# Hydrogen Forward Look

## Policy & Market Report

Foreign Commonwealth and Development Office

28 February 2023

→ **The Power of Commitment**

| Project name | | Hydrogen Forward Look | | | | | |
|---|---|---|---|---|---|---|---|
| Document title | | Hydrogen Forward Look \| Policy & Market Report | | | | | |
| Project number | | 12596456 | | | | | |
| File name | | 12596456_REP_Hydrogen Forward Look_Rev0 | | | | | |
| Status Code | Revision | Author | Reviewer | | Approved for issue | | |
| | | | Name | Signature | Name | Signature | Date |
| Draft | 0 | Taylor Hayes, Ade Aiyedun, Louise Dyer | Matthew East | | Matthew East | | 09/02/23 |
| Final | 1 | Taylor Hayes, Ade Aiyedun, Louise Dyer | Thomas Evans | | Matthew East | | 27/02/23 |

**Gutteridge Haskins & Davey Limited CN 05528602**

10 Fetter Lane, Level 6

London, London EC4A1BR, United Kingdom

**T** +44 203 077 7900 | **F** +44 203 077 7901 | **E** londonmail@ghd.com | **ghd.com**

*© GHD 2023*

This document is and shall remain the property of GHD. The document may only be used for the purpose for which it was commissioned and in accordance with the Terms of Engagement for the commission. Unauthorised use of this document in any form whatsoever is prohibited.

# Abbreviations

| | |
|---|---|
| BECCS | Bioenergy with carbon capture and storage |
| BEIS | Department for Business Energy and Industrial Strategy |
| BIL | Bipartisan Infrastructure Law |
| Bn | Billion |
| CAISO | The California Independent System Operator |
| CAPEX | Capital Expenditure |
| CARB | California Air Resources Board |
| CCS | Carbon Capture and Storage |
| CCUS | Carbon Capture, Utilization and Storage |
| CEC | California Energy Commission |
| CfD | Contract for Difference |
| CNG | Clean Natural Gas |
| CO2 | Carbon Dioxide |
| CO2e | Carbon Dioxide Equivalent |
| CPUC | California Public Utilities Commission |
| CRADA | Cooperative Research and Development Agreement |
| CSO | Compulsory stock obligation |
| DERA | The Diesel Reduction Act |
| DEVEX | Development expenditure |
| DfT | Department for Transport |
| DMV | Department of Motor Vehicles |
| DOE | US Department of Energy |
| EGLE | Michigan Department of Environment, Great Lakes, and Energy |
| EPA | Environmental protection Agency |
| ESG | Environmental, Social and Governance |
| EV | Electric Vehicle |
| FCEV | Fuel Cell Electric Vehicle |
| FEED | Front end engineering design |
| FID | Financial Investment Decision |
| GAFF | Governmental Alternative Fuel Fleet Grant Program |
| GHC | Green Hydrogen Coalition |
| GHG | Greenhouse Gas |
| GO-Biz | Government Office of Business and Economic Development |
| H2 | Hydrogen |
| HBM | Hydrogen Business Model |
| HOV | High Occupancy Vehicle |
| HTSBM | Hydrogen Transport and Storage Business Model |
| IDHRS | Industrial Decarbonization and Hydrogen Revenue Support |
| IIJA | Infrastructure Investment and Jobs Act |
| IRA | Inflation Reduction Act |
| ITC | Investment Tax Credit |
| LA | Los Angeles |
| LCFS | Low Carbon Fuel Standard |
| LCHA | Low Carbon Hydrogen Agreement |
| LCHS | Low Carbon Hydrogen Standard |
| LCOH | Levelized cost of hydrogen |

| | |
|---|---|
| M | Million |
| MDOT | Michigan Department of Transportation |
| NYSEDEC | New York state Department of Environmental Conservation |
| NYSERDA | New York State Energy Research and Development Authority |
| NZHF | Net Zero Hydrogen Fund |
| OEM | Original Equipment Manufacturer |
| OFME | Office of Future Mobility and Electrification |
| OSHA | Occupational Safety and Health Administration |
| PHEV | Hybrid electric vehicles |
| PTC | Production Tax Credit |
| R&D | Research & Development |
| RAB | Regulated Asset Base |
| RAG | Red-Amber-Green |
| RTFCs | Renewable Transport Fuel Certificates |
| RTFO | Renewable Transport Fuel Obligation |
| SJVAPCD | San Joaquin Valley |
| SMR | Steam-methane reforming |
| TCEQ | Texas Commission on Environmental Quality |
| TERP | The Texas Emissions Reduction Plan |
| TxDOT | Texas Department of Transportation |
| UK | United Kingdom |
| US | United States |
| ZEV | Zero Emissions Vehicle |

# Executive Summary

GHD has compiled this report to provide insight into the US and UK Hydrogen markets. These insights will be used to and inform the FCDO around three [3] distinct areas:

1. Hydrogen Policy Landscape
2. Hydrogen Market Understanding
3. Hydrogen Forward Look

The overall goal of this report is to inform the FCDO on a **Forward Look** into the hydrogen economy in both countries. Insights were drawn from the policy review and stakeholder engagement around the overall state of the market and where each market might go. This summary outlines the findings from both workstreams as a part of this study.

# Policy Landscape

## US Federal Level Policy Review

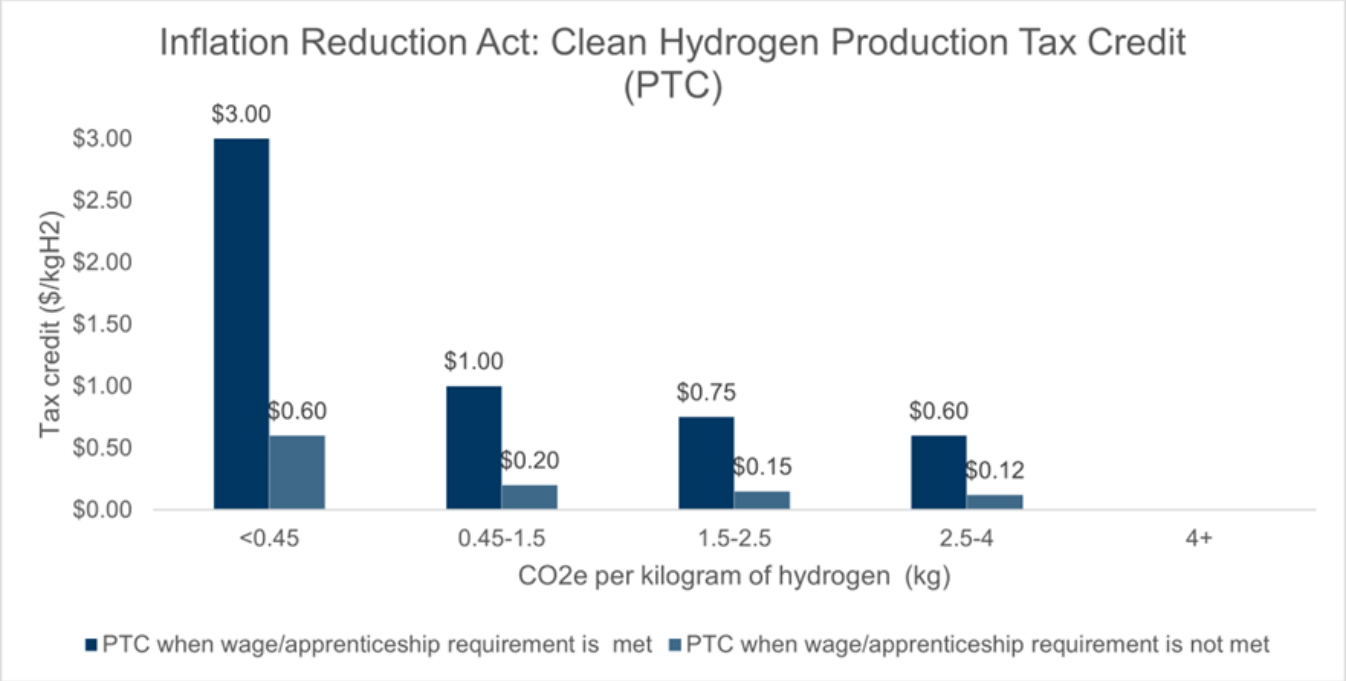
GHD has assessed and summarised hydrogen policies at a federal level and state-level for the US. The table below outlines the policies assessed, their major area of focus within the hydrogen economy, and the total amount of funding announced to support the industry growth.

| Policy | Focus | Funding Mechanism | Funding Amount |
|---|---|---|---|
| **Inflation Reduction Act: Clean Hydrogen** | **Producer** | **Tax rebate (ITC)**<br>**Tax rebate & cash refund (PTC)** | **$13.1bn credit (Covers both ITC and PTC)** |
| **Bipartisan Infrastructure Law/Infrastructure Investment and Jobs Act: Regional Clean Hydrogen Hubs** | **Producer, Consumer, Storage & Transport** | **Grant**<br>**Cooperative agreement**<br>**Other under consideration.** | **$8bn** |
| **Bipartisan Infrastructure Law/Infrastructure Investment and Jobs Act: Clean Hydrogen Electrolysis Program** | **Producer** | **Cooperative agreement** | **$1bn** |
| **Bipartisan Infrastructure Law/Infrastructure Investment and Jobs Act: Clean Hydrogen Manufacturing and Recycling Initiatives** | **Producer,**<br>**Midstream** | **Grant,**<br>**Contracts,**<br>**Cooperative agreements** | **$0.5bn** |
| **DOE H2@Scale: National Laboratories** | **Producer, Consumer, Midstream** | **Cooperative research and development agreement** | **$8M** |

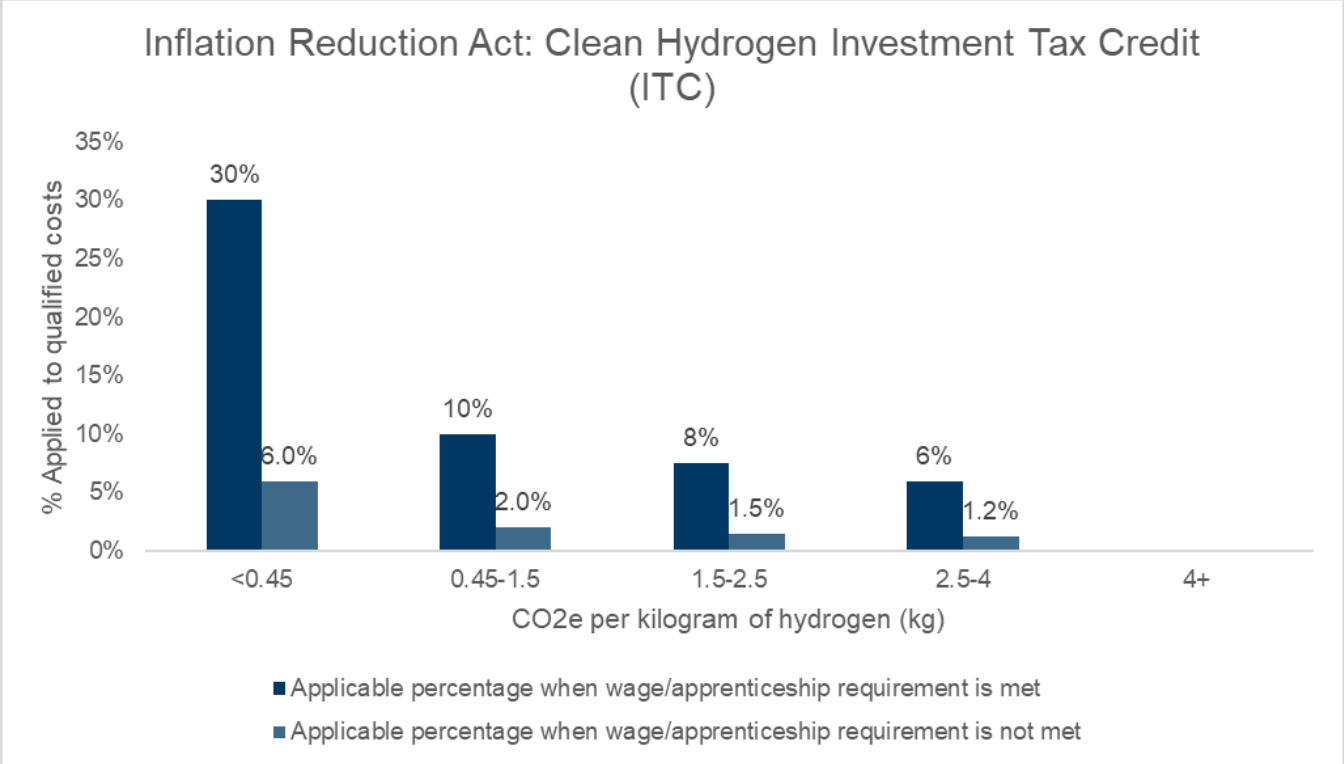
From this review, GHD have found that the major policies that are driving the current market are the Inflation Reduction Act and Regional Clean Hydrogen Hubs in the US and the Hydrogen Business Model under the Net Zero hydrogen Fund Strand 2 UK policy.

## Inflation Reduction Act: Clean Hydrogen Tax Credits

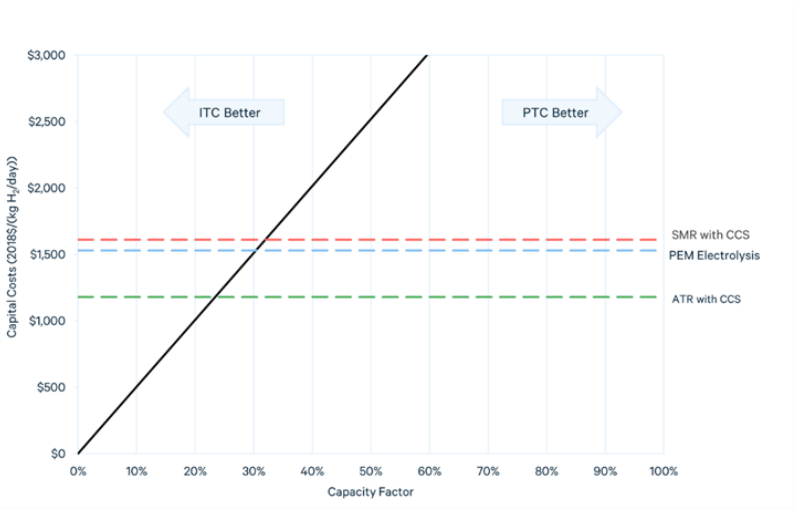
The Introduction of the Inflation Reduction Act is set to disrupt the hydrogen production market, with ~$13.1bn of funding committed to clean hydrogen within the decade. Within this review GHD has summarised the two producer focused tax credits: Production Tax Credits (PTC) and Investment Tax Credits (ITC).




Producers opting for the PTC can benefit from a tax credit of up to $3 per kilogram of low carbon hydrogen produced. As shown in the figure above, the exact tax credit amount is dependent on the volume of CO2e per kilogram of hydrogen produced.



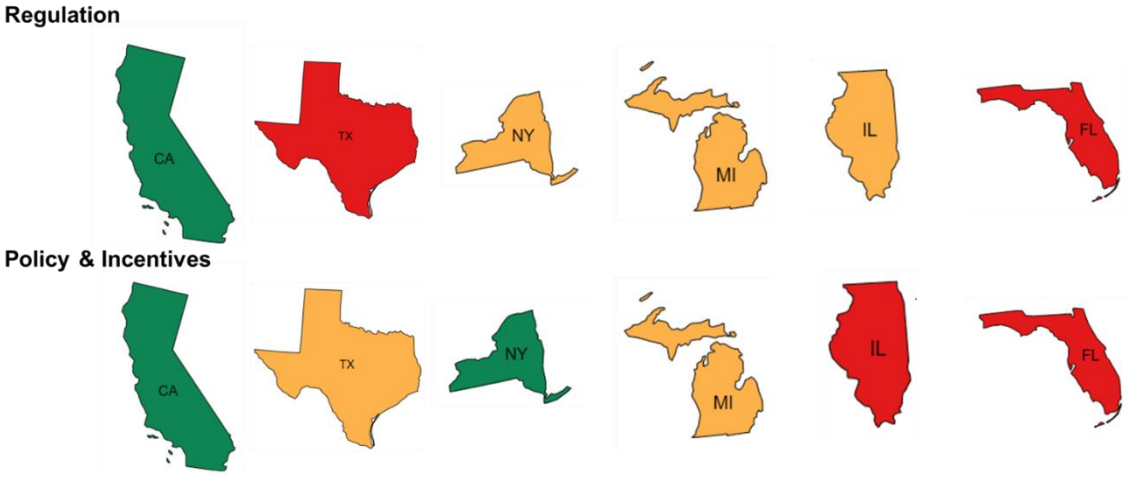

Producers opting for the ITC can benefit from a tax credit applied to 30% of qualified costs. As shown in the figure above, the percentage applied to qualified costs is dependent on the volume of CO2e per kilogram of hydrogen produced.




GHD have also analysed the relationship between the levelized cost of hydrogen (LCOH) and the trade-off between ITC and PTC. Both the ITC and PTC ensure that producers will benefit from a reduction in the LCOH regardless of project size, however, the trade-off between ITC or PTC occurs at the point in which the financial incentive from the PTC covers a greater percentage of the LCOH in comparison to the ITC.

## US State-level Policy Review

GHD have also assessed the state-level policy on a maturity basis. The assessment was done by selecting regional representative states and assessing their build-out levels of the hydrogen specific regulations and policies/incentives. These states were assigned a RAG rating based on the development level of their legislature. The selected states and their ratings can be found in the figure below.




Of these states, GHD found that there was a mixed level of development of legislature. Notably, California had the most progressive stance on hydrogen with multiple policies and incentives already in place and some regulation around hydrogen use developed.

## UK Policy Review

GHD has assessed and summarised hydrogen policies at a national level for the UK. The table below outlines the policies assessed, their major area of focus within the hydrogen economy, and the total amount of funding announced to support the industry growth.

| Policy | Focus | Funding Mechanism | Funding Amount |
|---|---|---|---|
| **Hydrogen Production Business Model** | **Producer** | **Contracts for difference** | **£100M** |
| **Net Zero Hydrogen Fund: Strand 1** | **Producer** | **Grant request** | **£80,000 - £15M Grant request** |
| **Net Zero Hydrogen Fund: Strand 2** | **Producer** | **Grant request** | **£200,000 - £30 M Grant request** |
| **Net Zero Hydrogen Fund: Strand 3 & 4** | **Producer** | **Awaiting further information** | **Based on funding amount for Strand 1 and Strand 2.** |

## Contract for Difference (CfD) Subsidy Model

Contract for difference was first introduced in the UK in October 2014, the CfD scheme was primarily designed to support deployment of large-scale renewable projects (greater than 5MW).

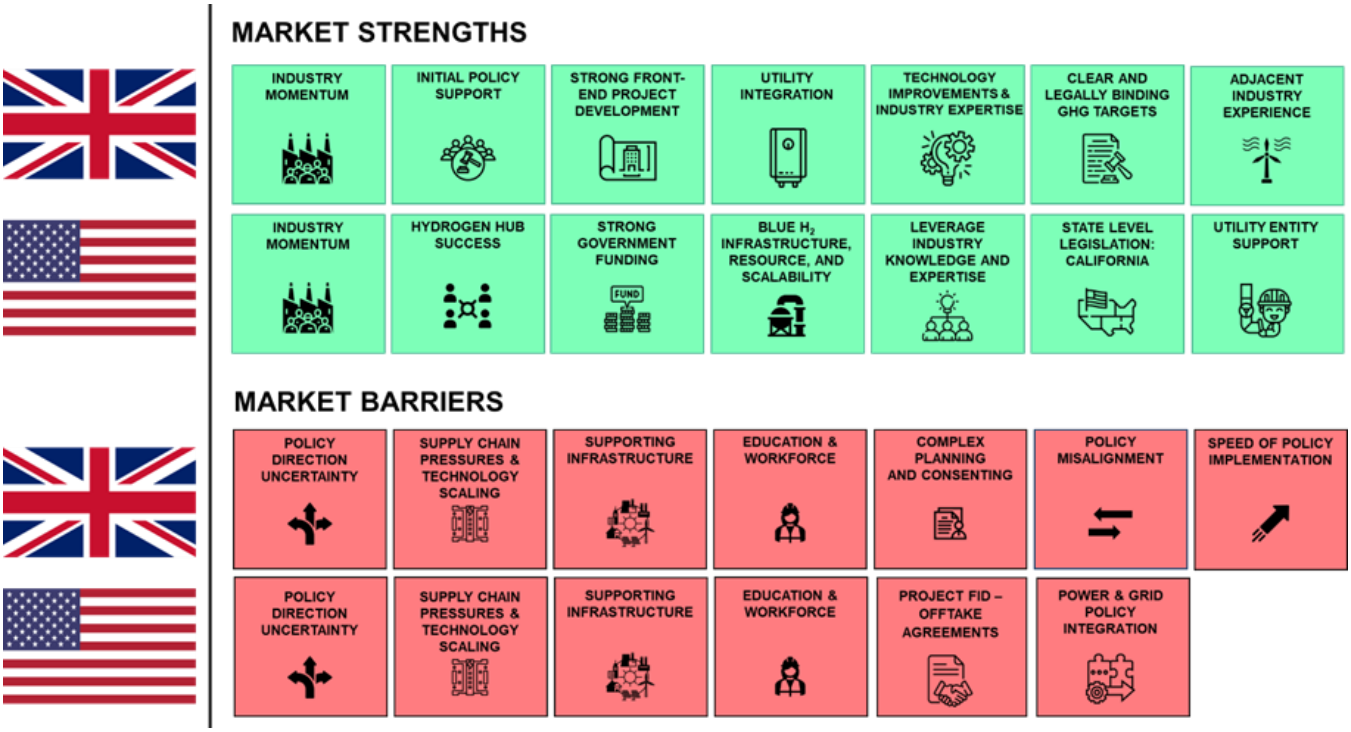
The Hydrogen Production Business Model (HPBM) will introduce a CfD model (variable premium price support model) where the premium/payment, is the difference between the cost of producing hydrogen (known as a ‘strike price’) and the market value of hydrogen (known as a ‘reference price’). The UK is considering the implementation of a CfD to support hydrogen storage which would address volume risk, in addition to a CfD to support transportation of hydrogen.

CfD subsidy models will effectively set a market price for hydrogen, benefiting both producers and consumers.

# Market Understanding

## Market Barriers and Strengths

During the second workstream, GHD engaged select industry stakeholders from both markets. The engagement was predominantly used to draw out major market barriers and strengths in both countries. The recurring barriers and strengths identified have been placed into the figure below. This list is intended as a summary of the main themes drawn from stakeholders rather than an exhaustive list of barriers.



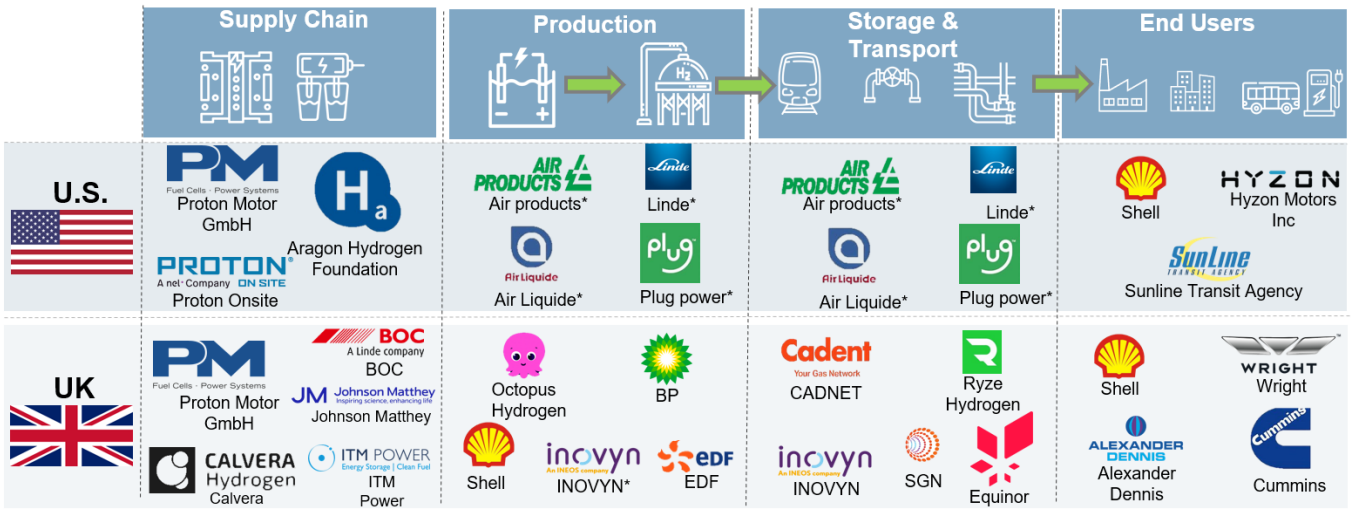

1

While all the identified barriers and strengths for both countries are relevant, some have more potential impact than others. Of these, stakeholders have identified the major barriers as policy uncertainty and misalignment, the lack of supporting infrastructure, and lack of education and undersupply of workforce. On the flip side of the coin, strong front-end project development and clear and legally binding GHG targets were identified as major market strengths within the UK, and the strong government funding of hydrogen projects has proven to be a key factor in the acceleration of the hydrogen economy in the US.

## Market Snapshot / Investment

As a wider part of the market understanding, GHD compiled a list of hydrogen industry major players. This list was gathered through both stakeholder engagement as well as GHD's personal industry experience. The figure below shows a list of major players in each area of the hydrogen value chain. Please note that this list in not exhaustive and there are many major industry players that sit outside of the list below.

[1] FID - Financial Investment Decision




*Supply Chain Players*[2]

Major players listed above have been categorised into the following groups within the hydrogen value chain. Each group can be broadly described as follows:

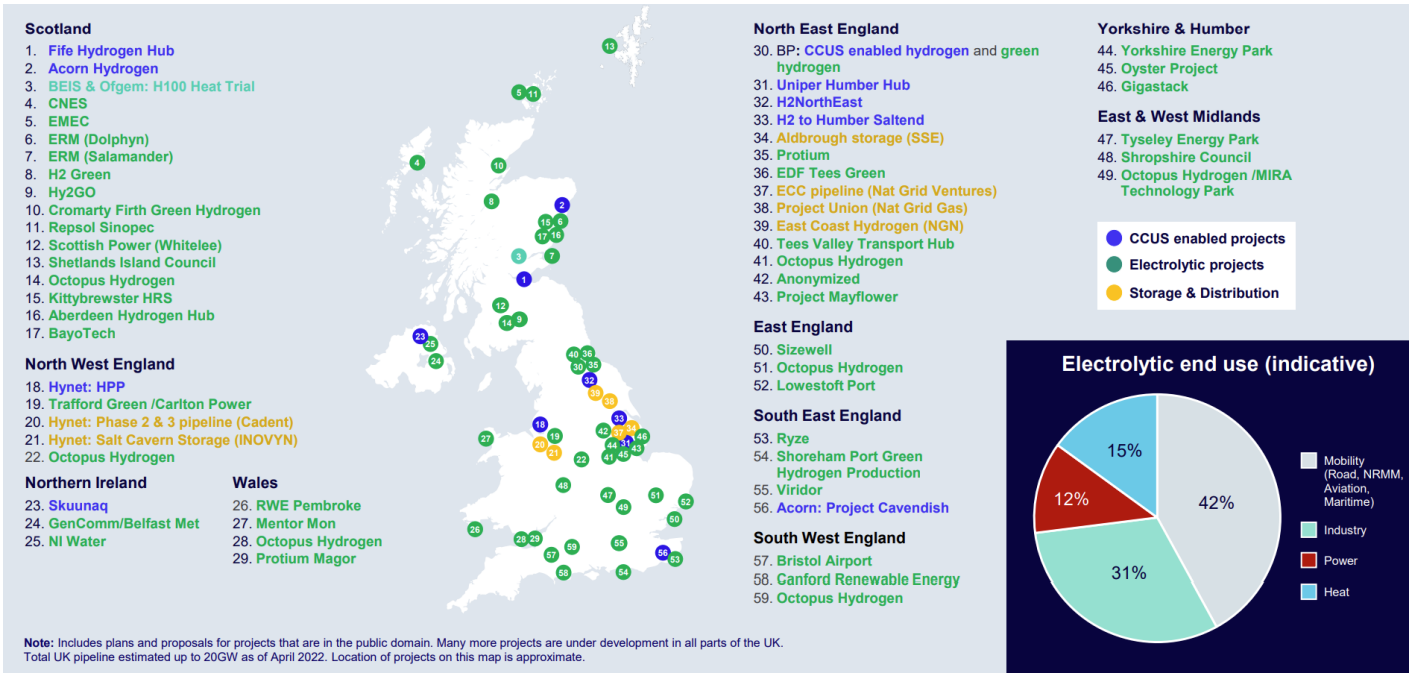
- *Supply chain – Original equipment manufacturers (OEMs) and technology providers for production, storage, transport, and use of hydrogen.*
- *Production – major players that specialise in producing (low carbon) hydrogen.*
- *Storage & transport – major players that focus on providing hydrogen storage and transport provisions.*
- *End users – major players that utilise low carbon hydrogen produced for end use applications in transport, property (residential and commercial), power and industry.*

## Investment Locations

Investment into both countries was identified to be highly regional and localised to industrial clusters or hydrogen hubs. This localisation of the hydrogen economy aligns with the national strategies of both countries who are focused on growing the sector through co-location of both production and consumption of hydrogen.

The image below shows a snapshot of where hydrogen projects are located around the UK[3]. The areas with major clusters include both the Northeast and Northwest of England as well as Scotland near the North Sea. The co-location of hydrogen projects and industrial clusters will limit the distance between hydrogen supply centres and areas of demand, consequently reducing associated costs relating to transport. The co-location of hydrogen supply and demand aligns with the UK government's National Hydrogen Strategy. These areas are likely to be where near-term hydrogen investment will flow if the co-location of the hydrogen economy model prevails.

[2] Proton Motor GmbH – fuel cell technology.
Aragon Hydrogen Foundation – electrolyser, fuel cell, filling station.
Proton Onsite – electrolysers.
BOC – Storage and transportation;
Johnson Matthey – carbon capture, fuel cells, electrolysers.
Linde – storage and transportation.
Calvera – storage and transportation.
ITM Power – electrolysers, fuel cells.
[3] As of April 2022




Similar to the UK, the US will also likely grow in a clustered approach. The main driver behind this growth is the US Department of Energy's (DOE) hydrogen hubs program. The hydrogen hub program has $8bn of funding assigned to selected hydrogen hubs located around the country. These hubs will only receive funding if their proposed approach meets specific criteria, one of which being the co-location of both production and use of hydrogen. This funding and co-location model will likely see major investment into the identified Hubs and surrounding regions. While the Hubs have not yet been selected, initial intent has been submitted to the DOE. Of these submissions, the DOE has encouraged a select few to continue with the full application. Some identified major hubs that were encouraged in this process can be seen in the image below. Should they be selected, these hubs will receive significant private investment into developing their hydrogen production, storage, transport, and utilization assets.

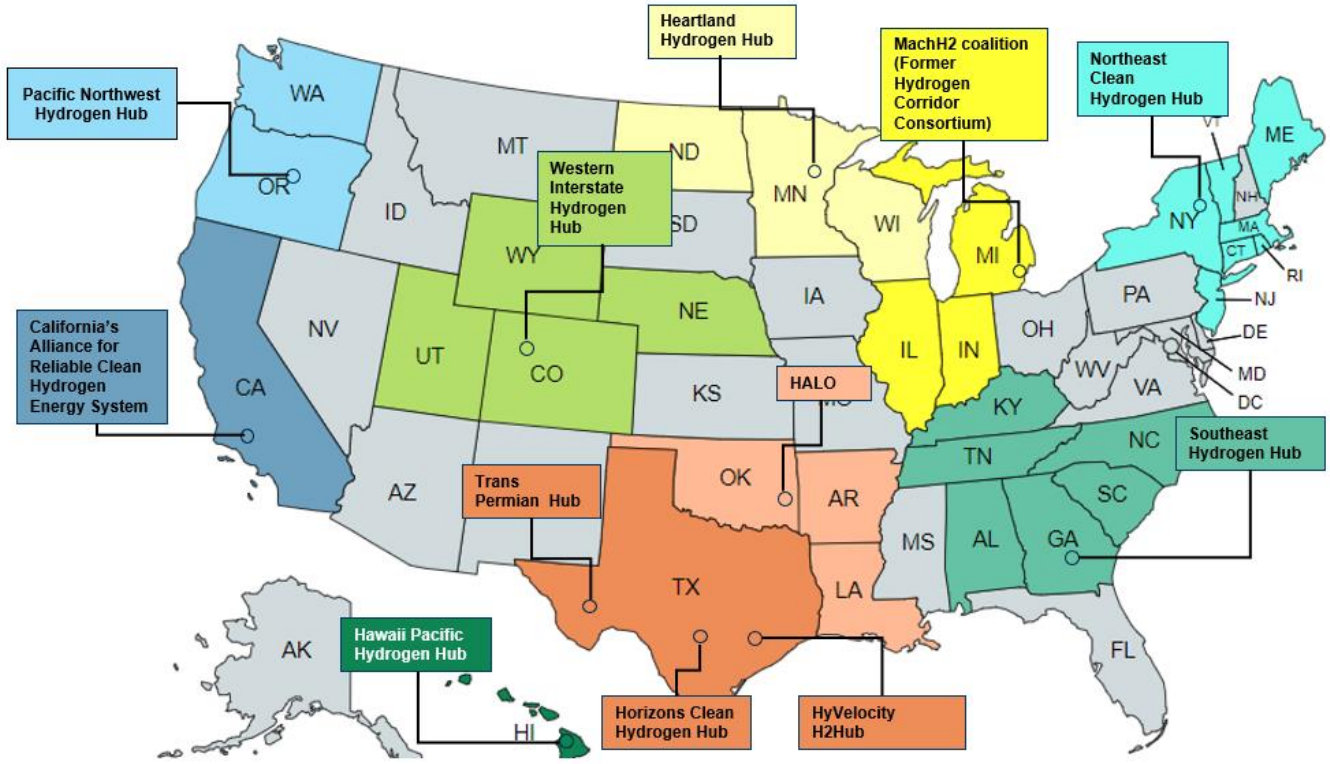
The following milestones are applicable for applicants of hydrogen hubs program:

- Full application deadline is April 7th, 2023.
- Pre- selection interviews scheduled to commence Summer 2023.
- Selection notifications take place during Fall, 2023.
- Expected timeframe for award negotiations will run from Winter 2023 through to 2024.

The DOE has outlined a four-phase structure for Hydrogen Hubs, with allocated funding soliciting plans for all four of the phases proposed. DOE intends to initially authorise funding for Phase 1 activities.

The DOE will review and evaluate deliverables reflecting activities in each phase to inform go/no -go decision that occur between or within phases.

Further details regarding four-phase structure are found  in section 3.3.3 of this report.




**Southeast Hydrogen Hub:** *Authority Dominion Energy, Duke Energy, Louisville G&E, Kentucky Utilities, Southern Company, Tennessee Valley*

**Western Interstate Hydrogen Hub**: *Xcel Energy, Avangrid, Dominion Energy Utah, Los Alamos National Laboratory, DOE's National Renewable Energy Lab (NREL), Sandia National Laboratories*

**Hawaii Pacific Hydrogen Hub:** *Hawaiian Electric, NREL and the University of Hawaii*

**HyVelocity Hub:** *University of Texas, Chevron, ENGIE, ExxonMobil, Fortescue Future Industries, Phillips66, Sempra Infrastructure, Shell, Siemens the Port of Houston*

**Trans Permian H2Hub:** *MMEX Resources, inclues Siemens Energy*

**Horizons Clean Hydrogen Hub:** *Headed by the Port of Corpus Christi, with around 30 private sector partners*

**California's Alliance for Reliable Clean Hydrogen Energy System:** *AECOM and Wood, as well as utility PGE, Toyota Corp., Plug Power, Hyundai, Michelin, BOSCH, Bloom Energy, Avantus*

**Pacific Northwest Hydrogen Hub:** *Undisclosed*

**Northeast Clean Hydrogen Hub:** Headed by NYSERDA with more than 60 ecosystem partners

**Heartland Hydrogen Hub:** *Bakken Energy, Bakken Energy announced an alliance with Cummins Inc. and Schneider Carriers Inc.*

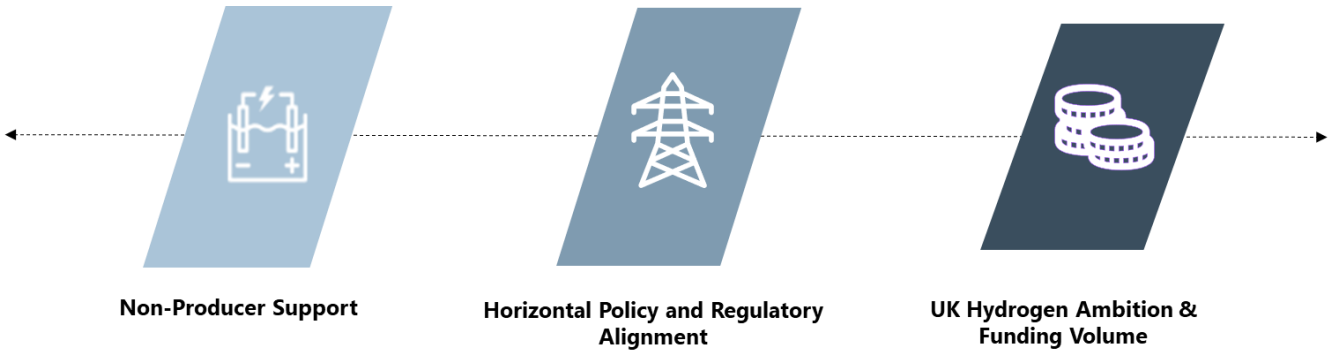
**MachH2 Coalition:** *ArcelorMittal, Governors State University, Nicor Gas, Northwestern University, the University of Chicago, the University of Wisconsin-Madison and the Argonne National Laboratory, NiSource, Applied Research Institute, BorgWarner, Cummins Inc., Energy Systems Network and Rolls-Royce*

**HALO:** *Shell, TC Energy, Williams, Halliburton, GE, Plug Power, Total Energies, Oak Ridge National Lab*

# FORWARD LOOK

GHD has compiled insights from both the policy review and stakeholder engagement workstreams to analyse the current state of UK and US hydrogen policy, identify main gaps in UK and US policy, understand where investment may flow, and present potential investment opportunities.

## Policy Gaps



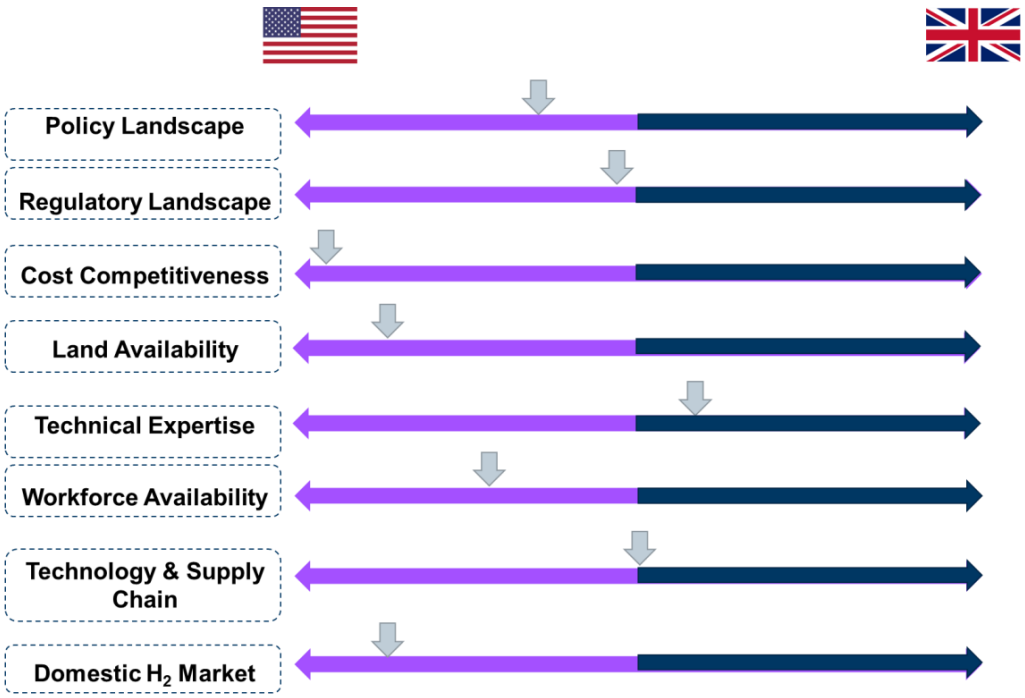

Both the UK and US have policies aimed at promoting the growth of hydrogen production. The UK has the Hydrogen Business Model, and the US has the IIJA/BIL and IRA funding. These policies provide support to hydrogen producers to increase the supply of hydrogen. However, capital costs for other parts of the value chain, such as technology scaling, supply chain manufacturing, infrastructure development and market growth, receive limited government support[4]. The UK has acknowledged the need for wider support and has launched the Hydrogen Transport and Storage Business Model and hydrogen use directives for non-industrial heating. The US has not announced any wider support for the hydrogen economy, but the significant funding for production may still drive growth in the wider value chain.

The national policies in the UK and US both support decarbonization goals and have funding criteria for low carbon hydrogen production. The majority of renewable energy in the UK is generated from wind power, but as an unintended consequence the CfD model may limit the amount of energy sold directly to hydrogen production. This may lead to hydrogen developers having to partner with existing renewable energy generators or develop their own, which could be difficult due to the complex and inconsistent planning processes and lack of land availability. The US policy lacks clarity around carbon accounting mechanisms and how they will apply to hydrogen production using grid power. Complex and inconsistent planning processes and technical challenges around steady renewable energy also apply to the US market.

The UK government has set a goal of reaching 10 GW of low-carbon hydrogen production by 2030. The UK has the potential for low carbon hydrogen production due to its abundant wind and tidal energy resources, well-developed energy infrastructure, and strong R&D sector. However, the current low carbon hydrogen production is small and significant growth is required to reach the government's goal. Despite the government funding of less than £1bn, 10 GW of hydrogen production would result in a £525.6bn industry. The current investment is seen as insufficient to support the government's ambitions, especially when considering the costs of supporting infrastructure.

[4] During stakeholder engagement sessions between 11 Jan 2023 - 31 Jan 2023.

## Market Direction




Lastly, GHD assessed the relative strength of each hydrogen market according to specific drivers. The figure above shows GHD's professional opinion on where each market currently stands relative to the other. Overall, the US market holds relative strength in the majority of the investment drivers. The UK market does hold an edge in existing technical expertise.

## Market Opportunities

GHD have identified three [3] potential market or collaboration opportunities between both the US and UK:

1. Hydrogen Solutions Export

   The UK's hydrogen industry experience and expertise can serve as an export for the rapidly growing US hydrogen market, which is expected to surpass the UK in production and utilization of low carbon hydrogen. The UK can assist with front-end project development, specifically lining up low carbon hydrogen offtake agreements.

2. Hydrogen Offtake

   The UK's demand for hydrogen may grow faster than the US due to legally binding GHG targets[5] and the penalties associated with emissions. With the potential oversupply of low carbon hydrogen in the US, the UK could potentially become an importer of US produced hydrogen.

3. Setting a global certification programme

   The UK government plans to introduce a globally recognized low carbon hydrogen certification scheme to increase transparency and confidence in the country's low carbon hydrogen sector by 2025. The certification scheme will play a vital role in promoting cross-border trade and boosting green jobs and will help verify sustainability claims in the growing green energy market.

[5] Applies to all UK companies that emit GHG's (exceeding total radiated thermal input of 20MW)., Companies must be compliant with the UK Emissions Trading Scheme (UK ETS) regulations for permitting (companies must hold a GHG emissions permit), monitoring, reporting and verification (PMRV). It is based on the "cap and trade" principle, which limits total GHG emissions released by participating sectors.