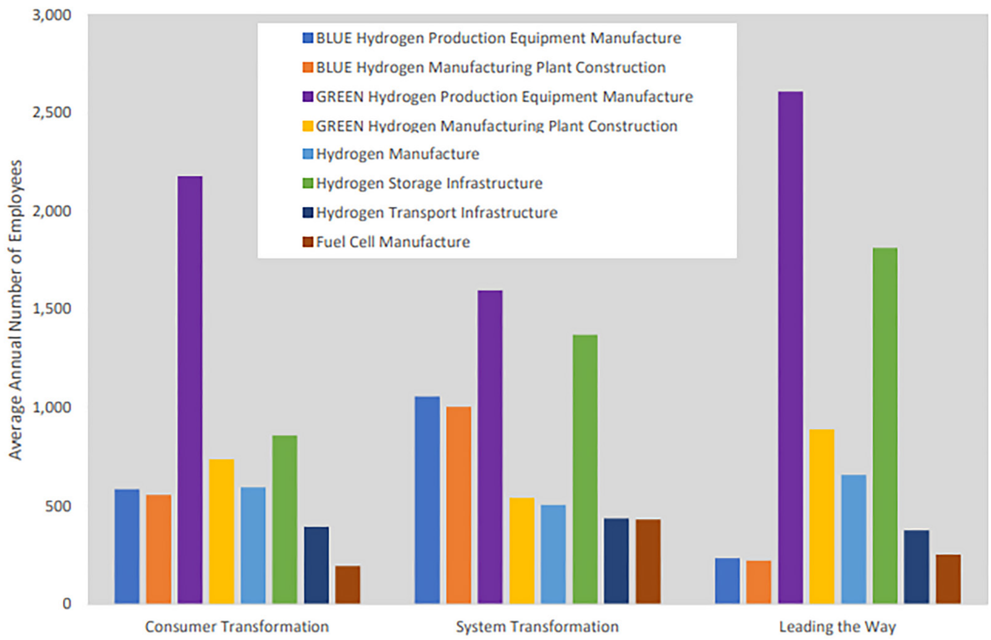
Recommendations:

- Build on the North Sea Transition Deal by investing more into dedicated reskilling programs for people within O&G. Enticing workers away from O&G and into green hydrogen requires a healthy pipeline of successful projects and an industry that guarantees prospects, particularly for younger generations.
- Invest in education and training, with structured training and upskilling skills around electrochemistry through collaboration between industry and academia. Clusters and hubs where projects and supply chains are being developed, for example, could be targeted as centres for strategic skills development.

Green hydrogen not only offers economic growth, but it also fosters the potential for human capital development, including specialised skills and high paying jobs. Moreover, it creates advancement opportunities for future generations, through innovative training schemes, apprenticeships and graduate roles.

In the short term, the green hydrogen economy will create new jobs. According to Wood and Optimat, meeting the required 2030 hydrogen capacity requirement could generate between 6,100 and 7,100 full time jobs between 2023 and 2029 (excluding exports).[14] This underscores the significance of manufacturing green hydrogen production equipment and developing storage infrastructure locally. This number is only set to increase, with the Scottish Government projecting that that establishing Scotland as

Figure 4 Estimated Annual Employment to Deliver 2030 Hydrogen Capacity



Source: Wood, Optimat

14. Supply Chains to Support a Hydrogen Economy, Wood, Optimat. June 2022. https://www.gov.uk/government/publications/supply-chains-to-support-a-uk-hydrogen-economy

15. Assessment of Electrolysers: Final Report, Scottish Government, October 2022. https://www.gov.scot/publications/assessment-electrolysers-report/documents/

an exporter of green energy to Europe could result in 126TWh of green hydrogen production, a £25bn contribution to GVA and over 300,000 jobs by 2045.[15] Ensuring these jobs are not lost overseas, however, means the UK must prioritise timely development of policy and pre-emptively upskill its workforce.

Reutilising skills within legacy industries

UK's transition to a green hydrogen economy relies on developing a skilled workforce and infrastructure to support the supply chain. Respondents noted the potential of utilising the pre-existing skills, expertise and infrastructure of the O&G industry to position the UK as a global leader in green hydrogen. In particular, the engineering, operations and maintenance skills found in the O&G industry (including welders, reservoir engineers and pipe fitters) were identified as a particular strength.

More broadly, the UK has a long-standing tradition of training engineers on the job which emphasises a practical approach of "hitting stuff with a hammer from day one" which will be essential for designing and building reliable systems and infrastructure. This practical approach is harder to find internationally and often importing labour is not as cost competitive due to travel costs and visa requirements, particularly for operation & maintenance services that are done on a frequent basis.

Importantly, skills found within O&G are abundant and easily transferable to the hydrogen sector, and retraining programmes could develop these into the necessary skills needed for a hydrogen economy. **The UK government has already taken steps in this direction with the North Sea Transition Deal, but there is still room for further repurposing – highlighting the need for more investment and dedicated reskilling programmes.**

However, to fully utilise O&G skillsets, a clear pathway into green hydrogen must emerge to entice workers into the sector. Green hydrogen is still nascent and there are high paying jobs already available in O&G (partly due to an aging workforce) which reduces the appeal of transitioning. Therefore, developing a market and supporting projects early will be key to demonstrating the career opportunities available in the green hydrogen sector over the medium and long term.

Creating new skills programmes for green hydrogen

The potential for the O&G industry to contribute to the development of green hydrogen is significant, but a notable gap in electrochemistry knowledge remains. It is important to recognise that the context for green hydrogen is quite different from O&G, as it involves the manipulation of both electrons and molecules – requiring a skillset that understands both.

Respondents praised the existing work performed through universities and other institutions in research & development programmes as well as the "hands-on" training programmes and apprenticeships focused on the green hydrogen economy. However, as the sector expands rapidly, there is a question about whether the UK can fill future roles.

Interviewees emphasised the need for more investment in education and training, with structured training and upskilling programs around electrochemistry quickly put in place through collaboration between industry and academia. Clusters and hubs where projects and supply chains are being developed were also cited as potential centres for strategic and targeted skills development.

Standardising procedures to boost productivity

As the green hydrogen industry matures, standardised procedures for project delivery are expected to emerge, resulting in greater efficiency in project rollout. Currently, the industry is adopting an approach similar to that of the O&G sector, with separate feasibility and front-end engineering design studies for each project, given the challenging offshore environments in which O&G platforms operate. However, as the number of onshore green hydrogen projects increases, respondents believe that standard development models will need to be established to streamline project delivery.

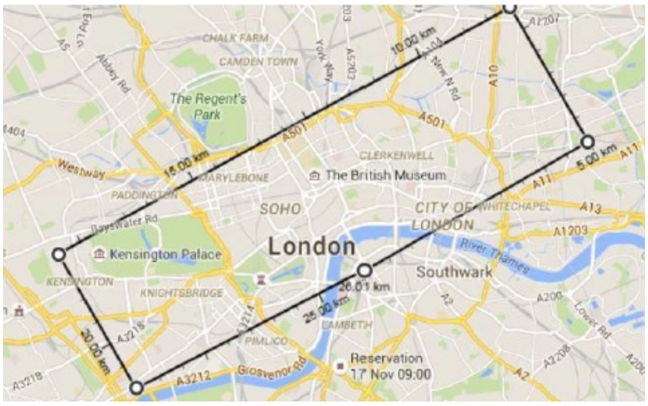
The electricity market has already developed standardised models for building substations and switch gears, resulting in significant efficiency gains. Adopting a similar approach for green hydrogen projects could mitigate the need for extensive engineering works and reduce the time and cost involved in delivering each project. With the majority of green hydrogen projects expected to be onshore, this approach has the potential to drive significant efficiency gains in project rollout.

3. Preparing the UK's infrastructure for green hydrogen

Recommendations:

- Bring forward the proposed delivery date for the Transport & Storage (T&S) Business Model from 2025 and, in the interim, explore separate bilateral agreements to between government and industry to build strategic infrastructure ahead of time.
- RenewableUK advocates for a comprehensive assessment of the UK's future hydrogen transmission pipeline requirements, followed by independent bilateral negotiations to fund them. Such negotiations should be conducted outside the current T&S business model if required. It is crucial that future offshore wind leasing rounds, such as ScotWind and the Celtic Sea, should be taken into account while formulating these negotiations.

Figure 5: Size comparison of underground "Rough" storage reservoir with London



Source: Wood, Optimat

Significant large-scale (underground) storage capacity is required to reach net zero, meaning repurposing pre-existing O&G reservoirs and creating new ones will be important. For example, HydrogenUK forecasts that the UK will require 3.4TWh of large-scale hydrogen storage by 2030, increasing to 9.8TWh by 2035.[16] Natural gas storage facilities can be repurposed for hydrogen storage which not only maintains pre-existing jobs at these sites, but also maintains the investment in the UK supply chain.

Centrica Storage, for example, is leading the charge in repurposing the Rough reservoir, spanning an area of 30km2 and located off the coast from Easington. Its previous incarnation as a natural gas reservoir saw it meet around 10% of the UK's peak daily demand before it was mothballed (i.e. put on pause). The project has since pivoted towards being converted to store hydrogen instead of natural gas, an ambitious initiative that is expected to create as many as 2,000 jobs in the Northeast during construction, and 350 positions once operational.

Financing transport & storage infrastructure

Plans to introduce the T&S business model by 2025 was viewed by respondents as a potential challenge to building the required infrastructure in time.[17] Developing new or repurposed T&S from legacy O&G infrastructure is essential for transporting hydrogen from production sites to demand centres and/or storing it in large volumes ahead of use; but this can take several years to build. According to interviewees, dedicated pipelines can take up to 5 years to build and salt caverns between 4 to 7 years.

To ensure the necessary infrastructure is available when large quantities of hydrogen are planned to be on the system (e.g. 2030), the proposed 2025 date for the T&S business model support must be brought forward. In the event that it cannot be accelerated, the government should pursue alternative measures such as establishing separate bilateral agreements with businesses to construct strategically positioned infrastructure. This will help ensure that the infrastructure is operational on time, enabling developers and potential end-users to have visibility of the available (future) infrastructure and plan accordingly, which may further incentivise potential end-users to switch.

16. Storage Working Group. HydrogenUK. Hydrogen Storage: Delivering on the UK's Energy Needs. December 2022. https://hydrogen-uk.org/wp-content/uploads/2022/12/HUK_Hydrogen-Storage-Delivering-on-the-UKs-Energy-Needs_online.pdf

17. DESNZ. Proposals for Hydrogen Transport and Storage Business Models. August 2022.
https://www.gov.uk/government/consultations/proposals-for-hydrogen-transport-and-storage-business-models

Building the pipelines which will enable the UK to capitalise on hydrogen exports

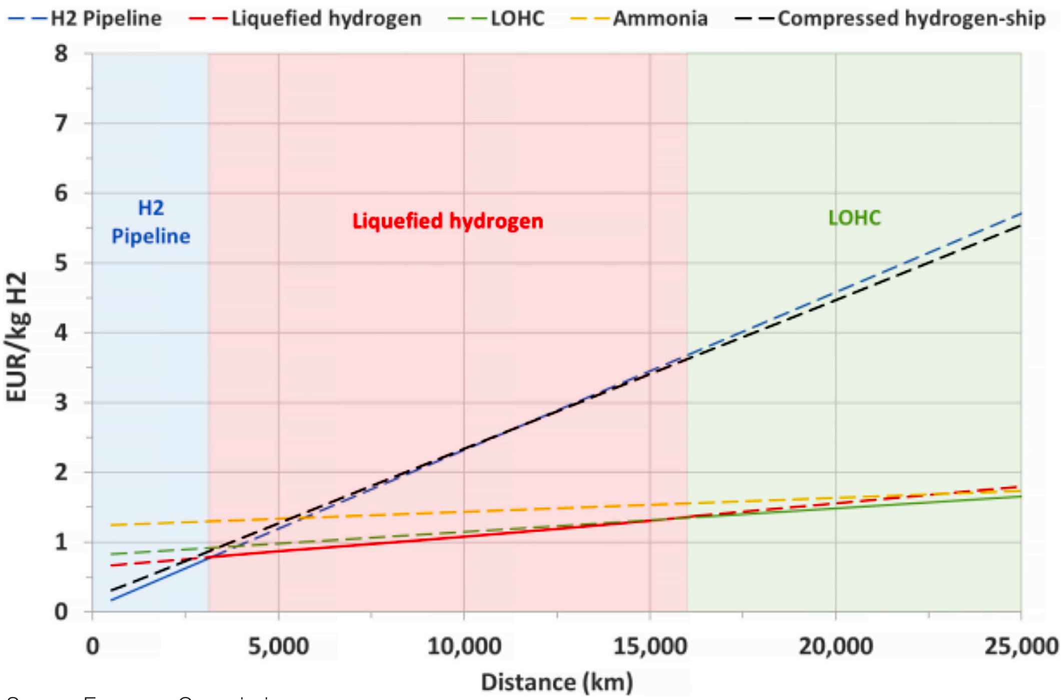
In global markets, the UK has potential to gain a significant foothold, particularly in Europe where the EU aims to import 10Mt of renewable hydrogen by 2030. Germany, with its projected hydrogen demand of 90-110TWh by 2030 and domestic production target of only 14TWh, for example, presents a huge opportunity.[18] The UK's abundant offshore wind resource and proximity to Europe position make it ideally positioned to meet this demand and become a major hydrogen exporter.

During interviews, industry respondents suggested that a viable opportunity was in building transmission pipelines to carry hydrogen from Scotland into mainland Europe, especially Germany. For distances up to 3,000km, compressed hydrogen delivered by pipeline is the cheapest transmission method compared to shipping hydrogen derivatives.[19] By capitalising on its favourable proximity to the EU market through the construction of transmission pipelines, the UK can improve its competitiveness vis-à-vis other countries that lack this geographic advantage, thereby mitigating the additional costs incurred by shipping hydrogen over long distances.

Gasunie and Tennet's recent analysis indicates that mainland Europe may require between 200TWh to 1,200TWh of hydrogen annually by 2050, depending on the scenario. To satisfy this demand, the UK would need to produce 40GW to 240GW of offshore wind power at the cost of £20-40/MWh, which would create an export industry for the UK worth between £4bn to £48bn per year.[20] In order words, the UK has the potential to play a pivotal role in meeting Europe's hydrogen demand and reap significant economic benefits in the process.

RenewableUK advocates for a comprehensive assessment of the UK's future hydrogen transmission pipeline requirements, followed by independent bilateral negotiations to fund them. Such negotiations should be conducted outside the current T&S business model if required. It is crucial that future offshore wind leasing rounds, such as ScotWind and the Celtic Sea, should be taken into account while formulating these negotiations.

Figure 6: Hydrogen delivery costs for a simple (point to point) transport route, for 1 Mt H2 and low electricity cost scenario



Source: European Commission

18. Franke, Andreas. German Cabinet Approves Hydrogen Strategy, Sets 14 TWh target by 2030. June 2020. https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/electric-power/061020-german-cabinet-approves-hydrogen-strategy-sets-14-twh-target-by-2030

19. European Commission, Assessment of Hydrogen Delivery Options. June 2021. https://joint-research-centre.ec.europa.eu/system/files/2021-06/jrc124206_assessment_of_hydrogen_delivery_options.pdf

20. Offshore Wind and Hydrogen: Solving the Integration Challenge, Catapult, September 2020. https://ore.catapult.org.uk/wp-content/uploads/2020/09/Solving-the-Integration-Challenge-ORE-Catapultr.pdf

4. Tapping into the UK’s plentiful wind resource

Recommendations:

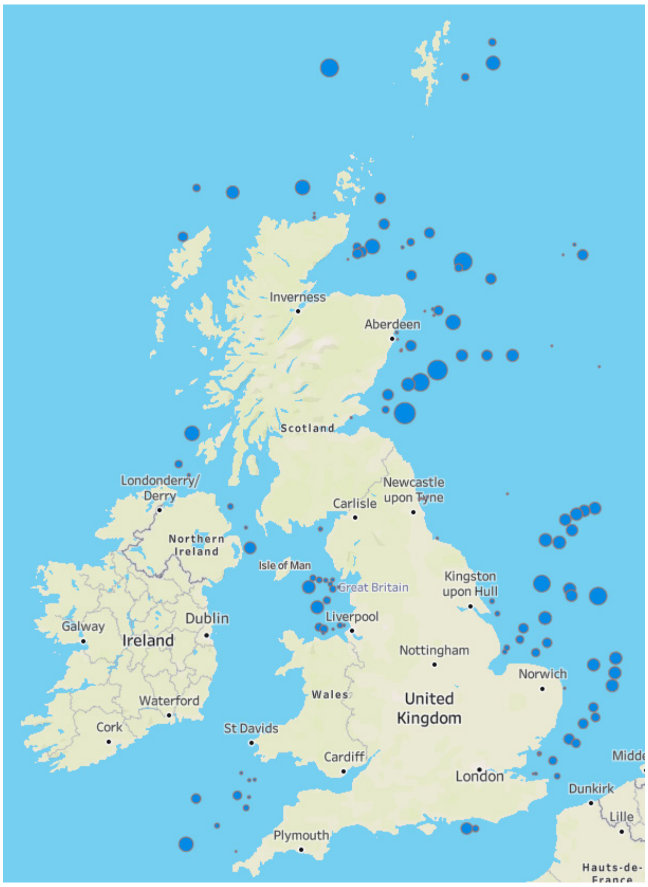
- A detailed study of policy and regulatory changes is necessary to incentivise the interface between renewable energy sources and green hydrogen. This study should validate initial assumptions and determine common requirements for the future needs of co-located projects to mitigate renewable intermittency and provide ancillary services to the grid.
- The government should consult with industry stakeholders to create potential hub specific to green hydrogen that maximize the use of renewables in these regions to the benefit of the UK’s energy security.
- National Grid ESO’s Connections Reform should consider an approach which rewards new technologies that help the system flexibility and stability, such as co-located electrolytic hydrogen. Currently the process only looks at capacity but does not consider how that capacity is utilised. Instead, it should be reformed to allow green hydrogen to function in ways that help balance the grid, such as when there is oversupply. National Grid should communicate any institutional barriers that may prevent this.

The UK boasts an enviable advantage over its international rivals thanks to its ample wind resources and long history in offshore wind, which is a key in the production of green hydrogen. According to IRENA, energy inputs represent between 50-75% of the final cost of hydrogen, depending on the operating regime.[21] Access to affordable and dependable renewable energy sources is pivotal in reducing the overall levelised cost of production.

Fortunately, the UK is well positioned in this regard, with RenewableUK’s EnergyPulse reporting 14GW of offshore wind capacity already installed and a total project pipeline of nearly 100GW.22 As more renewable projects come online and increase the supply of energy, the cost of electricity is expected to decrease while the curtailment of energy grows (i.e. wasted energy) as supply outstrips demand.

The Climate Change Committee forecast a future hydrogen storage capacity requirement of 2.8TWh by 2030, which may expand to as much as 5.2TWh by 2035.23 This capacity will serve as dispatchable power during “wind droughts” to enhance the country’s energy security and avoid the need to rely more heavily on carbon capture and grid storage to fill the deficit. The report’s technical summary cautions that the hydrogen and power sectors are intimately intertwined and that the failure of one sector can have repercussions for the other.

Figure 7: Total Offshore Wind Project Pipeline up to 2035



Source: RenewableUK/EnergyPulse

21. IRENA. Green Hydrogen Cost Reduction: Scaling up Electrolysers to Meet the 1.5°C Climate Goal. 2020. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Dec/IRENA_Green_hydrogen_cost_2020.pdf

22. EnergyPulse. RenewableUK. https://www.renewableuk.com/page/PIHome

23. Delivering A Reliable Decarbonised Power System. CCC. March 2023. https://www.theccc.org.uk/publication/delivering-a-reliable-decarbonised-power-system/

24. Connections Reform. National Grid. https://www.nationalgrideso.com/industry-information/connections/connections-reform

Numerous green hydrogen projects offer promising opportunities for co-location with new offshore projects, paving the way for novel market channels and system balancing services. However, the integration of electrolysis for grid balancing purposes demands a refined skillset, requiring a vast team of engineers well-versed in the dynamics of electrons and molecules. Moreover, the financial and physical policy mechanisms responsible for facilitating the flow of electrons between renewable energy sources and hydrogen remain unclear, and this is needed to ascertain their timing and application particularly during negative pricing periods. **A detailed study of policy and regulatory changes is necessary to incentivise the interface between renewables and green hydrogen. This study should validate initial assumptions and determine common requirements for the future needs of co-located projects to mitigate renewable intermittency and provide ancillary services to the grid.**

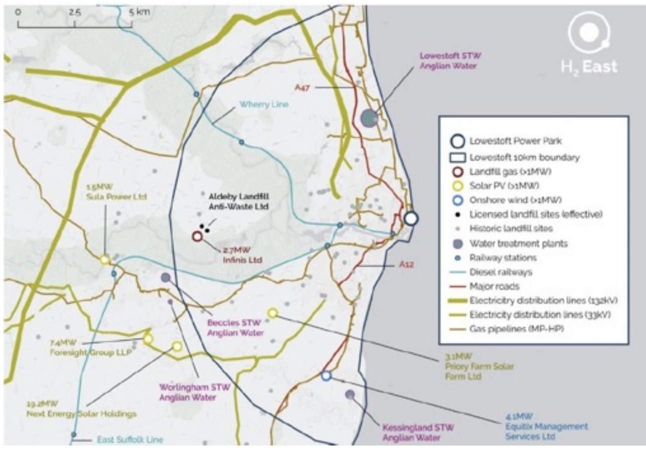
Additionally, National Grid ESO's Connections Reform[24] should consider an approach which rewards new technologies that help system flexibility and stability, such as co-located electrolytic hydrogen. Currently the process only looks at capacity but does not consider how that capacity is utilised. Instead, it should be reformed to allow green hydrogen to function in ways that help balance the grid, such as when there is oversupply. National Grid should communicate any institutional barriers that may prevent this.

Leveraging the UK's clusters for green hydrogen

Another key geographical advantage for the UK's green hydrogen production facilities lies in its industrial clusters. Several of the country's industrial clusters, including Teesside, Humberside and South Wales are situated close to generation locations along the coast, and two hydrogen clusters (H2Teeside and HyNet) have been chosen to proceed through the CCUS sequencing process. Given that hard-to-abate industries, such as steel and heavy transport, are likely to be key end-users of low carbon hydrogen, the presence of coastal industrial clusters represent a valuable opportunity for green hydrogen projects.

East Anglia, for example, has emerged as a promising regional hub for green hydrogen thanks to its local renewable energy generation and strategic proximity to key infrastructure such as Freeports East, water treatment works and the Bacton gas terminal.25 The area has demonstrated a visible appetite for green hydrogen in heavy transport, ports, agriculture, and food processing, which

Figure 8: Lowestoft and surrounding area



Source: Hydrogen East

may prompt the development of several small, diversified green hydrogen projects that could progressively scale up. The Lowestoft PowerPark has been identified one such project area, which could potentially host the early implementation of up to 5MW electrolyser stack in the region.

Respondents noted that clusters may also offer potential areas for the manufacturing of electrolysers and other components. Electrolyser manufacturing, for example, requires factory acceptance testing which require grid-power. With limited grid connections and long queues in many parts of the UK, local manufacturing may be disincentivised in this regard. However, heavy industry present in clusters means there is likely to be enough capacity to potentially overcome these challenges.

In light of these factors, there is a prime opportunity for the UK to leverage its industrial clusters located close to renewable sources to produce green hydrogen. However, most of the country's cluster strategy has to-date mainly focused on the development of blue hydrogen, potentially overlooking the potential of green hydrogen. **The government is therefore encouraged to consult with industry stakeholders to create and stimulate potential green hydrogen hubs that maximise the use of renewables in strategic regions to the benefit of the UK's energy security and decarbonisation goals.**

25. Brown, Michael. Charlotte Farmer, et al. LOWESTOFT POWERPARK: Executive Summary. Hydrogen East. December 2021.

Conclusion and summary of recommendations

The race to establish a green hydrogen economy is well underway, and the UK has potential to become a significant player in this field. Endowed with a legacy in O&G and a world-leading offshore wind sector, there is a clear opportunity for the UK to leverage its strengths to fulfil this goal.

For this to happen, however, it must prioritise the delivery of multiple operational green hydrogen projects and infrastructure, while also upskilling its workforce to underpin the sector. This will incentivise suppliers and assembly hubs to set up in the UK and ensure the country's competitiveness of the global stage. As such, we recommend the following actions:

1 Building large-scale projects complimented by solid policy foundations

- The UK government should show strict adherence to established deadlines for the completion of the Hydrogen Business Model and Net Zero Hydrogen Fund, finalise contractual terms for Hydrogen Allocation Round 1 (HAR1) and communicate a clear timeline for the passage of the Energy Bill, which enshrines the HBM into law; including a "Plan B" should the Bill be delayed.
- The allocation pots after HAR2 should be clarified up to 2030, and the application decision-making process should be streamlined to 6 months, in line with the CfD scheme.
- Conduct an ongoing and comprehensive review of the proposal to move HBM to competitive allocation, considering non-price criteria, and potentially delay this transition if the pipeline of projects and supply chain is not developed enough.
- Consult, and explore the potential for a working group with industry stakeholders, to establish tax incentives that make the UK a more competitive market for investment in the supply chain. Additionally, consider the role of the UK Infrastructure Bank or similar institutions to de-risk investment and unlock private capital.

- Publish a comprehensive roadmap setting out how it will achieve 5GW (or more) of green hydrogen by 2030. The roadmap should outline how the government plans to scale up green hydrogen and foster its uptake in key sectors and industries, as well as ensure green hydrogen is integrated effectively into the wider energy ecosystem for maximum benefit. Industry-government collaboration, such as through an industry taskforce, should be utilised to develop the roadmap and ensure that the interests of industry stakeholders are aligned with government policy objectives.
- Encourage collaboration through establishing a green hydrogen equivalent of the North Sea Transition Authority's Energy Pathway.
- Industry should fulfil ambitious projects at scale and then establish industry-wide standards that encourage local manufacturing through the facilitation of highly modular production and assembly lines for the primary components of electrolytic projects.

2 Plugging the skills gap

- Build on the North Sea Transition Deal by investing more into dedicated reskilling programs for people within O&G. Enticing workers away from O&G and into green hydrogen requires a healthy pipeline of successful projects and an industry that guarantees prospects, particularly for younger generations.
- Invest in education and training, with structured training and upskilling skills around electrochemistry through collaboration between industry and academia. Clusters and hubs where projects and supply chains are being developed, for example, could be targeted as centres for strategic skills development.

3 Preparing the UK's infrastructure for green hydrogen

- Bring forward the proposed delivery date for the Transport & Storage (T&S) Business Model from 2025 and, in the interim, explore separate bilateral agreements to between government and industry to build strategic infrastructure ahead of time.
- RenewableUK advocates for a comprehensive reassessment of the UK's future hydrogen transmission pipeline requirements, followed by independent bilateral negotiations to fund them. Such negotiations should be conducted outside the current T&S business model if required. It is crucial that future offshore wind leasing rounds, such as ScotWind and the Celtic Sea, should be taken into account while formulating these negotiations.

4 Tapping into the UK's plentiful wind resource

- A detailed study of policy and regulatory changes is necessary to incentivise the interface between offshore wind and green hydrogen. This study should validate initial assumptions and determine common requirements for the future needs of co-located projects to mitigate renewable intermittency.
- The government should consult with industry stakeholders to create and stimulate potential hubs specific to green hydrogen that maximize the use of renewables in these regions to the benefit of the UK's energy security and decarbonisation goals.
- National Grid ESO's Connections Reform should consider an approach which rewards new technologies that help the system flexibility and stability, such as co-located electrolytic hydrogen. Currently the process only looks at capacity but does not consider how that capacity is utilised. Instead, it should be reformed to allow green hydrogen to function in ways that help balance the grid, such as when there is oversupply. National Grid should communicate any institutional barriers that may prevent this.

Electrolytic Hydrogen Electrolyser | Image courtesy of Protium

RenewableUK members are building our future energy system, powered by clean energy. We bring them together to deliver that future faster; a future which is better for industry, billpayers, and the environment. RenewableUK are a UK membership body with a mission to ensure increasing amounts of renewable electricity are deployed across the UK. We support over 450+ members to access UK markets and to export all over the world. Our members are business leaders, technology innovators, and expert thinkers from right across industry.

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