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WORLD GREEN ECONOMY ORGANIZATION

UAE-UK Clean Hydrogen Collaboration

Accelerating the clean hydrogen sector through bilateral cooperation in policy, innovation, trade and investment

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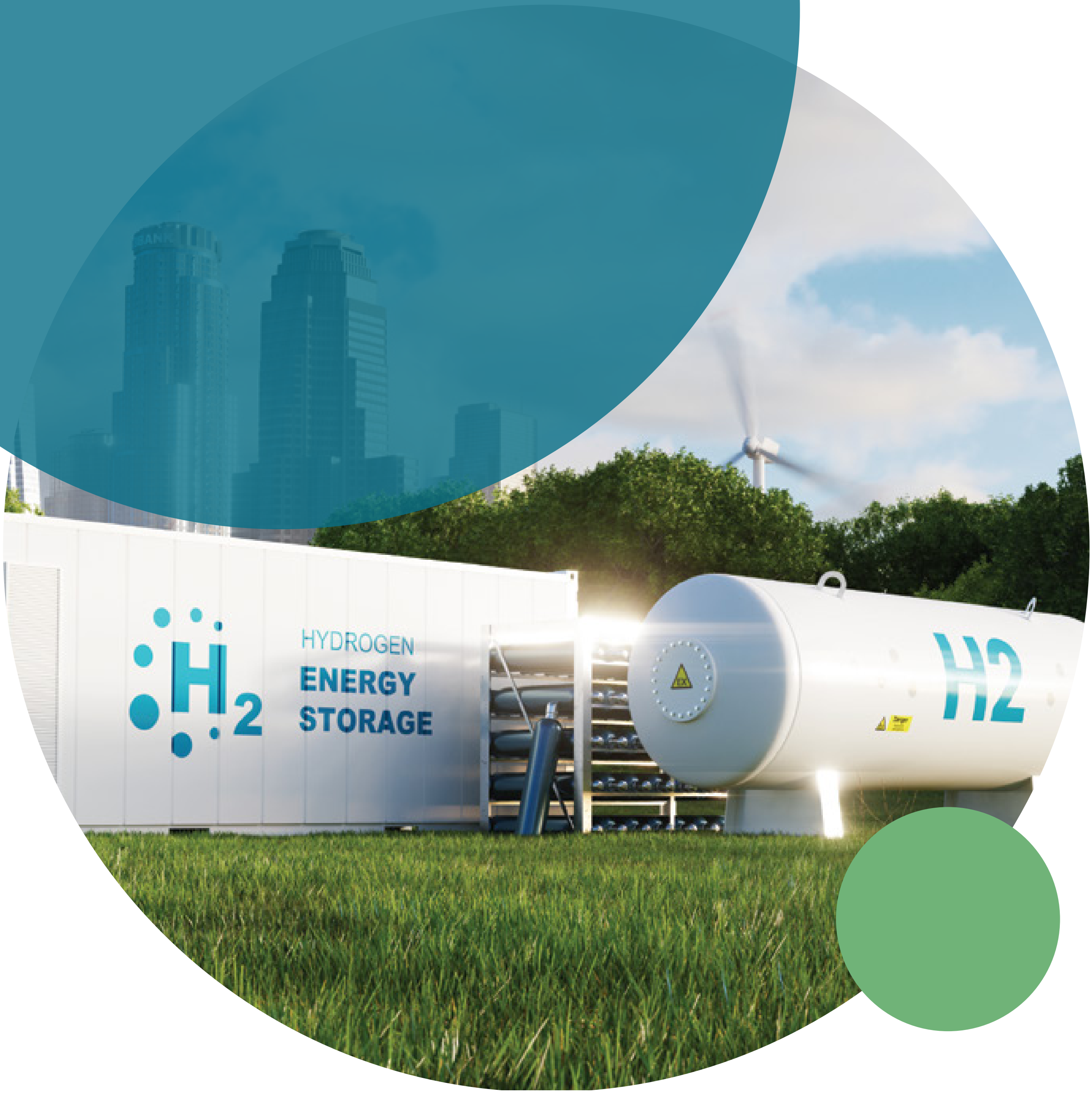

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About this Report

This report is funded by HSBC and delivered in partnership by the World Green Economy Organization (WGEO) and Zest Associates.

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HSBC is a global leader in sustainable finance, with an ambition to provide USD750 billion to USD1 trillion of finance and investment worldwide by 2030 to help clients in the transition to a net zero carbon emissions economy. Achieving net-zero commitments requires substantial changes across high-emission sectors in all markets. The volume of sustainability-aligned finance that is required to decarbonise the 10 sectors that represent 75 per cent of global emissions will have to grow to over $100–150 trillion cumulatively in the next three decades, and hydrogen will certainly play an important role on this transition.

The World Green Economy Organization (WGEO) is a multi-stakeholder organization aimed to promote the widespread adoption of green economy principles and practices within the context of sustainable development and poverty eradication.

The organization has a primary focus on sustaining economic growth, enhancing social inclusion, improving human welfare and creating employment opportunities while maintaining and nurturing the planet's ecosystems and mitigating the damaging impacts of environmental degradation on human health and welfare.

Zest Associates is a UAE-based sustainability consultancy that uses its global experience and deep sector expertise to inform public policy, support commercial decision-making and grow the clean tech sector. Zest creates sustainability solutions for governments, consultancies and private companies that want to thrive in the low carbon economy.

Zest develops strategies, policy options and programmes focused on clean tech innovation, green finance, and climate change. We translate aspirations into practical solutions, helping organizations move from ambition to action.

Acknowledgements

The partners express gratitude for contributions of:

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Ari Hawkins, Giuseppe Errante Parrino, and Waleed Shahid

Roundtable participants:

Eng. Abdulrahim Sultan (WGEO), Dr Alejandro Ríos Galván (Khalifa University), Andrea Lovato (ACWA Power), Andy Vaughan (Scottish Development International), Brett Ryan (Gemserv), Chris Smith (Meld Energy), Dan Feldman (Shearman & Sterling), Daniel Carter (Wood Plc), David Ramos (HSBC), David Wallace (Offshore Renewable Energy Catapult), Frank Wouters (Reliance Industries Limited), Graeme Sims (RSB), Hanan Bakr Sakr (HSBC), Hayleigh Barnett (Net Zero Technology Centre), Hertford King (Proton), Jamie Speirs (Imperial College London), Jamy Zakharia (Petrofac), John Gaffey (bp), Josh Carmichael (Wood Plc), Juliet Cramb-Low (Scottish Government), Kalyan Sarma (Johnson Matthey), Dr Lourdes Vega (Khalifa University), Nigel Holmes (Scottish Hydrogen and Fuel Cell Association), Omar Rashid (Blackstone Resilience), Philip Rice (Lloyd's Registry), Robert Bruce (Petrofac), Roland Roesch (IRENA), Setayesh Afshordi (Proton), Sgouris Sgouridis (DEWA), Steffan Eldred (Knowledge Transfer Network), and Taher Diab (Dubai Supreme Council of Energy)

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The findings in the report are based on experts' engagement and do not necessarily reflect the views of the sponsoring institutions or the UAE or UK Governments.

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Executive Summary

This study aims to accelerate the clean hydrogen industry in the UAE and UK by identifying priorities and finding opportunities to strengthen cooperation.

The UAE and UK enjoy a strong bilateral relationship and are already working together to advance the clean hydrogen industry. Deeper and broader collaboration across policy, innovation, investment and business could unlock mutual benefits for climate and economic development.

Clean hydrogen is playing a key role in the decarbonisation efforts of the UAE and UK.

Both countries' net zero commitments depend on clean hydrogen to deliver emission reductions, especially in hard-to-abate sectors. The countries' abundant renewable energy resources and natural gas endowments will be used to produce green, blue and potentially turquoise hydrogen, and their nuclear resources may produce pink hydrogen. Waste-to-hydrogen may also play a role. The countries have an opportunity to promulgate low carbon hydrogen standards internationally, moving away from colour-coding and towards the carbon content certifications required to guarantee hydrogen's low carbon credentials. Accounting for the embodied carbon of hydrogen is essential for it to support decarbonisation.

Hydrogen also supports the economic development agendas of the UAE and UK.

Hydrogen offers pathways for greater energy independence in the UK, economic diversification in the UAE, and job creation in both countries. By 2050, hydrogen is estimated to deliver up to AED 32 billion ($8.7 billion) annually to Dubai's economy alone, and £13 billion ($15.5 billion) Gross Value Added (GVA) to the UK, as well as over 100,000 new jobs in each country under high-adoption scenarios. These opportunities are driving multibillion-dollar investments, individually, and jointly through bilateral agreements and Memoranda of Understanding at government and corporate levels. These could be enlarged to match the scale of hydrogen investment required to achieve net zero.

This study draws its insights from nearly 100 hydrogen experts.

The study involved an extensive literature review of over 150 sources. This informed four expert Roundtables, which brought together 33 leaders from both the UAE and UK from across the policy, innovation, business and investment communities to discuss priorities and identify collaboration opportunities. The Roundtable outcomes were distilled into 39 areas of importance, which were grouped into seven thematic areas and formulated into a survey.

The areas include policy approaches, increasing supply, increasing demand, encouraging investment, scaling up, advancing innovation, and developing skills. Over 60 international hydrogen experts responded to a survey on these seven areas. They scored each of the 39 areas to evaluate their individual importance and ranked them in clustered groups to determine their relative merit. The outcomes are included in this report to substantiate its findings.

There is an opportunity to kick-start the market by stimulating supply and demand.

To overcome the 'chicken and egg' challenge facing hydrogen, governments have an opportunity to facilitate the market by mediating between producers and consumers to reduce risks and mitigate price constraints. Germany's H2Global provides a good model to address the top priority of securing government-backed offtake agreements and to overcome price and coordination challenges.

The UAE and UK Governments may also consider building a strategic hydrogen reserve, filled with hydrogen that is purchased at market prices and backed by government, to overcome this challenge. Stimulating demand is considered essential, with survey respondents expressing a strong appetite for policies that focus hydrogen on hard-to-abate sectors, underpinned by a price on carbon.

Coordination across sectors, disciplines, and geographies is crucial to accelerate the market.

The relevance of state-owned enterprises in the UAE's hydrogen landscape offers a special opportunity for directive coordination of supply and demand. The UK's hydrogen strategy and industrial clusters mission is strengthening coordination in the UK and the approach could be emulated in the UAE. Bolstering coordination across the energy, industry, transport, buildings, waste & water, and agricultural sectors would reduce market friction, lead to faster cost reductions, and better position hydrogen as a solution to whole-systems challenges in energy and decarbonisation. Cross-disciplinary coordination is also needed to make effective policy, build infrastructure, accelerate innovation, unlock finance and prepare the workforce. There is an appetite from stakeholders in the UAE and UK to deepen cooperation in these domains.

Hydrogen costs could be reduced through collaborative innovation and commercial-scale demonstrations.

Innovation in the UAE and UK is generally strong and improving, with the UK among the world's most innovative countries and the UAE leading regionally. Where the UK excels at early-stage innovation, the UAE excels at later-stage scale-up. This complementarity could be exploited through testing and demonstrations of new UK technologies at UAE facilities, potentially linked to UAE corporate venturing to accelerate scale-up and unlock shared financial returns. For carbon capture and storage – an enabler of blue hydrogen – the UAE's leading technical capabilities could be further utilised in the UK's industrial clusters.

Learning could be accelerated through a dedicated bilateral hydrogen platform that jointly originates innovation projects.

Pilot projects are a top priority of survey respondents, to demonstrate technical, commercial, and operational viability, reduce risks, and validate assumptions on costs and operating parameters. Establishing a bilateral multidisciplinary hydrogen platform that hosts regular exchanges of people and their viewpoints could seed broader "learning by interacting" and strengthen both countries' positions by accelerating cost reductions.

There is an opportunity to enlarge investment partnerships, including for enabling infrastructure.

With forecast investment in hydrogen at just 40% of global need, the UAE and UK need to improve the bankability of hydrogen projects to mobilise investment. UAE entities like Masdar, the Dubai Green Fund, or the Emirates Development Bank and the UK's Infrastructure Bank could act as Green Investment Banks to reduce risks, build technical capability and crowd in private sector finance for this relatively new market. To enable the market, there is an opportunity to enhance UAE-UK cross-border investment into new and refurbished pipelines, storage facilities, electricity transmission and port infrastructure.

The UAE and UK would benefit from joint skills development.

Preparing a skilled workforce first requires identifying skills needs and gaps. Supporting technical and vocational education and training, and retraining workers from the oil and gas workforce is also needed, ultimately leading to cross-border skills standards to ensure safety and facilitate construction. Training and academic cooperation is essential. There is enthusiasm for academic and business partnerships to advance joint training in the field.

As hydrogen's prominence continues to grow, deeper collaboration across policy, investment, innovation and business will strengthen both countries' positions domestically and internationally.

Both countries acknowledge clean hydrogen as pivotal to their decarbonisation and development agendas, and they are already capitalising on joint action. There remains opportunity to deepen government cooperation, form dedicated sharing platforms, accelerate joint innovation, and unlock bilateral investments. The global race for leadership in clean hydrogen has yet to be won. By working together, the UAE and UK can harness hydrogen's enormous economic potential and lead the global low carbon transition.


H2

01

The Role of Hydrogen in the Green Transition

1.1 **Objectives of the report**

The purpose of this study is to identify priorities to accelerate the clean hydrogen sector in the UAE and UK and to explore complementarities between the countries' goals, resources and capabilities.

Clean hydrogen is a rapidly emerging sector with significant forecast growth and it will be a key vector for decarbonisation. Both countries have an immediate opportunity to make hydrogen a focus of bilateral cooperation and turn their mutual ambitions into on-the-ground action. This report aims to inform and engage corporate executives, industry groups, governments, innovators, and researchers from both nations by exploring common prospects for low carbon hydrogen production and adoption. The UAE and UK can build on their strong relationship and forge a deeper partnership through hydrogen across policy and regulatory development, collaborative research, innovation and technology demonstration, joint investments and economic and industrial development.

Climate change is an urgent international challenge that requires all sectors of the global economy to be decarbonised.

Rapid and far-reaching transformations in the systems of energy, industry, transport, waste and land-use are needed to limit global warming below the internationally recognised threshold of 1.5°C above pre-industrial levels[1]. The severity and complexity of climate change are reflected in the most recent Intergovernmental Panel on Climate Change (IPCC) assessment, which notes that humanity must rapidly and drastically reduce greenhouse gas emissions to avoid severe losses and damages to the environment and economy.

Clean hydrogen is increasingly being recognised as playing a key role in achieving decarbonisation.

Hydrogen can be produced through a variety of methods using either electricity or hydrocarbons as a primary input. Depending on the way in which it is produced, hydrogen can be a low carbon energy solution or even a carbon negative energy solution. Low carbon hydrogen is attractive because of its versatility as an energy carrier and as a fuel, with applications across the industry, buildings, transport and power sectors. Many of its applications address so-called 'hard-to-abate' sectors like steel, chemicals, process heat, shipping and aviation, which are challenged by the high cost or technical infeasibility of decarbonising. For these reasons, clean hydrogen is receiving an upsurge of attention as climate change targets tighten and as innovative hydrogen production technologies advance.

1.1.1. Hydrogen's importance to the UAE and UK

Both the UAE and UK see clean hydrogen as significantly contributing to their climate goals.

The UAE and UK's Net Zero by 2050 strategies frame both countries' approaches to transitioning to a low carbon economy.[2,3] In the intermediate term, the UAE aims to reduce emissions 23.5% by 2030 relative to 2016 business-as-usual forecasts, and the UK aims for a 68% reduction by 2030 compared to 1990 levels, and a 78% reduction by 2035.[4,5] The UAE government sees hydrogen as playing a "key role in advancing the UAE's transition to a sustainable, low-carbon economy," while the UK government says that "low carbon hydrogen will be essential for reaching net zero."[6,7]

Hydrogen also supports objectives around energy security, economic diversification and long-term prosperity.

For the UAE, hydrogen represents an opportunity to diversify away from fossil fuel export earnings which comprise 30% of the country's GDP.[8] Hydrogen could also allow the country to maintain or grow its geostrategic energy position despite global decarbonisation policies. For the UK, primarily a net energy importer, hydrogen can become a means to improve energy security and long-term energy system resilience. Hydrogen also provides major economic opportunities in both countries, estimated to deliver by 2050 up to AED 32 billion ($8.7 billion) annually to Dubai's economy, and £13 billion ($15.5 billion) in GVA in the UK. In terms of jobs, both the UAE and UK expect over 100,000 new jobs to be generated throughout the hydrogen value chain by 2050 in high-adoption scenarios.[9,10]

1.2. Hydrogen must enable decarbonisation

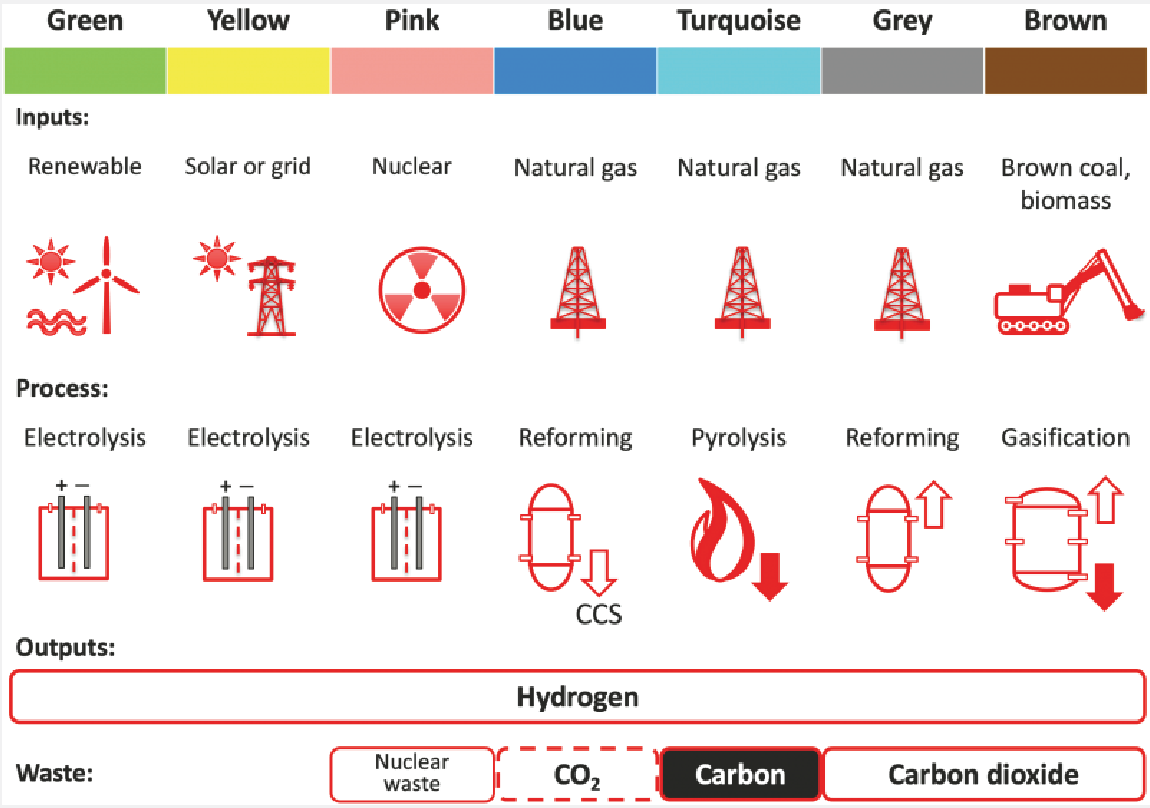
The emerging clean hydrogen industry is driven by the need to decarbonise the economy.

Current hydrogen production is responsible for 900 megatonnes of carbon dioxide emissions per year ($MtCO_2/y$), which is a fifth more than the total combined emissions of the UK and UAE.[11,12,13] Without the global consensus to reduce greenhouse gas emissions, clean hydrogen would not be an area of focus. Ensuring hydrogen's low carbon credentials is therefore of primary importance.

Hydrogen has been colour-coded to approximate the carbon impacts of different production methods.

Grey and blue hydrogen use fossil fuels as inputs while green and pink hydrogen use water and electricity. Turquoise hydrogen uses fossil fuels and heat, which can be generated from low carbon electricity sources. The colours of hydrogen and their inputs, process and outputs are shown in Figure 1.

Figure 1: The colours of hydrogen

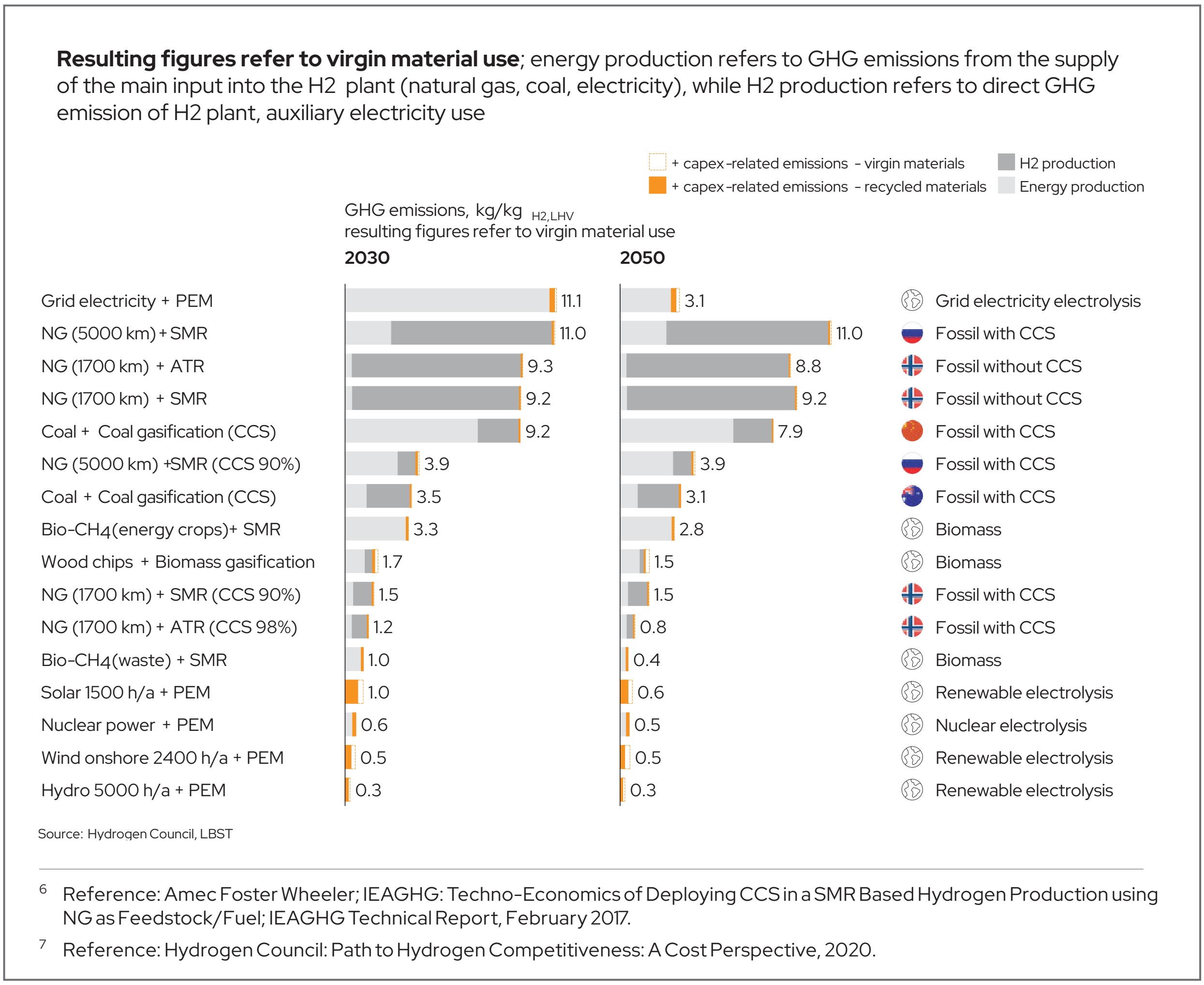


Source: Broadleaf[14]

Each type of hydrogen has a different greenhouse gas emissions impact.

Grey hydrogen represents 95% of today's supply and is produced through steam methane reformation (SMR) of natural gas or coal, which is incompatible with net zero goals.[15] Blue hydrogen is generated through SMR that is equipped with Carbon Capture and Storage (CCS) technology, which reduces greenhouse gas emissions compared to grey, but still releases emissions from upstream sources, fugitive emissions, methane leaks and incomplete CO_2 capture.[16] Green hydrogen splits water into hydrogen and oxygen using electrolysis powered by renewable energy, but may be limited by its cost. Pink hydrogen similarly electrolyses water using low carbon electricity from nuclear power. Turquoise hydrogen splits hydrocarbon chains into hydrogen and solid carbon through pyrolysis, though the technology is significantly less mature. Figure 2 shows the emissions associated with different production methods.

Figure 2: Carbon-equivalent by hydrogen production pathways, 2030 and 2050



Source: Hydrogen Council [17]

There is a growing recognition that colour coding hydrogen is insufficient to guarantee its low emissions credentials and that new carbon accounting standards are required.

Colour coding of hydrogen reflects its production method rather than its carbon intensity. Different facilities producing green or blue hydrogen will have a range of carbon footprints depending on many factors such as location, production efficiencies, availability of inputs, and rules governing the provenance of renewable electricity. Agreed lifecycle carbon accounting methodologies are needed to determine the carbon content of hydrogen in a rigorous and standardised way.

The UK is creating a national low-carbon hydrogen standard.

The Department for Business, Energy & Industrial Strategy (BEIS) recently released guidance on a UK Low Carbon Hydrogen Standard, which sets out the rules for calculating emissions from hydrogen production. At time of publication, the standard is in its infancy and is receiving regular technical updates.[18] The standard applies a greenhouse gas threshold of $20gCO_2e/MJ_{LHV}$[19], and outlines other considerations and conditions to standardise the scope, terminologies, system boundaries, value chain interactions and emission factors in measuring, monitoring, certifying and verifying low carbon hydrogen. Such standards are needed in all countries including the UAE, and for an effective global market and trading structure to develop, this standard needs to be internationally accepted.

As hydrogen grows into a more heavily traded global commodity, the UK and the UAE have an opportunity to shape a shared low carbon hydrogen standard.

Both countries have an interest in producing hydrogen from both gas and electricity, which supports the development of a low carbon hydrogen standard that covers different production methods. There exists academic capability at Khalifa University's Research and Innovation Centre on CO_2 and Hydrogen in the UAE. The Universities of Bath and Manchester were amongst the 96 respondents to the UK's consultation on low carbon hydrogen standards.[20] International collaboration at academic levels and could lay the groundwork for a harmonized scientific approach to measurement.

Aligned national standards could pave the way for an international standard.

Robust methodologies, which include some flexibility for future amendment as new information and technologies emerge, should be presented to National Standards Bodies for adoption, such as the British Standards Institution (BSI) or the Emirates Authority for Standardization and Metrology (ESMA). Ultimately, the standard can be proposed, prepared, scrutinized, approved and published by the International Standards Organization (ISO) for global adoption.[21] The standard can then be used to underpin accountability and transparency norms, and support disclosure frameworks and new capacities, including for auditors, verification methods and enforcement mechanisms.

1.3. The UAE and UK are well-positioned in the global move towards hydrogen

The UAE and UK have abundant renewable energy resources.

The UAE has a huge untapped solar potential and plenty of space to build solar farms, with forecasts of up to 20 gigawatts (GW) of capacity by 2030.[22] It also has among the world's lowest cost solar, with a record-low tariff of USD 1.35 cents/kWh set in 2020.[23] The UAE also has wind power potential, especially in the Northern Emirates, which can balance solar power's diurnal rhythm and enable 24/7 renewable-powered hydrogen production.[24] The UK's offshore wind capacity will grow from its current 14 GW of installed capacity to up to 50 GW by 2030.[25,26] It has 13.5 GW of installed solar PV as of May 2022. This is forecast to more than double to 28.6 GW by 2030 under business-as-usual scenarios but should reach at least 40 GW by 2030 to be on track to achieve net zero targets.[27,28,29]

They also have nuclear power and gas resources.

Both countries have nuclear power, with nuclear forecast to grow from 21% to 25% of the UK's electricity supply between 2021 and 2025, and the UAE's Barakah Nuclear Energy Plant supplying up to 25% of the UAE's electricity needs once fully operational in 2025.[30,31] Both countries have gas reserves. The UAE has 7.7 trillion cubic meters of proven gas reserves, ranking it seventh in the world.[32] The UK has 207 billion cubic meters, ranking it 41st in the world.[33] Both countries also have depleted wells that are suitable for carbon dioxide storage, a blue hydrogen enabler. Such wells may also be used for innovative hydrogen production technologies, whereby injected oxygen and downhole chemical reactions oxidize residual oil and generate hydrogen.[34]

These resources will be used to produce green and blue hydrogen, and possibly pink and turquoise hydrogen.

The UAE's Hydrogen Leadership Roadmap lauds the country's low-cost gas and amongst the world's lowest-cost solar PV as critical competitive advantages to produce low carbon hydrogen.[35] The UK's Hydrogen Strategy commits to a 'twin track' approach, using both clean electricity and gas to produce electrolytic and CCS-enabled hydrogen. This approach casts the net wide, allowing for innovation across all types of production methods to help deliver the volume of clean hydrogen needed to reach net zero. It also lets both countries capitalise on global competitive advantages in terms of natural resources, skills, capabilities and infrastructure. High gas prices being encountered in 2022, however, may make producers and policymakers rethink the long-term economic and political dimensions of using gas to make hydrogen.

1.3.1 **National strategies and production forecasts**

National hydrogen strategies are proliferating.

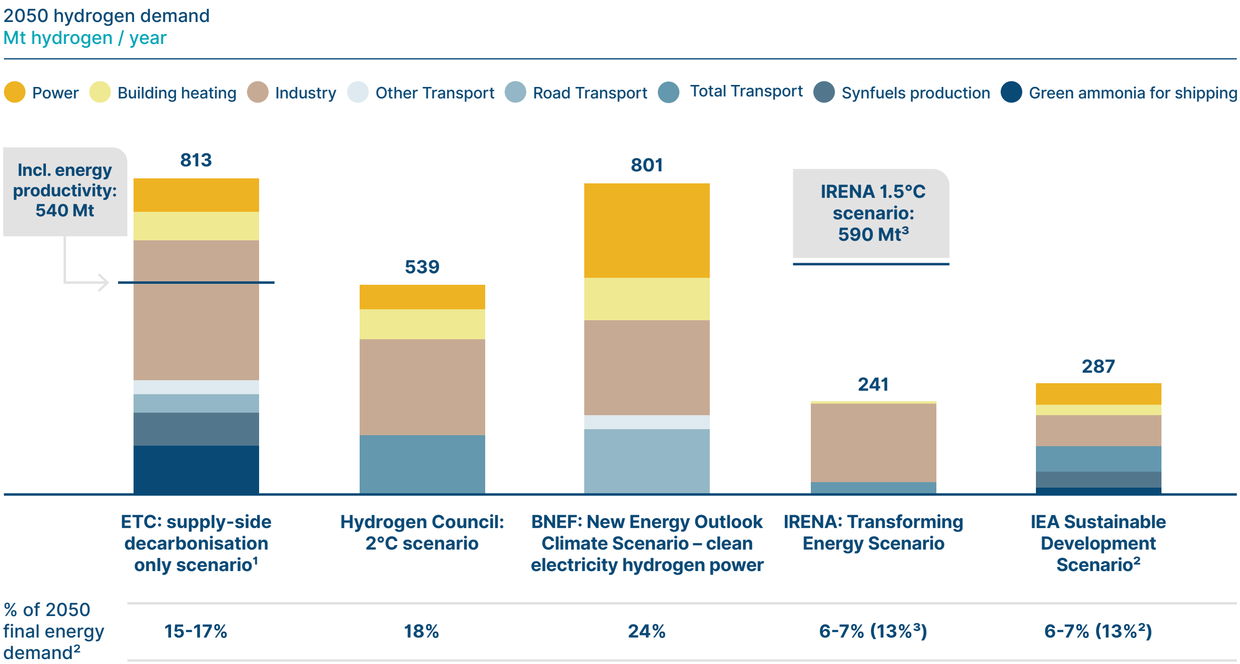
At least 17 countries and the European Union have already developed hydrogen strategies including the UK. About 20 other countries are presently formulating their policies with several expecting to publish this year. In the Middle East, this includes the UAE, Saudi Arabia, Oman and Israel.[36]

Global hydrogen production is expected to grow by about 20% by 2030, though estimates for long-term production vary considerably.

Announced pledges will see hydrogen grow from about 90 Mt in 2020 to nearly 110 Mt by 2030.

Global capacity of electrolysers reached 300 megawatts (MW) my mid-2021, double the volume from five years earlier, and the 350 projects currently underway could bring capacity to 54GW by 2030. An additional 40 announced projects could increase electrolytic capacity by another 35GW by 2030, and if all those projects are realised, roughly half of the growth (8 Mt) would come from electrolytic green hydrogen.[37] By 2050, hydrogen estimates range from 241 to over 800 Mt as shown in Figure 3. The huge range reflects uncertainty around future geopolitical circumstances, hydrogen's ultimate end-uses and the degree to which total decarbonisation scenarios materialise. For example, the REPower EU plan, announced in May 2022, doubled both the EU's domestic hydrogen production forecast and its import targets by 2030, illustrating the speed of change.

Figure 3: Range of 2050 hydrogen scenarios[38]



NOTES: ¹ Illustrative scenario considering 2050 final energy demand without application of energy productivity levers which would reduce energy needs in a net-zero scenario,
² Hydrogen reaches 13% of final energy demand by 2070 in IEA SDS, with hydrogen volumes of 520 Mt/year,
³ IRENA 1.5C scenario does not include split in uses, but represents 13% final energy demand.

SOURCES: SYSTEMIQ analysis for the Energy Transitions Commission (2021); Hydrogen Council (2017), *Hydrogen scaling up – A sustainable pathway for the global energy transition*; BloombergNEF (2020), *New Energy Outlook*; IRENA (2021), *World Energy Transitions Outlook – 1.5C Pathway*; IRENA (2020), *Global Renewables Outlook*, IEA (2019), *The future of hydrogen*

Source: Energy Transitions Commission[39]

The UAE's and UK's announced ambitions together represent a significant proportion of that growth.

The UAE announced that it aims to capture 25% of market share in export markets such as Japan, South Korea, Germany and India by 2030. It aims to achieve this by boosting ADNOC's blue hydrogen production from 300,000 mt to 500,000 mt per year, plus seven projects already underway and other new initiatives.[40] The UK Hydrogen Strategy's aim for 5GW of hydrogen production by 2030 was doubled to 10 GW in April 2022 with the release of its Hydrogen Investor Roadmap, soon after the European Union doubled its production plans in response to energy security concerns.[41,42] In the long term, the UK anticipates that 250-460 TWh of hydrogen could be needed in 2050, accounting for 20 to 35% of the UK's final energy consumption.[43] The Scottish Government Hydrogen Policy Statement aims to produce 5GW in Scotland alone by 2030.[44] Hydrogen's growth in Scotland will largely be powered by offshore wind, for which 25GW of new capacity was awarded in early 2022, building on nearly 2GW of current offshore capacity and 8.4GW of onshore wind capacity.[45,46,47]

1.4. Bilateral agreements lay a foundation for collaboration

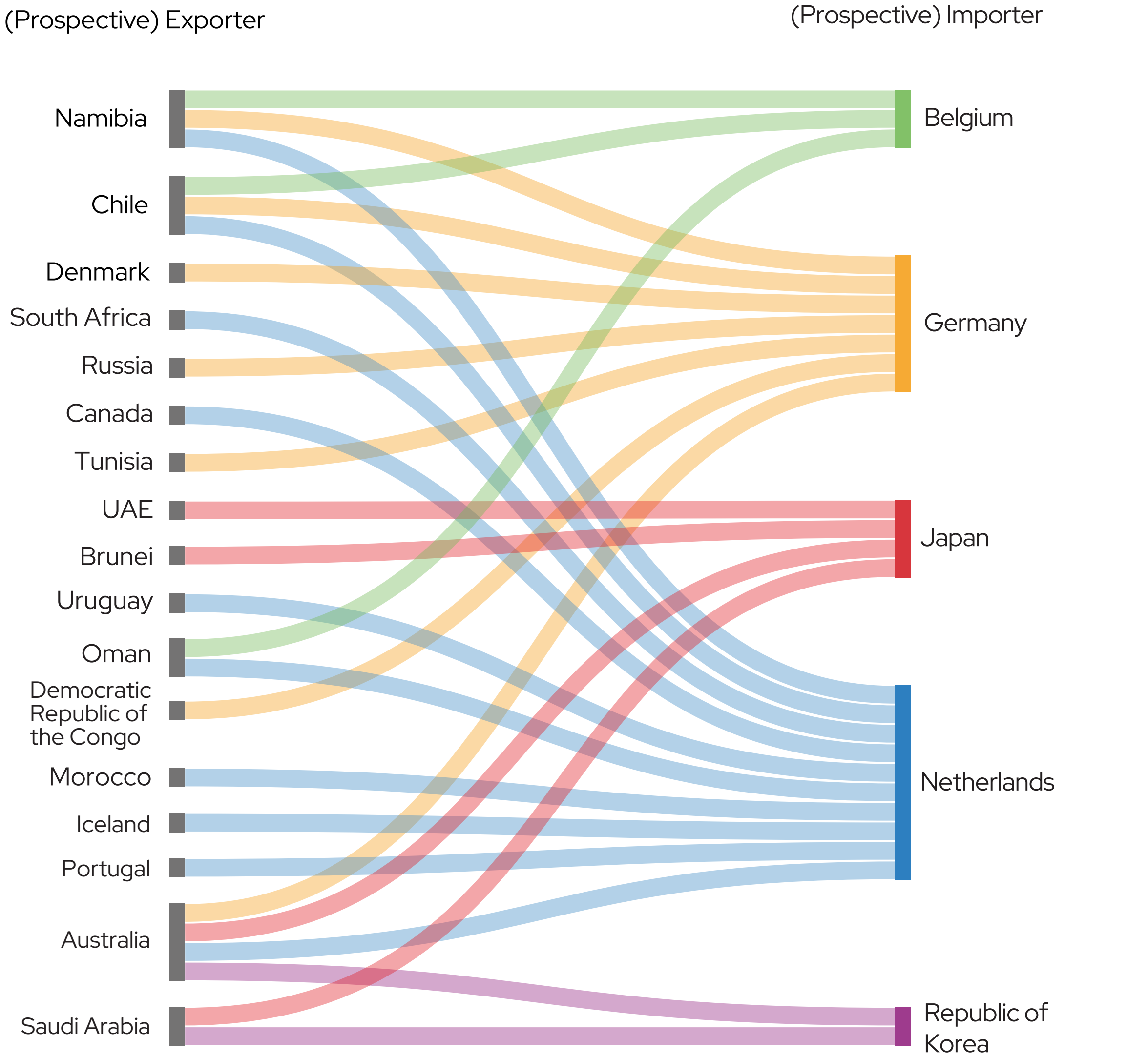
Bilateral agreements are laying the foundation for global market growth.

Hydrogen will influence the geography and geopolitics of the energy trade. Countries with lots of low-cost renewable energy and natural gas resources are likely to become producers of green and blue hydrogen. Trade partnerships will be shaped by their proximity to major future demand centres like Europe, East Asia and the United States. Already, dozens of Memorandums of Understanding have been signed between prospective exporters and imports, as shown in the non-exhaustive list in Figure 4. These agreements illustrate how major global trade corridors are likely to stimulate production and enable consumption, growing the global hydrogen market.

The UAE has signed over a dozen bilateral agreements at a government and industry level.

Many of these agreements are affirmations of partnership intentions at the governmental level, which can be used as a frame for private sector initiatives, as illustrated in Figure 5 and listed in more detail in Annex 1: MOUs and bilateral agreements. They tend to explore potential trade synergies, investment opportunities, and technical and economic feasibility studies, with some agreements looking at joint R&D initiatives

Figure 4: Bilateral trade agreements and MOUs



Note: Figure covers hydrogen trade related agreements only, based on public announcements and is not exhaustive. Private agreements and those that focus exclusively on technology co-operation are not included. MOU = Memorandum of Understanding.

Source: IRENA (2022)[48]

The UK has also secured international hydrogen partnerships through MOUs.

These include agreements to strengthen inter-connections, support hydrogen and CCS through industrial clusters, and advance industrial decarbonisation. The list of agreements identi-fied for this study is in Annex 1: MOUs and bilateral agreements.

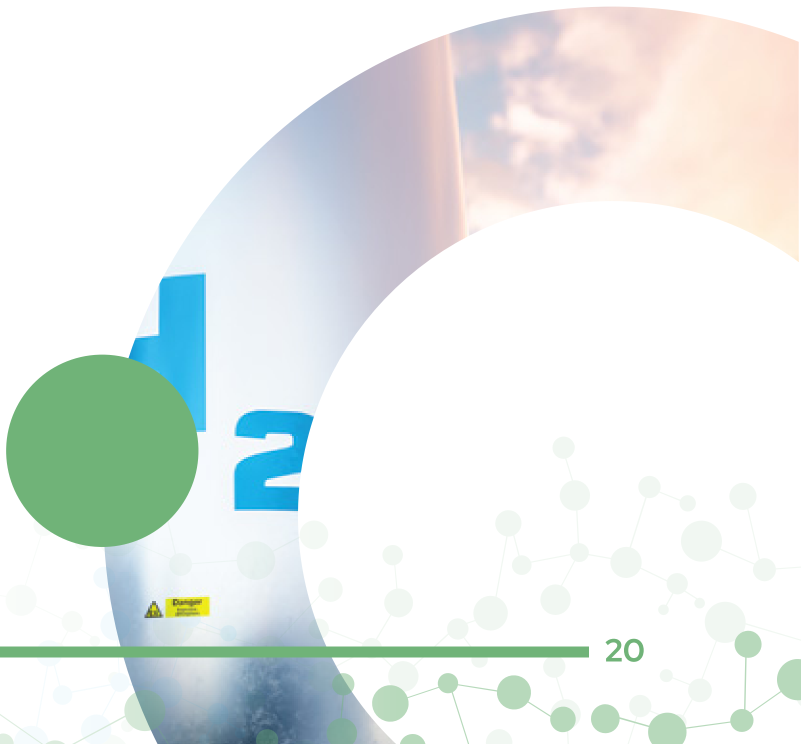
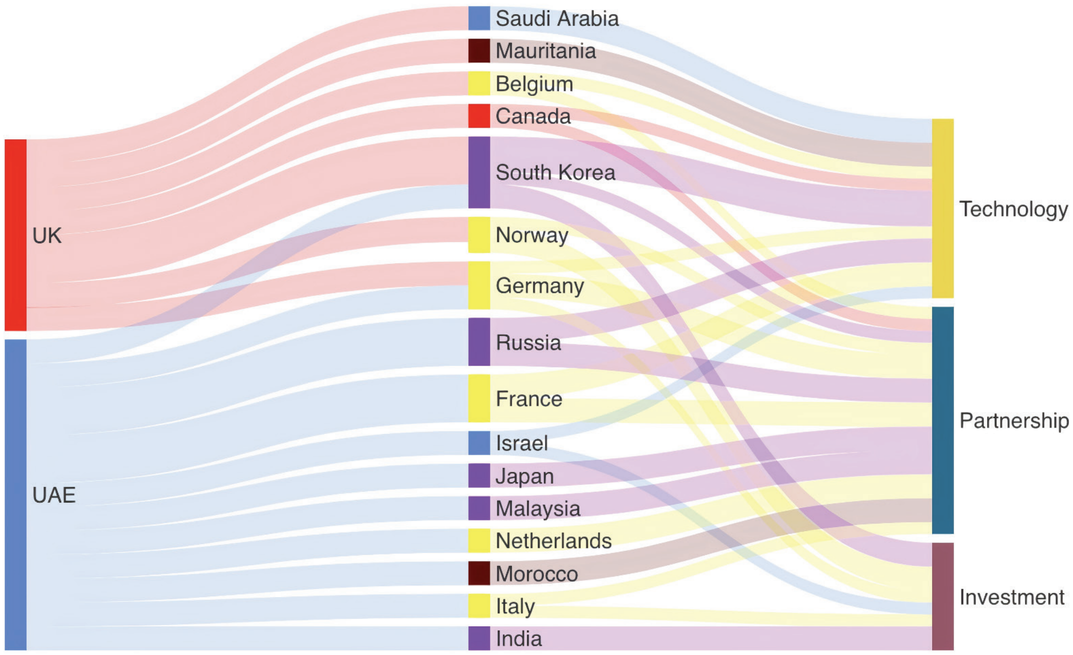


Figure 5: Hydrogen MOUs signed between the UAE, UK and other countries



Source: Author's analysis

Mapping the UAE and UK's agreements shows relatively little overlap in their choice of partners, illustrating the two countries' different objectives when it comes to international hydrogen relations.

The UAE intends to be a major global exporter, while the UK will likely be a modest importer with significant domestic production capacity, though Scotland's offshore wind forecasts and electricity grid connection limitations make it a good candidate for hydrogen export.[49] Most declarations of partnership intentions involve the UAE, while the UK has signed a large number of agreements focused on technology cooperation. The nature of the agreements shows that the UAE is actively seeking to establish itself as a first-choice trade partner, while the UK seeks to build on its early lead in innovation and technology development. The strongest links, however, remain between the UAE and the UK themselves.

The UAE and UK arguably have the most advanced bilateral hydrogen relationship, which shows that the two countries' complementarities are already acknowledged and that there exists mutual value in developing a special hydrogen relationship.

The two countries have signed several MOUs and bilateral agreements. The UAE-UK Partnership for the Future was signed in 2021 by His Highness Sheikh Mohammed bin Zayed Al Nahyan and the UK Prime Minister Boris Johnson to collaborate on ways to tackle climate change and expand the exchange of knowledge, skills and ideas.[50] The £10 billion ($12 billion) investment agreement to expand the UAE-UK Sovereign Investment Partnership was signed by UK Office for Investment and Abu Dhabi's Mubadala Investment Company in 2021, focused on energy transition, infrastructure and technology including hydrogen.[51] A Memorandum of Cooperation on Industrial and Advanced Technologies Co-operation between the UK Department for Business, Energy and Industrial Strategy (BEIS) and the UAE Ministry of Industry and Advanced Technology (MoIAT), with hydrogen as a priority area.[52] At a corporate level, co-investment and co-development of low-carbon hydrogen hubs were announced through trilateral collaboration between the UAE's Abu Dhabi National Oil Company (ADNOC), Masdar and the UK's BP.[53] This tight partnership signals opportunity for hydrogen collaboration across even more domains.


HYDROGEN
zero emission

Kick-starting the Market

2.1 Section Summary

Overview of priorities identified in this section

- Government intervention is needed to kick-start the market and overcome the misalignment between producers and consumers
- Policies that direct hydrogen towards hard-to-abate sectors are critical
- Directive policies are most effective when underpinned by price signals and a supportive macroeconomic environment
- Stimulating demand is considered more important than supporting supply
- Offtake agreements are critical to reduce risks, improve bankability and unlock finance
- Coordination across sectors, disciplines and geographies helps to establish domestic markets, balance supply and demand, align stakeholders' interests and overcome market friction

Opportunities that the UAE and UK may wish to explore

- Consider introducing carbon trading mechanisms or carbon pricing in the UAE, or raising the carbon price in the UK, and reduce fossil fuel subsidies to help level the playing field for hydrogen and stimulate demand
- Outline specific policy details for how hydrogen is expected to contribute to both countries' national net zero commitments to build confidence in the market
- Encourage corporate net zero targets to orient the industry towards specific offtakers
- Focus government support and public investment on hard-to-abate sectors to maximise hydrogen's commercial competitiveness and its climate impact
- Collaborate on initiatives directed at the industrial and transport sectors, especially shipping and aviation, to create domestic markets that lead to scale-up and cost reductions
- Consider Germany's H2Global as a model to mediate between producers and consumers, secure offtake agreements and manage price constraints
- Create a UAE-UK coordination platform to facilitate the whole supply chain, including technical, commercial, operational and policy stakeholders

2.2 Hydrogen Faces a Chicken & Egg Challenge

One of the primary challenges facing the hydrogen sector is a misalignment between hydrogen producers and would-be consumers.

High prices for clean hydrogen dampen demand, and a lack of demand fails to stimulate supply. Potential users are reluctant to invest in equipment that uses hydrogen when there is uncertainty. Uncertainties include hydrogen's long-term availability at an affordable price, delivered reliably and in sufficient quantities in the right locations at the right time under an accommodating policy and regulatory framework. Producers remain uncertain about investing in the innovation, scale and enabling infrastructure that will ultimately bring down prices because of the softness of demand. This impasse results in what economists call a market failure.

Hydrogen is not the first sector to face this challenge.

Electric vehicles (EVs) have been slow to take off for similar reasons. While Tesla released its first EV in 2008, fully electric vehicles still comprise less than 6% of total global vehicle sales nearly 15 years later.[54] Uncompetitive costs, an absence of charging infrastructure, range anxiety and general satisfaction with the status quo limited consumer appetite for EVs. From a producer perspective, large automotive incumbents in a fiercely competitive market lacked incentives to invest in disruptive and immature EV technology that would not deliver short term returns. Instead, they chose to invest in incremental innovations to the dominant design. Regulatory pressure for improved environmental performance was likewise incremental. By mandating stepwise efficiency gains, it prolonged the viability of the internal combustion engine and failed to trigger the radical innovations required to escape lock-in of the internal combustion engine.[55] This misalignment mirrors the current status of hydrogen. Consumers face high costs and uncertainties. Energy sector incumbents lack sufficient near-term incentives for disruptive innovation. And policymakers instruct incremental environmental improvements that fail to break the dominance of fossil fuels.[56]

Overcoming this market failure requires government involvement to kickstart the market from at least three angles: stimulating demand, support supply & coordinating policy to unlock infrastructure and investment.

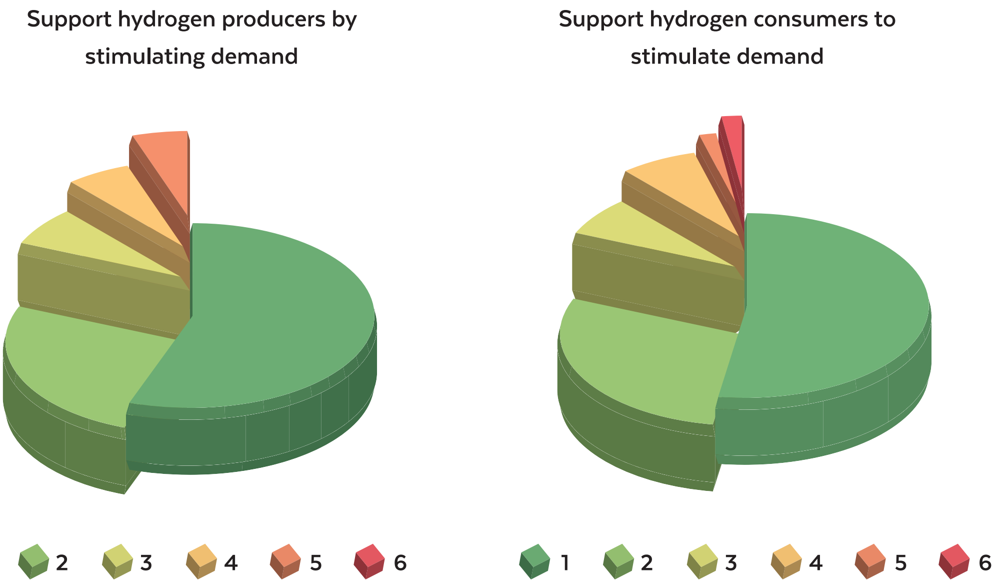
Ultimately, the hydrogen sector faces a multi-party coordination problem. Producers and consumers are not aligned and the policy frameworks are insufficient to catalyse infrastructure development & investment certainty. The market needs intervention for a change to take place at the speed and scale required to achieve decarbonisation goals. Assistance should be geared towards three core activities: supporting demand, supporting supply, and bolstering overall sector coordination.

2.3 **Demand Must be Supported**

Stimulating demand addresses one half of the chicken & egg problem.

A demand-side focus means that potential hydrogen consumers need to be encouraged to want hydrogen. Survey 1 shows very strong support for initiatives that aim to stimulate demand.

Survey 1: Importance of stimulating demand[57]



Source: Author's survey analysis

Governments can play different roles to encourage hydrogen demand.

They can follow a 'free market approach' and let prices determine where and how hydrogen is used. This requires creating a level playing field that encourages a low-carbon future, which includes removing fossil fuel subsidies and putting a price on carbon. Governments can also follow a more 'directive policy approach' that focuses initiatives & incentives at boosting demand in particular sectors. This requires innovation spending, support programmes and financial incentives directed at high-value or 'hard-to-abate' sectors like fertilizer, steel, cement, shipping, and aviation, where hydrogen may be more cost-competitive than alternatives.

[57]Survey questions – Where 1 is extremely important and 6 is not at all important, how important is it to: Stimulate demand, e.g. through public procurement policies, carbon pricing, decarbonisation regulations (Stimulate demand); Support hydrogen consumers, e.g. through policies that decrease up-front costs of equipment that uses hydrogen or by subsidizing hydrogen costs (Support hydrogen consumers)

> There is debate about whether policies should direct hydrogen towards some sectors, or whether markets and pricing should be the guide.

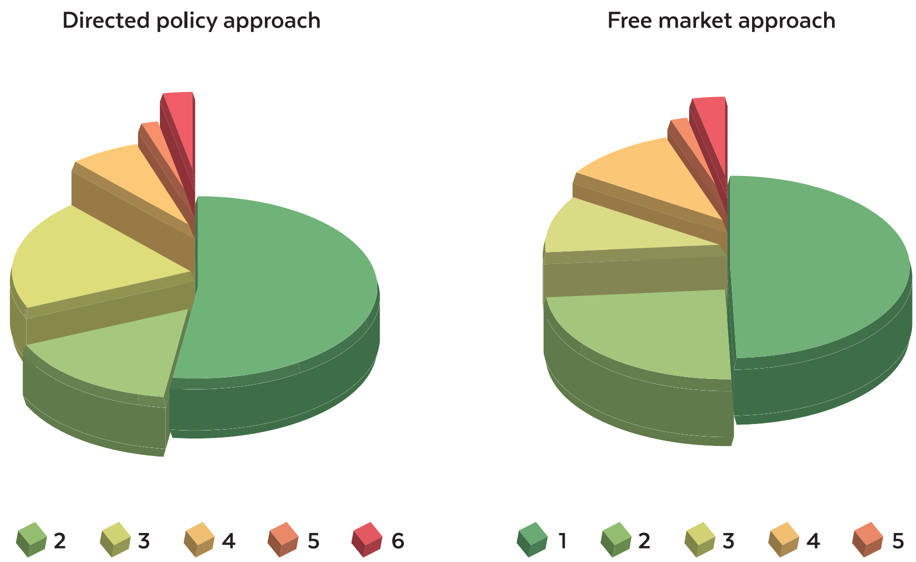
The free market perspective contends that policymakers should set a level playing field and use carbon pricing to internalize the otherwise unaccounted for negative externalities of fossil fuels. If the fight is fair, directive policy isn't needed. Prices and local conditions are better determinants than policies. By 'picking winners' with directive policies, the government could inadvertently lead to an excessively costly energy transition by failing to account for all circumstances and scenarios. There may be an 'academic merit order' for hydrogen, but the real world is interlinked and diverse.

The directive policy perspective suggests that, to maximize emission reductions today, top priority should be given to replacing grey hydrogen with a lower-carbon form of hydrogen, and hard-to-abate sectors should be prioritized next. Clean hydrogen is a scarce resource requiring huge amounts of land and power. Policymakers should 'pick winners' by supporting R&D in certain sectors, developing infrastructure and issuing licences for hydrogen use-cases that will maximize benefits to the whole system.

A combination of approaches is likely to be most effective.

Setting the right macro conditions through markets lays a foundation of incentives that improve the economic viability of hydrogen. Directive policies help trigger action when the underlying financial incentives are not strong enough and overcome non-financial barriers. Survey 2 shows that respondents believe both approaches are important.

Survey 2: Importance of different policy approaches to supporting the hydrogen market[58]



Source: Author's survey analysis

[58]Survey questions – Where 1 is extremely important and 6 is not at all important, how important is it to: Develop a hydrogen hierarchy and focus policy initiatives at "high-value" / "hard-to-abate" sectors (e.g. fertiliser, steel, shipping & aviation, chemicals) (Directed policy approach); Create a level playing field that encourages a low-carbon future (e.g. remove fossil fuel subsidies and put a price on carbon) and let markets and prices determine where and how hydrogen is used (Free market approach)

2.3.1 **Free market approach**

By setting national net zero targets, both the UAE and UK are creating a macro policy environment that is encouraging demand for hydrogen.

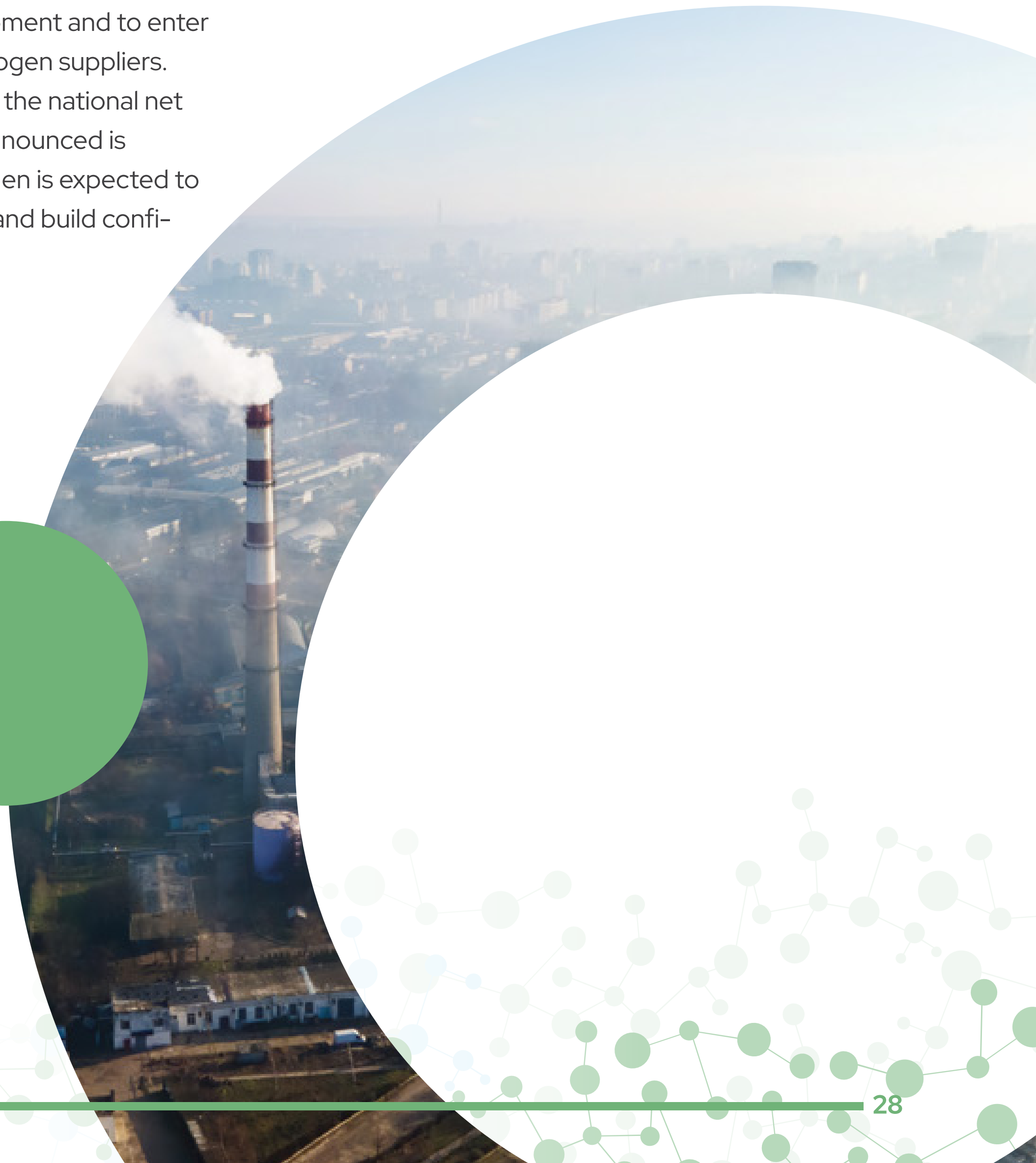
Potential hydrogen consumers need to know that decarbonising their operations is a necessity. It is the government's role to shape the macroconditions that make decarbonisation economically rational. Both the UAE and UK announced net zero targets that have set the countries' future direction of travel to 2050. [59,60]

It is important that policy detail augments and reinforces national net zero targets to specify how hydrogen fits.

National carbon reduction plans help give potential hydrogen customers confidence to make investments in hydrogen-using equipment and to enter long-term contracts with hydrogen suppliers. Additional policy detail around the national net zero targets that have been announced is needed to specify how hydrogen is expected to fit into the carbonisation plan and build confidence in the future market.

Corporate net zero targets also stimulate demand.

Committing to decarbonise at a corporate level triggers corporate emissions inventories, planning and strategic coordination within an organisation. These identify a range of emission reduction opportunities and plot their relative cost and their implementation timeline. Where hydrogen offers a competitive alternative to higher-carbon methods, capital investments are scoped and contracts for new fuel supplies are sought. Corporate net zero targets use market forces to stimulate demand for hydrogen without the need for governments to specify hydrogen as a preferred alternative.



Carbon pricing and removing fossil fuels subsidies also levels the playing field for hydrogen.

The purpose of carbon pricing is to account for the harm that greenhouse gas emissions cause to society, which is otherwise unaccounted for. Economies with fossil fuel subsidies or without a carbon price are distorted in favour of fossil fuels. Carbon pricing through carbon taxes or cap and trade systems provides a financial incentive to decarbonise, which gives low carbon hydrogen a relative advantage over carbon-intensive alternatives. Carbon pricing in the UK covers 68% of emissions from energy use through a combination of instruments.[61] Its Emissions Trading System covers emissions from power producers and large industry, while the fuel excise tax targets the transport, buildings & industrial sectors. Instruments like these that raise the cost of carbon reduce the relative cost of replacing fossil fuels with low carbon hydrogen.

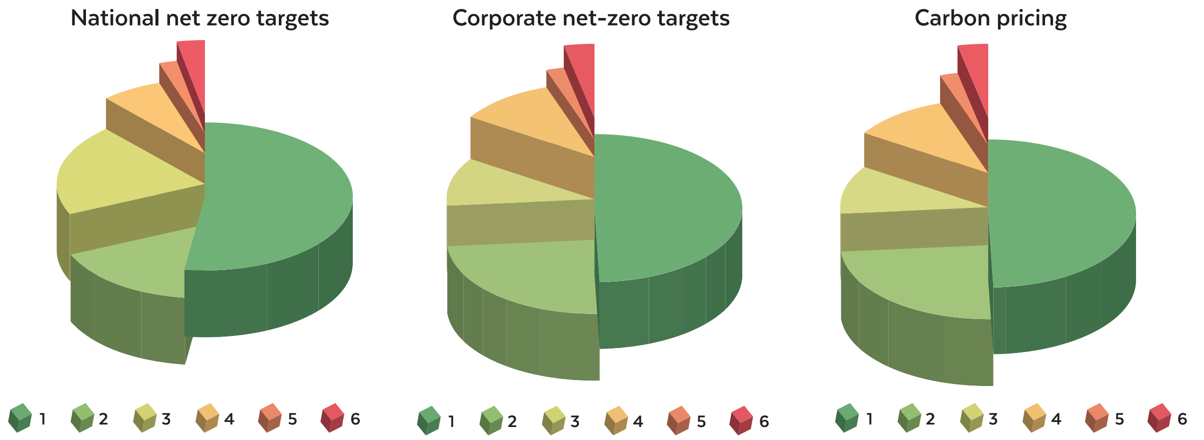
Carbon pricing is overwhelmingly seen as critical to boosting hydrogen demand, while national zero targets lead corporates ones.

Survey 3 shows the strength of support for each mechanism. This survey result is consistent with analysis of carbon pricing as one of the most effective and lowest-cost ways to reduce emissions but extends the finding specifically to boosting hydrogen demand.[62] Best practice suggests that carbon pricing will be especially effective at boosting hydrogen demand if it is accompanied by carbon border adjustments to reduce carbon leakage.[63] It makes sense that national net zero targets are considered more effective than corporate ones since national targets set the macro framework in which corporations must operate. But survey respondents' belief in corporate targets suggests that hydrogen demand can be stimulated even in the absence of national action.

More specific policy around national net zero targets is seen as critical to supporting demand.

Survey respondents strongly felt that the role of hydrogen in achieving national net zero targets needed to be further elaborated. Despite the UK having a hydrogen strategy, it still lacks policy detail that will help the country move from strategy to implementation. The UAE has the Dubai Future Foundation's options paper, but its purpose is to lay out different scenarios and options rather than saying which ones the UAE will pursue.[65] Specific policy detail is required to help potential hydrogen producers and consumers confidently make investment decisions and prioritise uptake.

Survey 3: Importance of different free market options to boost demand[64]



Source: Author's survey analysis

[64] Survey questions –Where 1 is extremely important and 6 is not at all important, how important is it to: Add additional policy detail around the national net zero targets that have been announced to specify how hydrogen is expected to fit into the decarbonisation plan and build confidence in the future market; Encourage more corporate net-zero targets to send demand signals to hydrogen stakeholders about their potential interest in hydrogen; Apply a carbon price to greenhouse gas emissions to strengthen the commercial case for low-carbon hydrogen as an alternative to higher-carbon fuels like natural gas, coal or petrol;

2.3.2 **Directive Policy Approach**

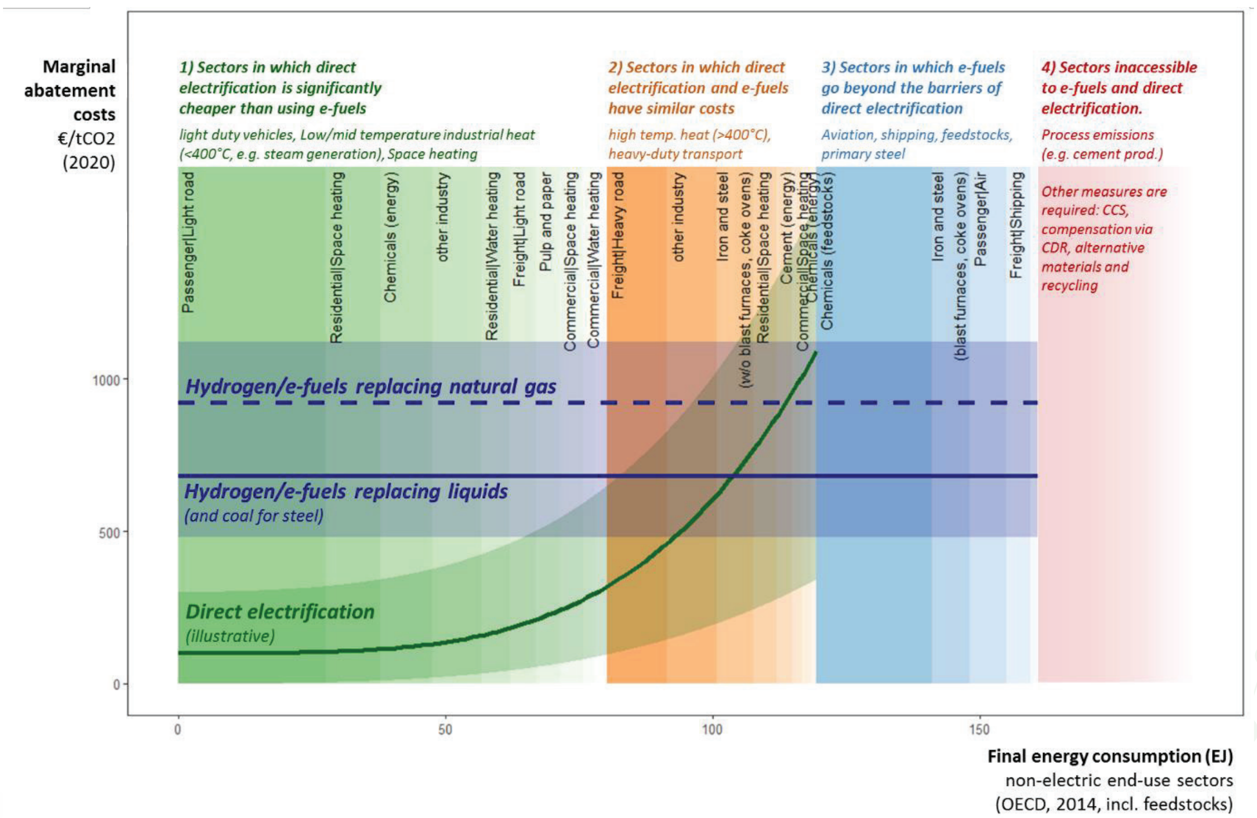
Demand can be stimulated using policies to encourage particular industries to adopt clean hydrogen.

While the free market approach uses prices to dictate where hydrogen is best used, the directive policy approach selects specific industries for which hydrogen is considered higher priority. The directive policy approach requires governments to establish a merit order or 'hierarchy of use' for hydrogen, which can be developed based on the technical or economic viability of alternative decarbonisation options for an industry or activity. Figure 6 suggests a hydrogen hierarchy based on the availability and cost of alternatives for set of sectors.[66] So-called 'hard-to-abate' sectors and activities are at the right, and activities that already have commercially and technically viable low carbon alternatives are at the left.

The UAE sees domestic industrial demand for hydrogen as a catalyst for the industry and is using state-owned enterprises to lead the change.

The largest industrial company in the UAE outside oil and gas, signed a MOU with GE Gas Power to explore using hydrogen blended fuels to minimize carbon emissions related to its 33-turbine onsite gas fleet with a total power generation capacity of 5,200 MW. TAQA, the Abu Dhabi National Energy Company and state-owned Emirates Steel agreed to develop a large-scale green hydrogen project to enable the first green steel produced in the MENA region.[68] Fertiglobe is a 42% state-owned company and is the world's largest export-focused nitrogen fertilizer platform and the largest producer in the Middle East and North Africa. It is working with Masdar and Engie to develop a 200 MW green hydrogen facility to help decarbonise its operations and is building a facility to produce up to 1 million tons per year of blue ammonia.[69,70]

Figure 6: Potential of hydrogen for climate change mitigation



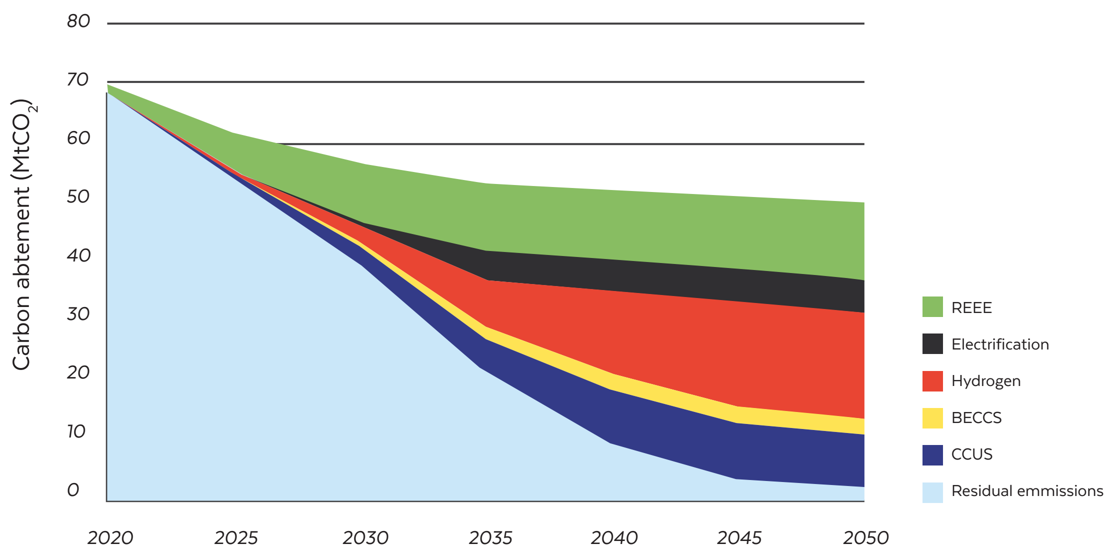
Source: Ueckerdt et al[67]

These examples demonstrate how state-led industrial action in the UAE is creating a ready pipeline of large-scale off-takers required to build confidence in demand for hydrogen.

The UK is also providing support to boost hydrogen demand in the industrial sector.

The industrial sector makes up 16% of UK emissions and its Industrial Decarbonisation Strategy outlines how low carbon fuels including hydrogen will replace fossil fuels.[71] The UK launched a £55 million ($65 million) Industrial Fuel Switching Competition with two phases: a feasibility phase for studies into fuel switching and fuel switch enabling solutions and a demonstration phase for projects to demonstrate such solutions.[72] As part of its £1 billion ($1.2 billion) Net Zero Innovation Portfolio, it is also running a £26 million ($31 million) Industrial Hydrogen Accelerator Programme competition to fund innovation and integration across the full technology chain, from hydrogen generation and delivery infrastructure through to industrial end-use.[73] Should hydrogen networks permeate the UK, including widely available transport and storage infrastructure, hydrogen is expected to represent the largest decarbonisation option in the UK's industry, as shown in Figure 7.

Figure 7: UK industrial decarbonisation options under a national networks scenario



Source: UK Government[74]

The two governments are stimulating demand for hydrogen in the transport sector through public procurement and incentives.

Public procurement can be an effective way to secure long-term offtake agreements and support demand. The UAE recommends that up to 50% of all public fleets of heavy goods vehicles be converted to hydrogen by 2050 to maximize demand for hydrogen.[75] The UK has dedicated £23 million ($27 million) to the Hydrogen for Transport Programme, which is supporting investment in hydrogen refuelling stations & hydrogen-powered refuse vehicles and trains.[76] There are already over 300 hydrogen powered vehicles operating in the UK, mostly passenger vehicles and buses, with 20 double-decker buses launched in London and another nine in Aberdeen, Scotland, in 2021.[77,78,79] The UK has also launched a £40 million ($48 million) Red Diesel Replacement Competition to provide grant funding for the development and demonstration of low carbon alternatives to diesel for the construction, quarrying and mining sectors, with the aim of decarbonising these industries reliant on red diesel, a fuel used mainly for off-road purposes & which is responsible for nearly 14 million tonnes of carbon emissions each year.[80] There are clear signals from both countries that the transport sector, supported by public procurement and incentives, is an effective conduit to boost domestic demand.

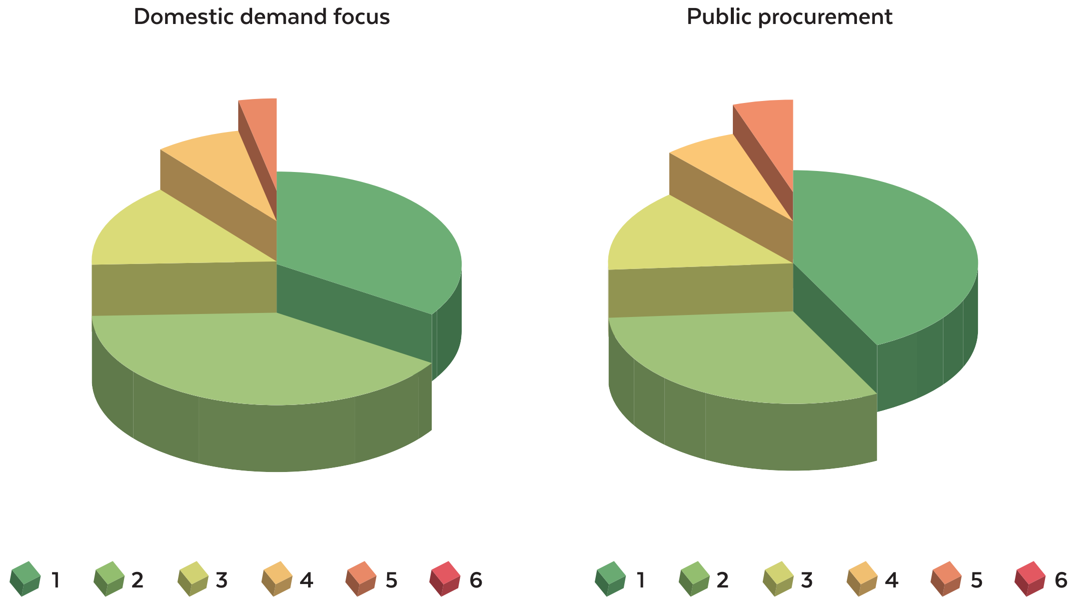
With two of the world's busiest airports and among the world's largest airline holding groups, the UAE and UK have a major interest in decarbonising the aviation industry.

Hydrogen can play a role in decarbonising flight, either by providing propulsion directly or through synthetic fuels, or synfuels, which combine hydrogen and carbon dioxide into a jet fuel substitute.[81] Synfuel can be used in current aircraft engines and is viable in this sector since there are few other alternatives.[82] In the UAE, Abu Dhabi Department of Energy, Etihad Airways, Lufthansa Group, Khalifa University of Science & Technology, Siemens Energy, TotalEnergies, and Marubeni Corporation, are cooperating on an initiative focused on developing a demonstrator plant to use green hydrogen and carbon dioxide to produce sustainable aviation fuel.[83] The UK's sustainable aviation fuels mandate requires that where hydrogen is used as a process input, the hydrogen must be low carbon. Taken together, aviation is considered by both countries to be a key target sector to support demand.

These directive policy approaches garner significant support individually but are considered less important than the free market approaches outlined earlier.

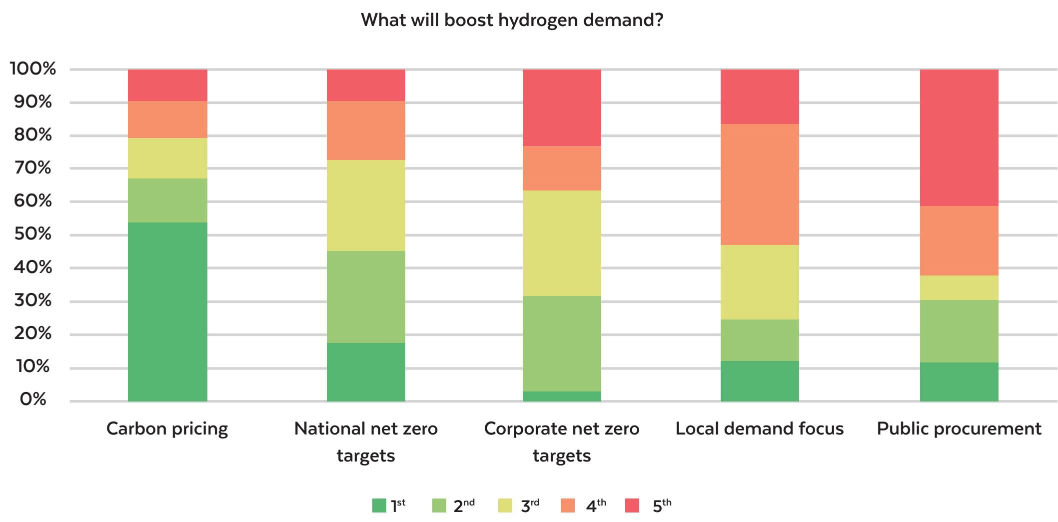
Survey 4 shows that survey respondents generally agree that demand should be supported locally and through public procurement. But Survey 5 demonstrates that, compared to the market mechanisms outlined above, these specific directive policies are considered less effective at boosting demand.

Survey 4: Importance of different directive policy options to boost demand[84]



Source: Author's survey analysis

Survey 5: Relative importance of ways to boost demand[85]



Source: Author's survey analysis

[84]Survey questions – Where 1 is extremely important and 6 is not at all important, how important is it to: Encourage domestic demand for hydrogen to kick-start the industry at home (e.g. through grants, loans, local or regional strategies and local trials); Use government procurement of public assets (e.g. buses, ferries, fleets) to kickstart demand for hydrogen and raise awareness about hydrogen in the public sphere.

[85]Survey question – Please rank the following from "top priority" (1) to "lowest priority" (5) in terms of encouraging the development of a clean hydrogen industry: Carbon pricing, Corporate net zero targets, National net zero targets, Local demand focus, Public procurement.

2.4 Supply Must be Supported

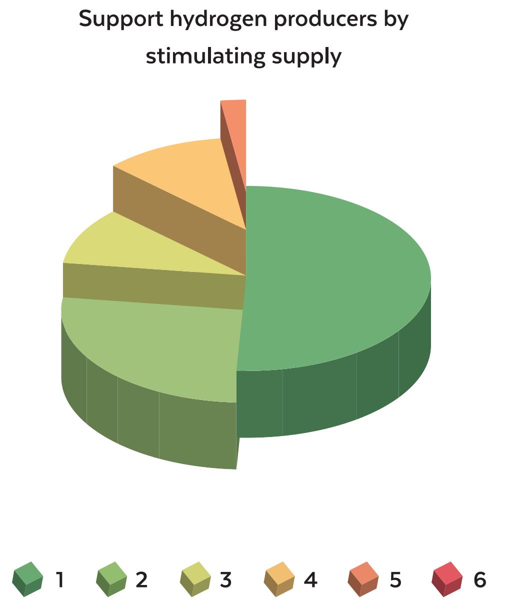
Stimulating supply addresses the other half of the chicken and egg problem.

A supply-side focus means that potential hydrogen producers need to be encouraged to make hydrogen. Survey 6 shows support for such initiatives, but significantly less enthusiasm than for policies that aim to stimulate demand shown in Survey 1.

Governments can stimulate supply by reducing risks, reducing production costs or incentivizing production.

Risk reduction is critical for project developers and lenders and a stable and supportive regulatory and subsidy environment helps suppliers make investment decisions confidently. Dedicated funds or production subsidies can also help suppliers produce hydrogen more costcompetitively. The supply-side market can also be supported in other ways, including by increasing the value of hydrogen's by-products.

Survey 6: Importance of stimulating supply[86]



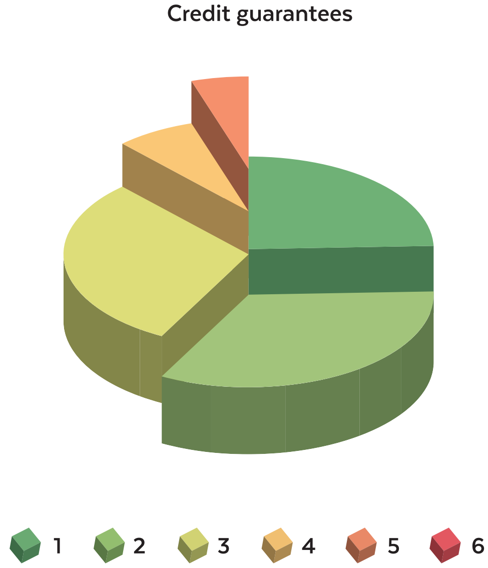
Source: Author's survey analysis

[86]Survey question: Where 1 is extremely important and 6 is not at all important, how important is it to support hydrogen producers by stimulating supply, e.g. through public offtake agreements, production subsidies, guarantees, tax measures

Risks can be reduced through guarantees, which lowers the cost of loans and improves bankability.

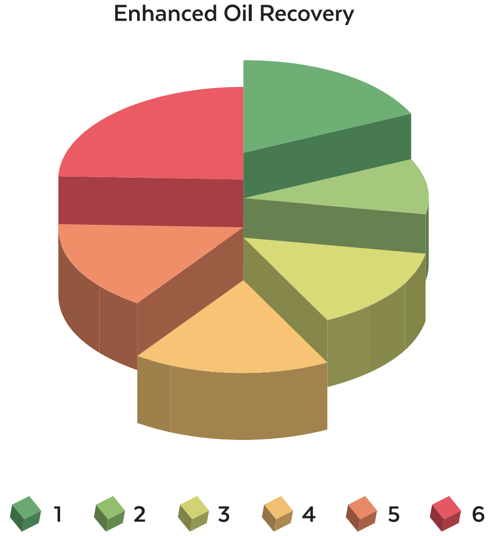
Publicly backed credit guarantees can reduce the cost of capital and unlock projects that financial institutions deem risky. The UK's Green Finance Institute outlines a Green Finance Guarantee Facility which proposes to provide competitively priced long-term funding, provide credit guarantees, and mitigate currency convertibility risk.[88] UK Export Finance also offers Export Development Guarantees, which are partial guarantees covering up to 80% of the risk to lenders for up to 10 years for loans that develop clean growth exports such as clean hydrogen projects.[89] Extending these to 20 year tenors, which better reflects the duration of most green hydrogen projects, may help the sector. The UK company Wood Plc recently received a £430 million ($512 million) green transition loan from UK Export Finance to capitalise on opportunities linked to clean energy, hydrogen and decarbonisation.[90] Survey 7 shows that credit guarantees are considered somewhat important.

Survey 7: Importance of credit guarantees[87]



Source: Author's survey analysis

Survey 8: Importance of encouraging Enhanced Oil Recovery[92]



Source: Author's survey analysis

Production costs for suppliers can be reduced through tax measures like accelerated capital cost allowances or corporate tax breaks.

The UK offers capital claim allowances that allow businesses to deduct the full value of a purchased item from its profits before paying tax, which provides a tax incentive to invest in new equipment. Hydrogen refuelling equipment, zero-emissions goods vehicles and passenger vehicles with zero emissions all qualify.[91] The UAE's recently introduced corporation tax provides an opportunity to offer corporate tax rebates for companies that support national priorities like hydrogen.

Creating value for by-products like oxygen, carbon black or captured carbon dioxide can reduce the effective cost of producing hydrogen.

Oxygen is a by-product of electrolytic hydrogen production and the global oxygen market is valued at roughly $21 billion per year.[93] Carbon black is a byproduct of turquoise hydrogen

[87]Survey question: Where 1 is extremely important and 6 is not at all important, how important is it to provide public credit guarantees to reduce the risks of lending to hydrogen producers

[92]*Survey question – Where 1 is extremely important and 6 is not at all important, how important is it to encourage Enhanced Oil Recovery using CCS to create a market for captured carbon, thereby reducing the cost of blue hydrogen*

production and its global market is roughly $20 billion per year.[94] Enhanced Oil Recovery (EOR) can increase the life of depleted oil wells and is currently the largest industrial use-case for captured carbon.[95] The UAE intends to boost oil output by up to 30% from depleted reservoirs using EOR.[96] Such practices give captured carbon a value, since it helps to recover more oil, and therefore reduces the effective production price of blue hydrogen. While the carbon intensity of blue hydrogen is reduced by injecting carbon dioxide underground, the net effect of using captured CO_2 for enhanced oil recovery is likely to lead to increased atmospheric emissions.[97] This drawback likely drove survey respondents' unenthusiasm for EOR as a supply-side support mechanism, as Survey 8 shows.

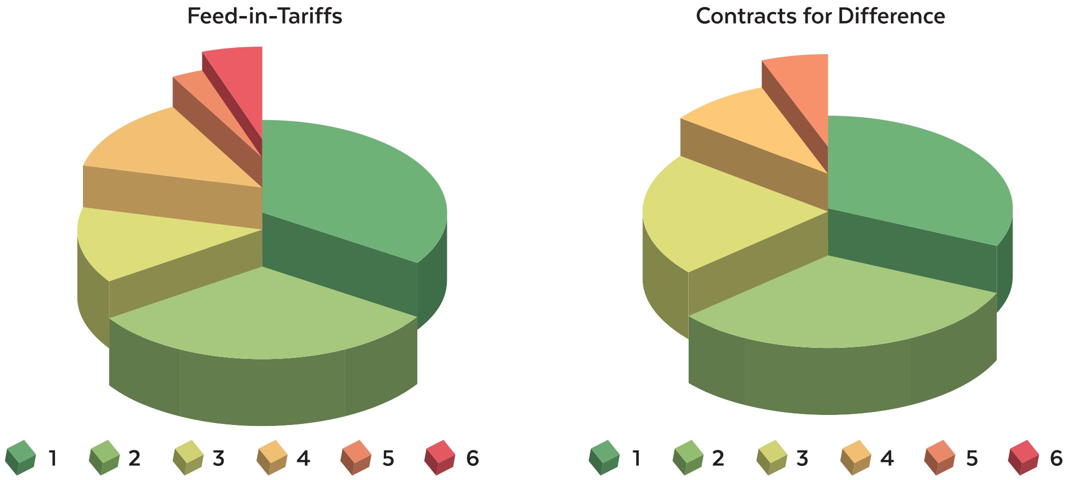
Production incentives like feed-in tariffs can also help to stimulate supply but suffer from drawbacks.

A feed-in tariff is mechanism that encourages investment in a product by providing producers a with a per-unit subsidy on their production. Feed-in tariffs strengthen the economic case for hydrogen and typically involve long-term contracts, which gives producers certainty over future revenue and builds the confidence of lenders in the viability of projects. They have been effective tools to stimulate the rapid deployment of renewable energy and could be applied to hydrogen, especially if it is fed into the existing gas grid.[98] Feed-in tariffs for hydrogen suffer from several drawbacks, however, including securing off-takers, difficulty controlling policy costs, failing to encourage price competition between project developers, and not directly addressing high upfront capital costs of projects.[99] These drawbacks were recognised by survey respondents, as shown in Survey 9.

Contracts-for-difference address some challenges of feed-in tariffs and are the UK's preferred support mechanism, but face their own limitations in the hydrogen market.

A Contract for Difference (CfD) is an agreement between a hydrogen producer and the government where the government agrees to pay the other party the difference between the actual market price and an agreed upon value ("strike price"). CfDs create a flexible subsidy and mitigate investor risk. CfDs have been used in the UK to support the offshore wind sector, though establishing the baseline market price for the hydrogen market is more challenging than for the wholesale electricity market.[100] 100 Despite this challenge, the UK intends to proceed with a CfD support mechanism.[101] While preferred over feed-in tariffs, Survey 9 shows that survey respondents were mostly supportive of CfDs, with some detractors.

Survey 9: Importance of different production subsidy mechanisms[102]



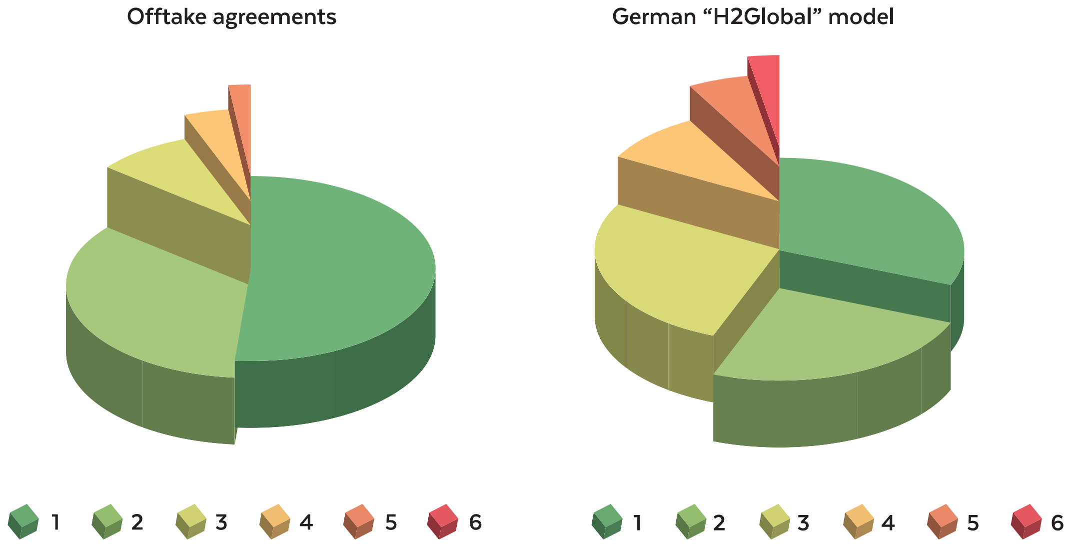
Source: Author's survey analysis

[102] *Survey questions – Where 1 is extremely important and 6 is not at all important, how important is it to: Provide subsidies to hydrogen producers per unit of hydrogen sold (Feed-in Tariff); Provide subsidies per unit of hydrogen sold equivalent to the difference between supply prices (production and transport) and demand prices (the wholesale price or "strike price" for hydrogen) (Contracts for Difference).*

More innovative mechanisms that position the government between producers and consumers may best address cost barriers and the challenge of securing long-term offtake agreements.

For example, the UAE and UK could opt to build a strategic hydrogen reserve. A recent options paper on accelerating the hydrogen market in the EU recommends developing a strategic reserve of hydrogen. Filled to 90 days of net imports, the reserve would act as an energy security buffer whilst providing suppliers with a ready, government-backed offtaker.[103] The German H2Global Mechanism is another good example. It aims to overcome market failures related to the mismatch between supply and demand, which leads to underinvestment in hydrogen production facilities and corresponding lack of decarbonisation of important CO2-emitting sectors. H2Global has set up a company called the Hydrogen Intermediary Company to agree long-term purchase contracts on the supply side and shortterm sales contracts on the demand side.[104] Similar to the CfD approach, the difference between supply prices and demand prices will be compensated by grants from the German Government. Securing government-backed offtake agreements are overwhelmingly considered essential to support supply as shown in Survey 10. The figure also shows, however, that the German H2Global model is either not the preferred mechanism to secure offtake, or respondents may be unfamiliar with how it works.

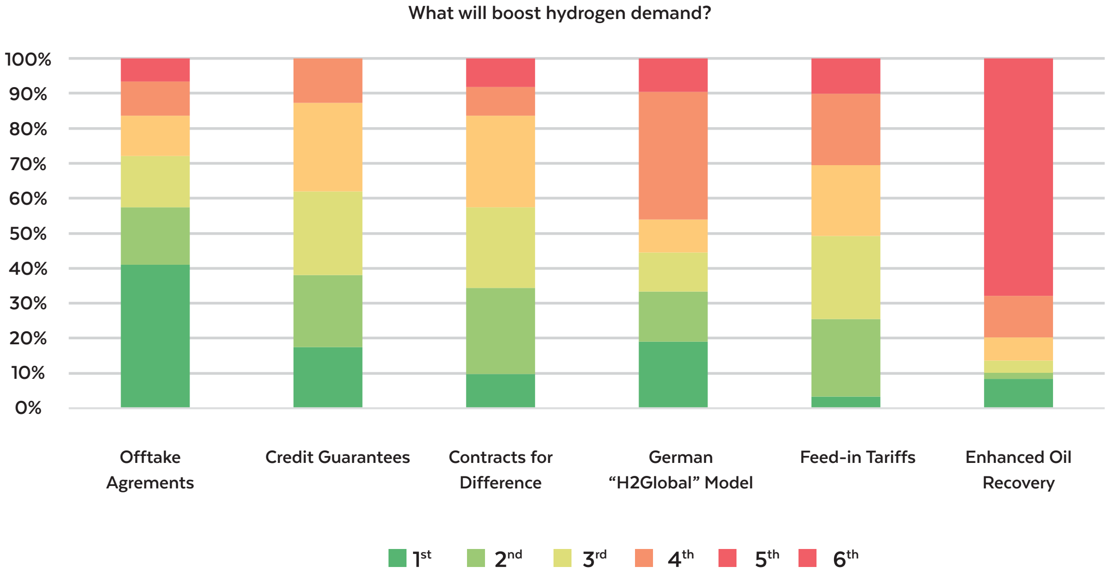
Survey 10: Importance of supporting supply through offtake agreements and models[105]



Source: Author's survey analysis

[105] Survey question – Where 1 is extremely important and 6 is not at all important, how important is to: Provide governmentbacked long-term offtake agreements to provide certainty to producers and reduce risks for lenders (Offtake agreements); Similar to the Contracts for Difference (CfD) approach, provide subsidies equivalent to the difference between supply prices and demand prices, but discover supply prices and demand prices through a double-auction. The government effectively becomes the primary off-taker and the primary wholesaler by buying and selling large pools of hydrogen (German H2Global model).

Survey 11: Relative importance of ways to boost supply[107]



The German model could be emulated in the UAE or UK.

Despite hesitancy among survey respondents, the German H2Global model is a mechanism that acts upon their top priority shown in Survey 11 of providing government-backed long-term offtake agreements. It is likely be expanded Europe-wide, as seen in a draft of the Delegated Act in May 2022.[106] In the UAE or UK, governments could competitively tender for hydrogen, buy it at the production price, and then sell it downstream at a price that it is competitive with alternatives like gas. By holding a double-auction and awarding contracts to the lowest bid price and the highest selling price, the price difference compensated by government would be as low as possible. This double-auction approach is more effective than a CfD model where the benchmark (i.e. wholesale price) of hydrogen is otherwise difficult to establish. Compensation awarded by the government would also be limited by the volume of hydrogen it tendered for, avoiding the challenge of uncontrolled policy costs faced by the feed-in tariff model. Compensation costs per unit would likely shrink over time as production costs fall and as buyers' willingness-to-pay grows in line with tighter emissions caps or higher carbon prices. Survey 11 also shows that credit guarantees are considered effective at stimulating supply.

[107]Survey question: Please rank the following from "top priority" (1) to "lowest priority" (6) in terms of facilitating the development of a clean hydrogen industry. Credit Guarantees, Offtake Agreements, Feed-in-Tariffs, Contracts for Difference, German "H2Global" Model, Enhanced Oil Recovery

2.5. **Coordination is required**

Coordination is essential to establish the hydrogen market.

This includes coordination across sectors, disciplines, geographies, and the supply chain. The UAE and UK have rolled out policies and initiatives to support this coordination but there is an opportunity to do more.

Sector coordination is needed to establish domestic markets, balance supply and demand and align the interests of different stakeholders.

Hydrogen's cross-cutting applicability means that actors in the energy, industry, transport, buildings, waste & water, and agricultural sectors have a stake in when, where and how hydrogen is produced and used. Table 1 shows how each sector plays a role in hydrogen supply and demand. Relying on bilateral agreements between stakeholders in each group creates market friction and limits the speed of growth and efficiency of the market as a whole. Building supply and demand in parallel requires broader sector coordination, especially in the market's early stages when hydrogen is not yet established as a widely available, heavily traded, and liquid commodity market.

Table 1: Role of different sectors in hydrogen supply and demand

	Supply of hydrogen	Demand for hydrogen
Energy	Electricity supply (green hydrogen) Gas supply (blue hydrogen) Transmission and distribution Hydrogen and gas blending	Repowering gas turbines System balancing Long-term energy storage
Industry	Petrochemical facilities Green and blue hydrogen production facilities	Grey hydrogen replacement Industrial heat Industrial processes
Transport	Pipelines Ports and ships Road transport	Road vehicles Rail Shipping Aviation
Buildings		Low carbon heat
Waste & water	Waste-to-hydrogen Desalination for electrolysis	
Agriculture	Biogas-to-hydrogen	Fertiliser (ammonia) Farm vehicles and onsite power generation

Source: Author analysis

Cross-disciplinary coordination is also needed to effectively create policy, build infrastructure, accelerate innovation, unlock finance and prepare the workforce.

Each of these disciplines is moving forward at different speeds as they grapple with the implications of a rapidly accelerating hydrogen sector. Integrated strategies and initiatives are needed to bring together cross-disciplinary groups where needs, risks and barriers can be discussed and understood. This will help unblock policy and regulatory hurdles, anticipate infrastructure needs, rationalise risk perceptions to reduce the cost of finance, avoid costly duplication of effort and redundancy in innovation, and upskill the workforce to match areas required by industry.

The UAE Government has made strides around sector and cross-disciplinary coordination through the Abu Dhabi Hydrogen Alliance and other collaborations.

The Abu Dhabi Hydrogen Alliance is formed of Mubadala, ADNOC, ADQ[108] and the Ministry of Energy and Infrastructure.[109] In 2022, the Alliance was strengthened when ADNOC, Mubadala and TAQA (an ADQ company) became shareholders in Masdar, respectively holding 43%, 33% and 24% of Masdar's green hydrogen business.[110] In parallel, the Abu Dhabi Department of Energy, Masdar, Etihad Airways, Lufthansa Group, Khalifa University of Science and Technology, Siemens Energy and Marubeni Corporation signed a partnership agreement around green hydrogen and sustainable aviation fuels.[111] In Dubai, the utility DEWA is collaborating with Siemens Energy to produce green hydrogen using renewable electricity from the Mohammed bin Rashid Al Maktoum Solar Park.[112] Moreover, the MENA Hydrogen Alliance is strengthening corporate and government collaboration across the region.[113]

These collaborations signal a very serious national commitment to hydrogen.

Together, these groups represent some of the country's biggest and most influential organisations from all sectors and spanning investment, innovation and policy. That they are state-backed entities demonstrates the seriousness with which the UAE is taking hydrogen. It is creating an architecture to coordinate the UAE's position, bringing together its biggest stakeholders to advance the field.

The UK's coordination efforts are driven by both the public and private sector through industrial clusters, a huge number of industry associations and quasi-government entities.

The £170 million ($202 million) Industrial Cluster Mission is backed by the UK's Industrial Strategy Challenge Fund[115]. It aims to bring together innovators, investors, industries, policymakers and local communities to decarbonise six industrial areas using hydrogen as a key driver.[116] The UK has eight industry associations[117] dedicated to hydrogen and a further seven forums[118] in which hydrogen plays a major role. These represent hundreds of companies across the UK. Recognising the lack of an integrated UK-wide hydrogen directory, start-ups like Clean H2 Limited are building one.[119] Other initiatives such as Hy4Heat played a practical role facilitating quality standards, certifications, appliances requirements, safety, demonstration and community trials.[120]

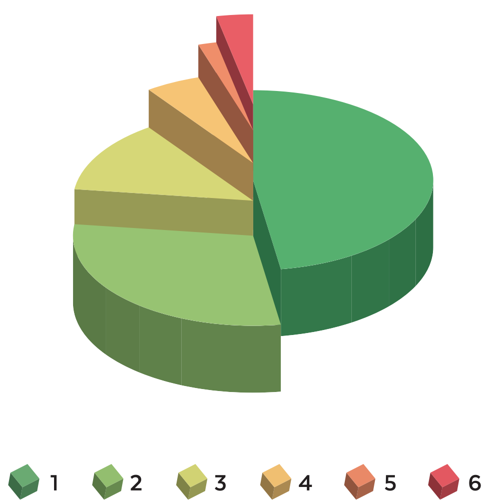
To capture domestic value and unlock a UK-wide hydrogen market, the UK's Catapult Network is spurring interdisciplinary and supply chain coordination.

Survey 12 shows the importance of supply chain coordination. The Catapults are actively coordinating from a technology innovation, supply chain and investment perspective. They are playing a role as convener, market designer, integrator, advisor and innovator to co-create a strategic approach to innovation, investment, and deployment.[121] The Catapult Network also launched the Hydrogen Innovation Initiative to accelerate innovation, help grow in the UK hydrogen supply chain and overcome technology and integration challenges.[122]

There remains an opportunity and an appetite to enhance UAE-UK coordination and set policies that encourage the market.

The experts that participated in the Roundtables assembled for this study expressed a desire to collaborate across borders and between businesses and innovation organisations. Coordination requires a 'whole supply chain' mindset that includes producers, consumers, investors and policymakers. Innovation needs to involve end-users from the start and needs to engage new technology providers as well as incumbents. Coordination should take place across the supply chain to enable integration of different parts of the system and technology components. Hydrogen associations, education providers and industry need to work together to identify new and emerging skills gaps and create programmes and work placement opportunities to fill them. Survey 13 shows the relative importance of different approaches to supporting the market outlined in this chapter, with a preference for using directive policies to boost demand including by supporting hydrogen consumers.

Survey 12: Importance of supporting the supply chain[114]

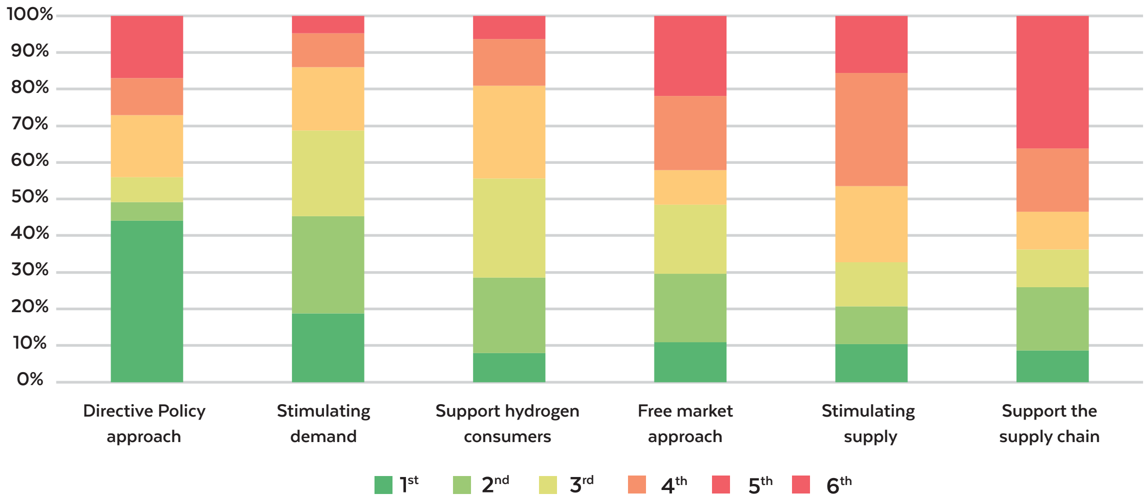


Source: Author's survey analysis

[114]Survey question – Where 1 is extremely important and 6 is not at all important, how important is it to support coordination among the supply chain to facilitate integration across the sector.

Survey 13: Relative importance of ways to encourage the market[123]

To encourage the market, what actions should the government support?



Source: Author's survey analysis

[123]Survey question – Please rank the following from "top priority" (1) to "lowest priority" (6) in terms of facilitating the development of a clean hydrogen industry. Directive policy approach; Free market approach; Stimulating demand; Stimulating Supply; Support hydrogen consumers; Support the supply chain.

03

Pathways to scale-up & reduce cost

3.1 Section Summary

Overview of priorities identified in this section

- Innovation and scale are needed to drive down hydrogen's costs
- There remains significant scope for innovation for technologies that produce and use hydrogen
- Pilot projects are considered most important to prove hydrogen's technical and commercial viability
- Innovation in electrolysers is preferred over technologies that use gas for hydrogen
- The UK excels at earlier-stage innovation, while the UAE excels at later-stage scale-up
- Different types of learning contribute to cost reductions, and 'learning by interacting' is especially important for the hydrogen industry

Opportunities that the UAE and UK may wish to explore

- Capitalise on the UAE and UK's complementary positions regarding early- and late-stage innovations and demonstrations to run pilot projects
- Establish joint research and testing programmes or accelerator initiatives to test technologies in representative environments
- Form a joint hydrogen platform for exchange between disciplines and sectors to maximise 'learning by interacting' and accelerate innovation and cost reductions
- Leverage joint programmes for technology exchange and corporate venturing activity to accelerate scale-up and unlock shared financial returns
- Capitalise on existing strengths in CCS to enable genuinely low carbon blue hydrogen
- Consider the UK's industrial clusters approach in the UAE to facilitate coordination and reduce costs

3.2. **Clean hydrogen costs must decrease**

Despite an abundance of natural resources to produce clean hydrogen in both the UAE and UK, relative costs are challenging to establish in the short- and long-term.

Table 2 shows the current and forecast costs of green and blue hydrogen production in the UAE and UK. This compares to the cost of grey hydrogen of roughly US$0.70 – $2.20 in the absence of a carbon price. For clean hydrogen to approach a competitive cost position, significant cost reductions are required.

Table 2: Current and 2050 forecast costs of hydrogen production in the UAE and UK

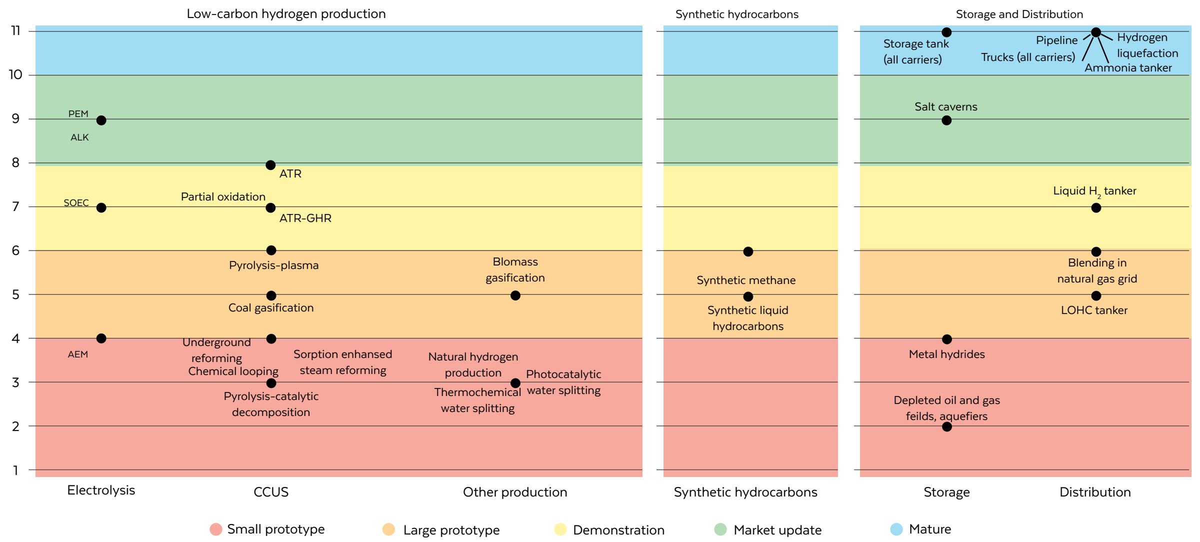
	Cost of green hydrogen (USD)		Cost of blue hydrogen (USD)	
	Current	2050 forecast	Current	2050 forecast
UAE	2.60 – 4.50	0.70 – 1.10	1.30 – 2.90	0.80 – 1.30
UK		1.00 – 1.50		1.20 – 3.00

Source: Energy Transitions Commission[124]

Technologies to produce, store and transport clean hydrogen are relatively immature, which leaves significant scope for innovation and cost reduction.

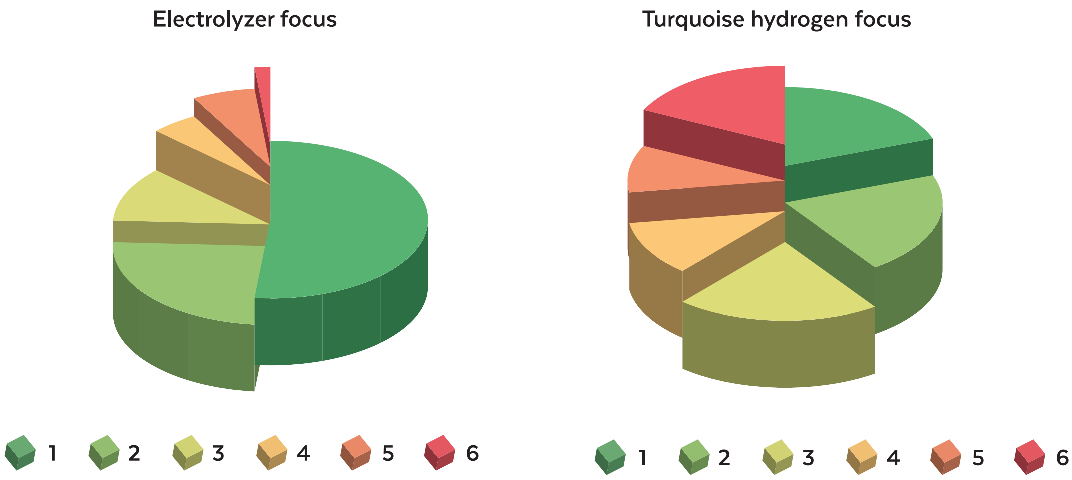
The technology readiness levels of various technologies for hydrogen production, storage and distribution are shown in Figure 8. It shows that most technologies lie in the demonstrate stage or earlier and there are few mature low carbon hydrogen production technologies. Survey respondents are significantly more committed to focusing on reducing the costs of green hydrogen rather than more innovative but less mature approaches like turquoise, as Survey 14 shows.

Figure8: Technology readiness of hydrogen production, storage and distribution technologies



Source: IEA[125]

Survey 14: Importance of different innovation areas to focus on[126]

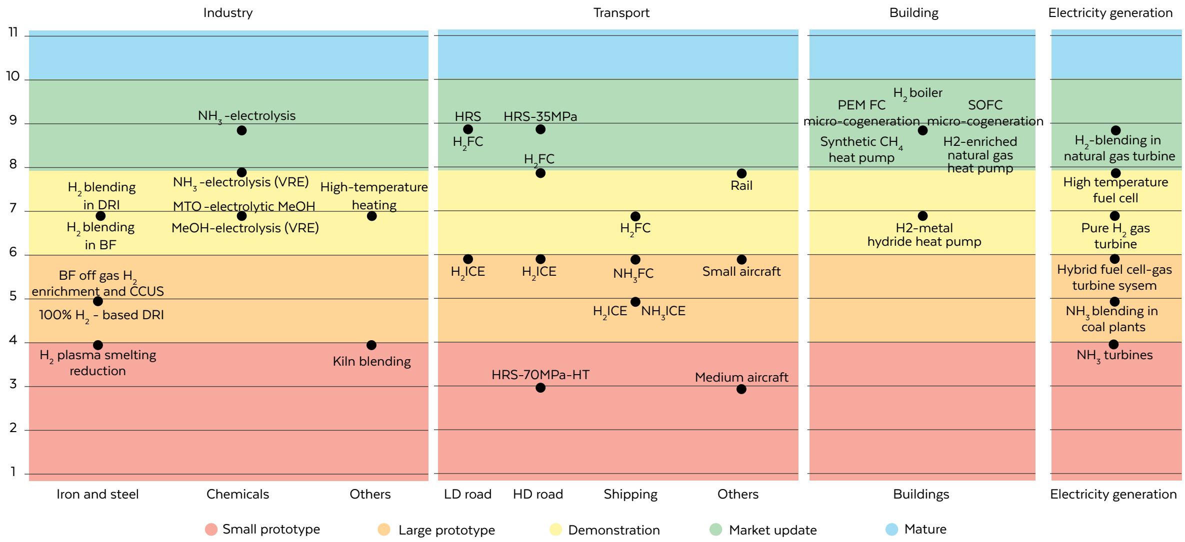


Source: Author's survey analysis

Similarly, technologies in different sectors that use hydrogen are also in the earlier stages of technology development. As shown in Figure 9, in the industry and transport sectors, the industries that are hardest to abate like steelmaking and long-haul aviation have some of the earliest technology readiness levels. More mature hydrogen-using technologies exist in the buildings and electricity sectors, but these applications, like heating and gas turbines, have significantly lower-cost and more mature alternatives like heat pumps and renewable electricity.

[126]Survey questions – Where 1 is extremely important and 6 is not at all important, how important is it to: Stimulate demand, e.g. through public procurement policies, carbon pricing, decarbonisation regulations (Stimulate demand); Support hydrogen consumers, e.g. through policies that decrease up-front costs of equipment that uses hydrogen or by subsidizing hydrogen costs (Support hydrogen consumers)

Figure 9: Technology readiness of hydrogen use technologies in industry, transport, buildings and electricity generation



Source: IEA[127]

Innovation, scale and market dynamics all play a role in bringing down energy technology costs.

The factors that drive cost reductions in energy technologies have been extensively studied as policymakers and researchers aim to accelerate energy system decarbonisation.[128] The following sections outline opportunities in the UAE and UK to drive down costs through innovation, demonstrations and learning.

3.3. Drive down costs through innovation

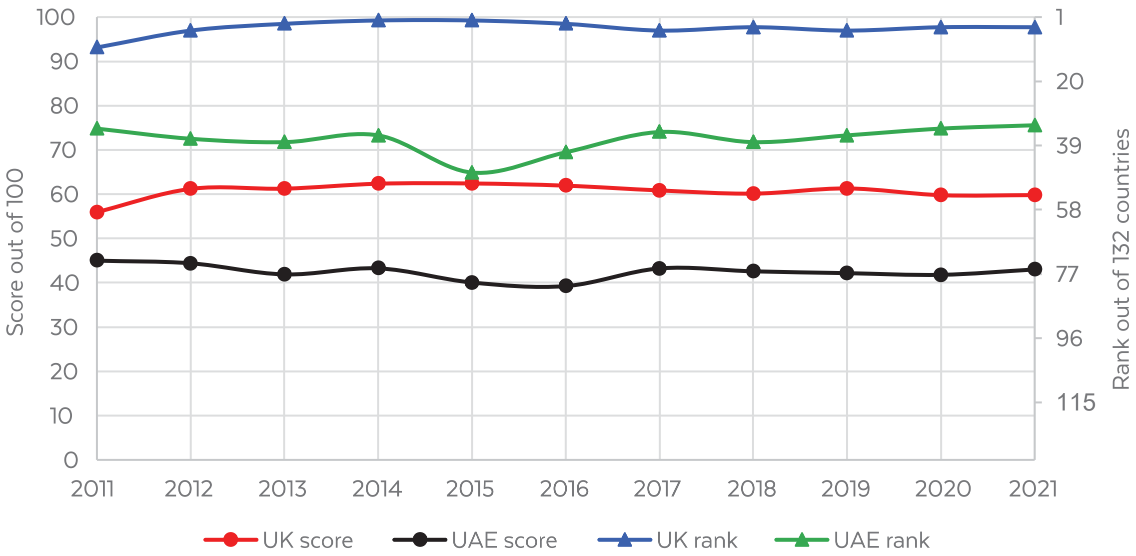
Governments have a central and wide-ranging role in supporting innovation.

They set objectives and priorities, disburse funding, create incentives, provide enabling infrastructure and facilitate demonstration projects. They bring together policymakers, researchers, investors, entrepreneurs, corporations and civil society to identify needs, overcome barriers and orchestrate partnerships. To achieve net zero and develop the solutions like hydrogen that are required to reach it, significant investment in innovation is required.[129]

Innovation in the UAE and UK is generally strong and improving, with the UK among the world's most innovative countries and the UAE leading regionally.

The UK has ranked within the top five countries in the Global Innovation Index since 2012, while the UAE's rank has wavered over time but consistently improved for the past several years as shown in Figure 10. The UAE's performance is unusual in that it scores within the top three best countries among its geographic peers, outperformed only by Israel, but as a country in the high-income group, its innovation performance as defined by the index falls below expectations for its level of development.[130]

Figure 10: UAE and UK Global Innovation Index ranks and scores, 2011 - 2021



Source: Adapted from WIPO[131]

The UAE has access to skills, especially international expertise, strong facilities and universities, and good infrastructure, but is challenged to turn those assets into patents and commercial products.

The UAE ranked 33rd out of 132 countries in the 2021 Global Innovation Index. It ranks among the world's top five for tertiary education and inbound mobility of expertise, research talent, infrastructure, and gross domestic expenditure on R&D by business. The country's score is brought down by a less sophisticated investment market, and weak knowledge creation and technology outputs, evidenced by few patents, trademarks, industrial designs and scientific and technical articles.

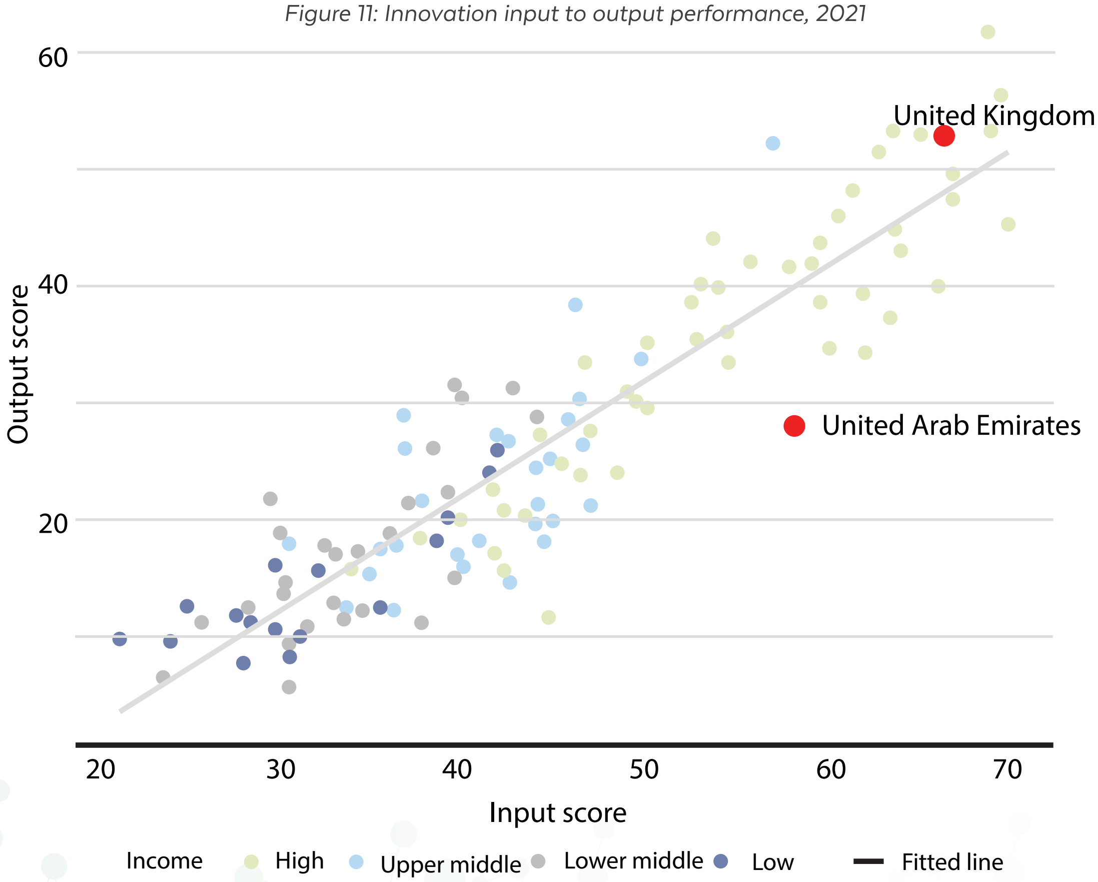
The UK has good access to human capital, research and infrastructure, sophisticated investment markets, and strong corporate investment in R&D, but has low labour productivity growth and low gross domestic investment.

The UK ranked fourth among the 132 countries surveyed in the 2021 Global Innovation Index. It ranks among the world's top five in universities, citable documents, access to information and communication technology, environmental performance, investment and trade diversification, and market scale. It has a supportive business environment, strong R&D capability and investment, and good intellectual property creation. On the other hand, its foreign direct investment net inflows rank 59th and gross capital formation and labour productivity growth rank 111th and 112th respectively.

The UK excels at turning innovation investments into outputs whereas the UAE is growing its innovation ecosystem and is expected to witness major advances in the coming years.

The UK ranks seventh in terms of innovation inputs and sixth in terms of outputs, while the UAE ranks 22nd in terms of inputs to innovation but 47th in terms of outputs. The capacity to turn innovation investment into producing ideas and technologies that can be applied and exploited to create impact is key to achieving a balanced and productive innovation system. The UAE is an outlier here, though its output score is improving. This likely reflects the country's emphasis on innovation inputs and the time lag between inputs being transformed into outputs, leaving positive room for growth in this domain. Figure 11 shows the relative performance of the UK and the UAE, where

Figure 11: Innovation input to output performance, 2021

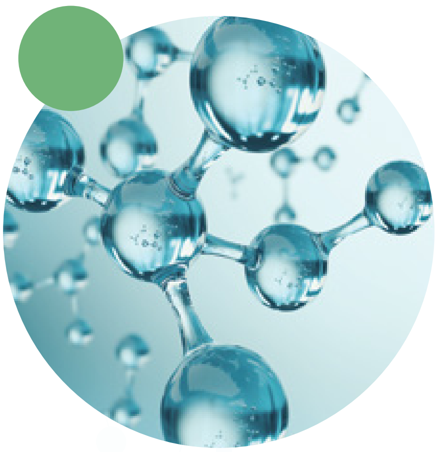


Source: Adapted from WIPO[133]

countries above the line outperform in terms of inputs translating inputs into outputs, and countries below the line have room to improve in that translation.[132]

Hydrogen accelerators, national test centres and translational initiatives are being used in the UK to commercialise innovations and support economic growth.

For example, Scotland's Hydrogen Accelerator is a partnership between the University of St Andrews and the University of Strathclyde and is funded by Transport Scotland to test and demonstrate hydrogen's transport applications and coordinate government, researchers and the supply chain.[134] The utility National Grid launched a test centre to establish the viability of using hydrogen in the gas grid.[135] The UK Catapult initiative discussed in section 2.5 has a mission to accelerate translational research to grow the hydrogen economy.[136] The University of Sheffield's Energy Institute hosts a Translational Energy Research Centre, one of the largest research and development facilities in Europe for zero-carbon energy, hydrogen, bioenergy, and carbon capture, utilisation and storage.[137] Heriot-Watt University is leading the Industrial Decarbonisation Research and Innovation Centre (IDRIC), a £20 million ($24 million) centre that is linking



multidisciplinary research to the UK's industrial clusters. IDRIC is responding to decarbonisation issues faced by industry, shaping research challenges to respond to needs, and helping to co-create and share knowledge across networks and stakeholders.[138]

The UAE's leading centres of excellence are also bridging the research-industry divide.

Though at present the UAE has fewer examples than the UK, Khalifa University is a key player in this domain. Its Research and Innovation Center on CO2 and Hydrogen (RICH) aims to carry out state-of-the-art research and innovation, generate intellectual property, and help build knowledge exchange and education in carbon dioxide and hydrogen.[139] As mentioned above, Khalifa University is also part of a Masdar-led consortium involving Siemens Energy, the Abu Dhabi Department of Energy, Etihad Airways, Lufthansa, Marubeni Corporation, to produce and commercialise green hydrogen for both road and aviation fuel.[140]

There is already collaborative innovation activity between the UAE and UK.

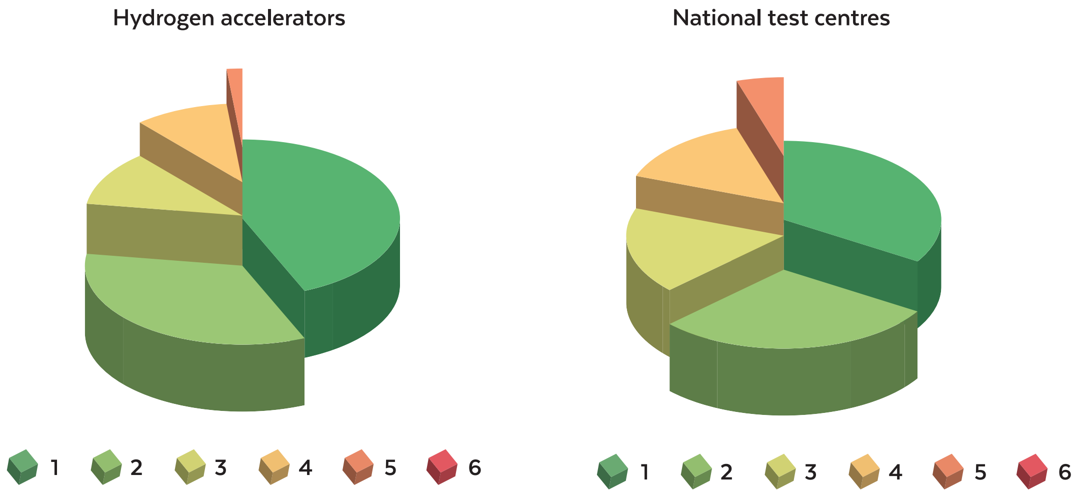
The UAE's ADNOC has partnered with the UK's Net Zero Technology Centre to host the TechX clean energy accelerator programme. The accelerator is supporting 12 clean energy start-ups, including a hydrogen fuel cell company, with up to £100,000 ($120,000) of funding, mentorship support an industry-leading partnerships.[141]

There remains an opportunity for the UAE and UK to further strengthen cross-border research collaborations and create knowledge infrastructure like test centres that support the whole innovation lifecycle.

Dedicated test centres could be established, or existing ones augmented, to focus on hydrogen and enable large-scale commercial testing of new technologies.

The complete integration of technologies must be demonstrated, and demonstration results need to be validated by accredited facilities. Partnerships could be established between large facilities and innovators with subcomponents of a hydrogen system, to test the component in a real-world environment. The perceived need for accelerators and national test centres is strong, as shown in Survey 15.

Survey 15: Importance of accelerators and national test centres[142]



Source: Author's survey analysis

[142]Survey questions – Where 1 is extremely important and 6 is not at all important, how important is it to: Establish accelerators to support innovators develop new technology, build business skills and bring technology to market; Establish large-scale national testing centres so that new technology can be tested and validated.

3.4. Scale-up the market through learning and demonstrations

3.4.1. Learning across the technology development chain reduces costs

Different types of learning advance technologies and lead to cost reductions.

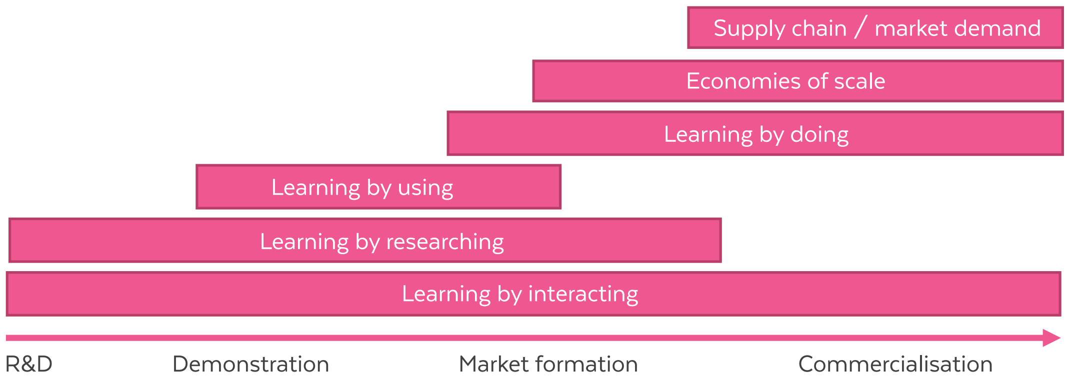
The process of how learning leads to cost reductions has been studied for clean technologies like wind and solar. Understanding how this process works for hydrogen is especially important for countries that want to establish a competitive advantage in hydrogen, so that they can create the environments required to accelerate the process. Learning has been studied across four stages of technology development, being R&D, Demonstration, Market Formation and Commercialisation. Depending on the stage of technology development, learning plays a more intensive or less intensive role. Learning can be broken down into the following:

- **Learning by interacting** generates cost reductions through interactions between researchers, industry, policymakers and users, sharing between different geographic locations, and knowledge exchange between adjacent sectors known as inter-industry spillover. It occurs across the full technology development value chain with especially high impact in the R&D and demonstration stages.
- **Learning by researching** generates cost reductions through technical improvements from knowledge creation achieved through research. It is especially impactful in R&D and demonstration stages.
- **Learning by using** generates cost reductions from feedback received from users on technical needs, initially from industry players at the demonstration stage, and later from customers during market formation and commercialisation.
- **Learning by doing** generates cost reductions from experience gained during the production process and is most prevalent during market formation and commercialisation stages.
- **Economies of scale** generate cost reductions at the device, plant and industry level, and have most impact in the market formation and especially the commercialisation stages.
- **Supply chain and market demand** generate cost reductions from efficient supply chains, lower materials costs, more mature sales markets and more competitors in the commercialisation stage.

The intensity of each type of learning varies along the technology development journey.

Figure 12 shows that learning by researching and learning by using delivers more dividends in the earlier stages of technology development, whereas learning by doing and scale and market effects are more impactful later. Learning by interacting takes place across the whole technology development journey.

Figure 12: Sequence of different types of cost reduction drivers



Source: Author's adaptation from Source: Elia, Kamidelivand, Rogan & Gallachóir (2021)[143]

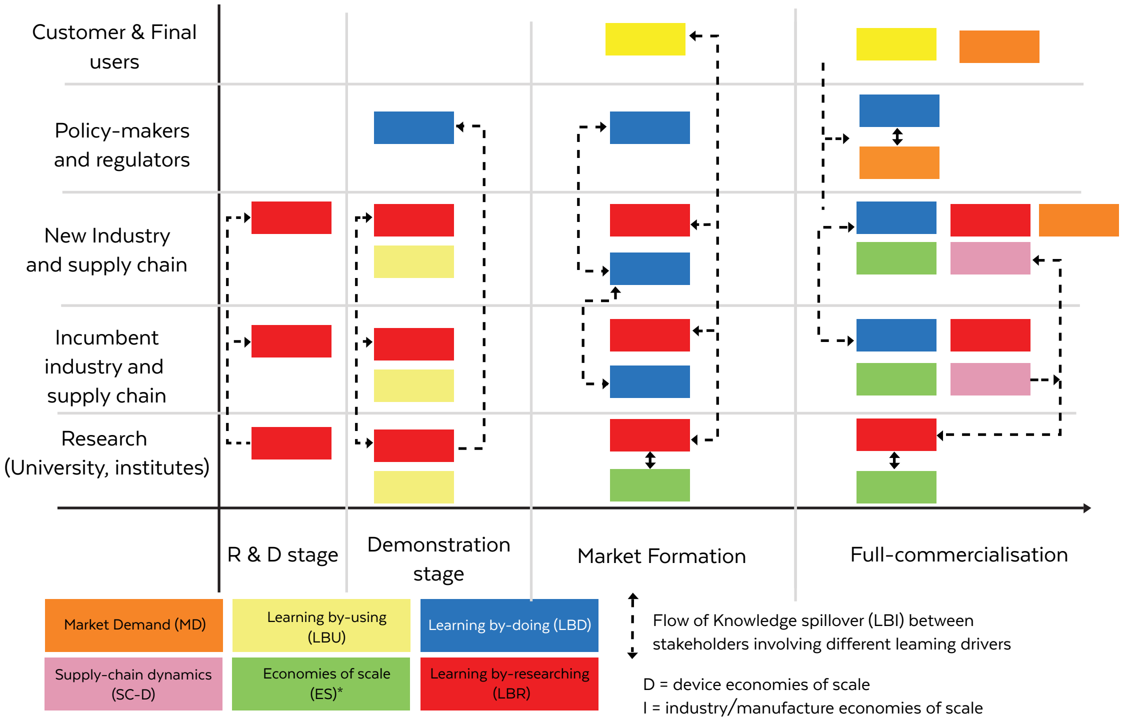
Learning by interacting is likely to be especially relevant to reducing costs since hydrogen straddles different sectors, geographies, technologies and stakeholder types.

Hydrogen will be a key input across the sectors of energy, industry, transport, buildings and agriculture. Over 30 countries are actively researching hydrogen and are building production facilities and infrastructure. Hydrogen also has at least 17 production methods and multiple use-case technologies that sit across multiple technology readiness levels.[144] Bringing hydrogen from its current position to full commercialisation will involve innovators, policymakers, businesspeople and financiers. This diversity of sectors, geographies, technologies and stakeholder types means that interacting across and between them will be critical to achieve rapid cost reductions. This reinforces the need for more coordination highlighted in the previous chapter.

There is an opportunity to analyse the stakeholders that drive different types of cost reduction to shed light on the pathways that may bring most benefit to the UAE and UK individually and through collaboration.

Different stakeholders play different roles in realising cost reductions along the technology value chain. The technology cost reduction model shown in Figure 13 shows the types of learning that different stakeholders utilise to reduce hydrogen's cost. Note the increasingly intertwined nature of 'learning by interacting (LBI)' as the technology progresses along its development journey.

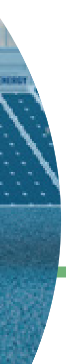
Figure 13: Technology cost reduction model along the value chain



Source: Elia, Kamidelivand, Rogan & Gallachóir (2021)[145]

More interaction between stake-holders in the UAE and UK would accelerate the industry, which could be facilitated by establishing a bilateral multidisciplinary hydrogen platform.

Hydrogen is likely to require more interacting across stakeholder groups at earlier stages of technology development to keep pace with the industry's rapid evolution, avoid false starts and reduce the risk of building stranded assets. The hydrogen market is currently in its earlier stages of growth, where policies, innovations and investment decisions are shaping the race for global leadership. The market is poised to take off in the mid 2030s[146], but that acceleration depends on cross-sectional relationships being developed now. Establishing a bilateral multidisciplinary hydrogen platform that hosts regular exchanges of policy, technical, commercial and operational developments could strengthen both countries' positions.

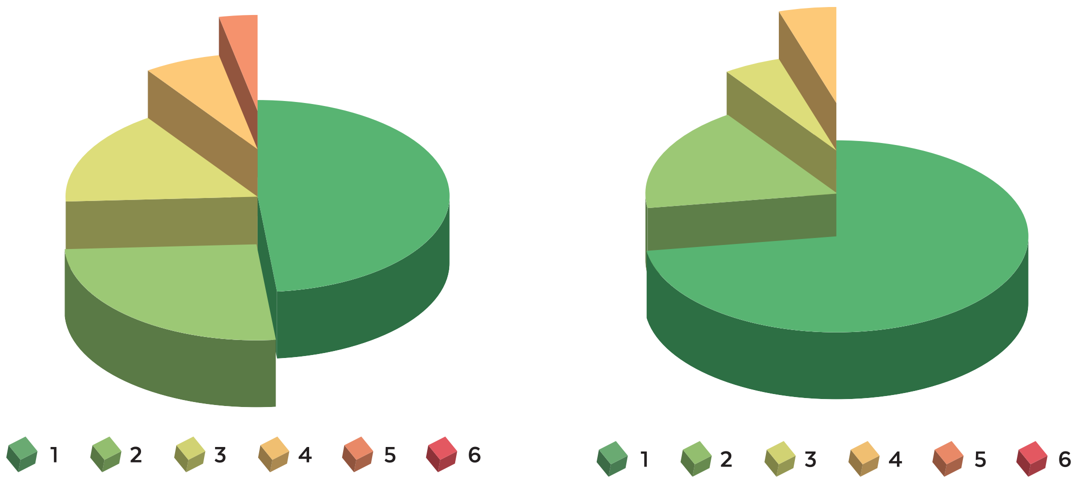


3.4.2. Technology demonstrations support scale-up

Early-stage research and pilots are both needed for the industry to scale- up, but pilots are considered especially important.

Research and pilots produce learning that enables technologies and markets to scale -up. As shown in Survey 16, there is overwhelming agreement that pilots are extremely important to enable the industry to grow. Early-stage research is still considered very important, which shows the need for innovation to deliver cost reductions across the whole technology development chain.

Survey 16: Importance of early-stage research and pilots[147]



Source: Author's survey analysis

The UAE has more focus on pilots and larger-scale projects that are positioned further along the technology development path.

The UAE has two active flagship pilots. One is a solar-powered green hydrogen project implemented in collaboration between DEWA, Expo 2020 Dubai, and Siemens Energy at the outdoor testing facilities of the R&D Centre at the Mohammed bin Rashid Al Maktoum Solar Park.[148] The second is waste-to-hydrogen project being implemented by Bee'ah in partnership with a UK

[147]Survey questions – Where 1 is extremely important and 6 is not at all important, how important is it to: Support investment into early-stage innovations that prioritises the development of new technologies and new methods; Direct investment towards pilot projects to test new technologies, build learning and provide a safe testing environment before scaling up.

company, Chinook Sciences, using their patented thermal treatment system.[149] The projects that have been announced in the UAE are also of a massive scale, ranging from 1 GW to 5 GW of capacity.

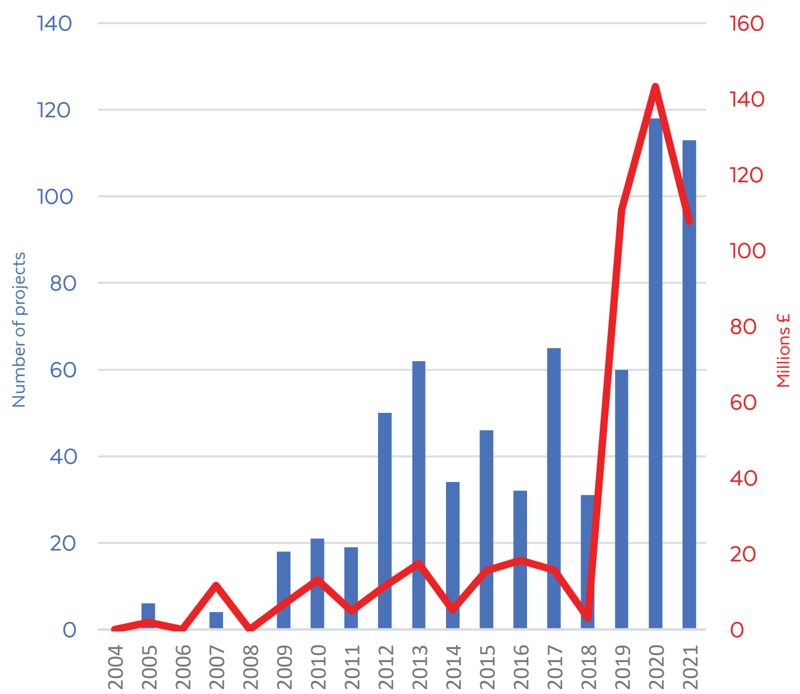
The UK is extending its strength in early-stage research out to larg-er-scale demonstrations.

Analysis of the UK's public funding land-scape for hydrogen shows a significant shift in the value, volume and type of funding that has been dedicated to hydrogen. Figure 14 shows that while the number of hydrogen projects being funded by Innovate UK has roughly doubled over the past few years, the value of projects funded has increased more than five-fold. This signals both a serious commitment to hydrogen innovation and a move towards later-stage innovations and demonstrations, which are more expensive than early-stage research.

A focus on hydrogen demonstrations is a key part of the UK's net zero agenda.

The Scotland-based European Marine Energy Centre (EMEC) is dedicating roughly half of its innovation effort to hydrogen demonstrations.[151] EMEC Hydrogen has supported over a dozen demonstrations, including the world's first hydrogen-electric flight, producing synthetic jet fuel for the Air Force, hydrogen for marine transport using containerised fuel cells and also by trialling a hydrogen/diesel dual fuel conversion system, using wind and tidal power to produce hydrogen, integrating a hydrogen power system for island environments, piloting low-pressure hydrogen storage, and demonstrating AI software-controlled hydrogen storage – projects amounting to roughly £50 million ($60 million).[152] Hydro-gen is also one of 10 technologies included in the UK's £1 billion ($1.2 billion) Net Zero Innovation Portfolio.[153]

Figure 14: Innovate UK hydrogen projects and funding, 2004 - 2021



Source: Innovate UK[150] and author's analysis

Funding dedicated to hydrogen includes:

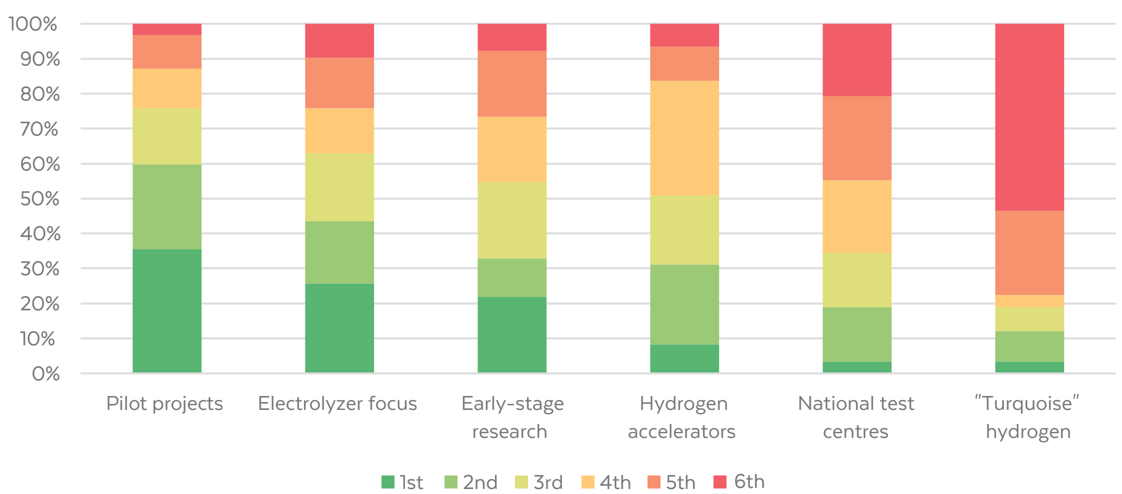
- £93 million ($111 million) Low Carbon Hydrogen Supply Competition, including a £33 million ($39 million) first round and a £60 million ($71 million) second round, which can fund earlier stage (TRL 4 – 6) feasibility studies for up to £300,000 ($357,000) and demonstrations up to £6 million ($7 million) each.[154]

- £26 million ($31 million) Industrial Hydrogen Accelerator Programme to demonstrate end-to-end industrial fuel switching to hydrogen, which is additional to the £55 million ($65 million) Industrial Fuel Switching Competition that included hydrogen among other decarbonisation options like electrification, biomass and wastes.[155,156]

- £11 million ($13 million) Green Distilleries Competition Phase 2 for four demonstration projects to decarbonise distilleries with hydrogen.[157]

Survey 17: Relative importance of different innovation options[159]

How should innovation be supported?



Source: Author's survey analysis

[159]Survey question: Please rank the following from "top priority" (1) to "lowest priority" (6) with respect to innovation to advance the hydrogen sector: Electrolyser Focus; Pilot projects; National Test Centres; Hydrogen accelerators; Turquoise" hydrogen; Early-stage research

- $5 million ($6 million) Hydrogen BECCS (Bioenergy with carbon capture and storage) Innovation Programme to support technologies which can produce hydrogen from biogenic feedstocks and be combined with carbon capture.[158]

There remains an opportunity for deeper bilateral collaboration, especially related to demonstrating UK innovations in the UAE so that they can effectively scaled.

A critical part of the technology development journey is testing innovations in a representative environment. While the UK is a crucible for innovation, its environmental conditions are very different from the UAE's hot and dusty climate. Demonstrations also help to overcome nontechnical issues like supply chain dynamics, business relationships, policy differences and system integration. The UK's early-stage innovation focus may act as funnel of novel technologies that can feed larger-scale demonstrations and deployments in UAE. A UAE based accelerator programme or corporate venturing activity could help to attract and localise the technologies the UAE needs to achieve the scale of deployment it seeks, whilst providing opportunities for UAE investors and a commercial pathway for UK companies.

Comparing different innovation options shows very strong support for pilot projects and strong support for electrolyser research to produce green hydrogen.

Despite hydrogen accelerators scoring higher than early-stage research when assessed independently in Survey 15 and Survey 16, accelerators fell behind early-stage research in the comparative assessment shown in Survey 17. It also shows that establishing national test centres was not considered to be a high priority, while innovating in much less mature technologies that continued to use gas as a feedstock (turquoise hydrogen) was resolutely deprioritised. Survey 17 illustrates the relative positions of each innovation option.

04

Ways to Enable the Market

4.1 Section Summary

Overview of priorities identified in this section

- To accelerate the hydrogen market, investment must be facilitated, infrastructure built and skills developed
- Just 40% of the investment in hydrogen that is required to reach net zero is forecast by 2030, leaving significant scope for bigger UAE and UK investment activity
- Improving the bankability of hydrogen projects is a top priority to access finance
- Green Investment Banks are considered helpful to mitigate risk perceptions and mobilise private sector finance
- New and refurbished pipelines, storage facilities, ports and electricity transmission infrastructure are considered critical
- Identifying skills gaps is a top priority to prepare the future hydrogen workforce, with a special focus on technical and vocational education and training

Opportunities that the UAE and UK may wish to explore

- Consider leveraging existing entities like the UAE's Masdar or the UK's Infrastructure Bank to provide technical assistance and innovative finance that attracts private investors to hydrogen projects and enabling infrastructure
- Establish a joint investment vehicle, for example, a $10 billion UAE-UK hydrogen investment fund, to mobilise finance into the sector
- Apply the UK industrial clusters approach, or 'hydrogen valley' concept, in the UAE, where complementary industries are collocated to capitalise on shared infrastructure and close proximity of hydrogen inputs, outputs, supply, demand and transport
- Develop case studies that demonstrate the technical, financial and operational viability of hydrogen projects to reduce risk perceptions and unlock finance
- Build on the UAE-UK Sovereign Investment Partnership and create new investment agreements to increase the volume of cross-border investment into hydrogen projects and infrastructure
- Bring together UAE and UK stakeholders from industry, academia and training academies to identify future skills gaps and develop appropriate training programmes
- Consider how oil and gas workers in both countries can be retrained to enable a just transition and capitalise on the workforce's existing skillset
- Pioneer the development of international skills standards and training activities to facilitate cross-border projects and to become global centres of excellence in hydrogen skills
- Connect UAE and UK training centres to promulgate shared training courses, potentially using UK satellite campuses in the UAE

4.2 Unlocking Investment

Global investment in hydrogen is forecast to reach $500 billion by 2030, far short of the $1.2 trillion investment in hydrogen that is required to reach long term net zero goals.

About $150 billion, or 30% of the overall investment is mature, meaning investment is in the planning stages, the investor has made a final investment choice, or the investment is tied to a project that is already built, commissioned, or under development.[160] To reach net zero emissions by 2050, however, a worldwide investment in hydrogen of $1.2 trillion is required by 2030 and $10 trillion by 2050, which includes end-use technologies (about 60% of total investment) and infrastructure (14-18% of the total).[161] This compares to about $22.5 trillion of required investment into renewable energy to achieve a low carbon global energy transformation.[162]

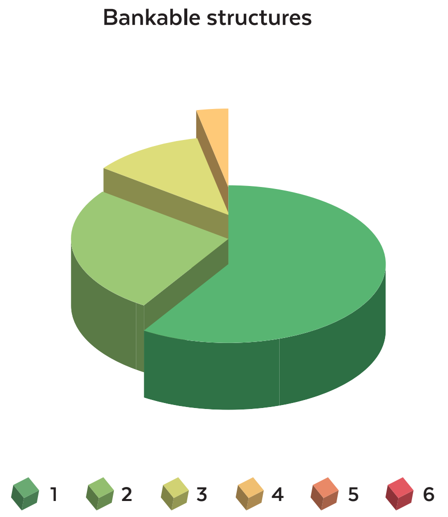
Investment in the UAE and UK could hit $50 billion by 2030.

The UAE's ADNOC is reflecting on its mandate from the former Supreme Petroleum Council to "become a hydrogen leader" as it allocates its $122 billion 5-year capital investment programme up to 2025.[163] Other major investment cores in the UAE include the 2 GW $5 billion joint green hydrogen investment by Engie and Masdar, the $1 billion Khalifa Industrial Zone green ammonia facility in Abu Dhabi, and a 2 GW green ammonia facility developed by TAQA and Abu Dhabi Ports.[164,165,166] The UK aims to unlock £4 billion ($4.8 billion) of private investment for the production of blue and green hydrogen to promote the development of the UK's hydrogen economy.[167] Independent analysis suggests that the capital expenditure value of electrolysers and offshore wind energy to produce hydrogen could amount to £23 billion ($28 billion) by 2030.[168]

Bankable projects must be prepared to raise the volume of investment required to meet net zero.

Currently, bankable hydrogen projects generally require a direct relationship between producers and offtakers, supported by long-term offtake agreements, to demonstrate the long-term viability of the project. Investors require assurance that the full project can be delivered, which developers of first-of-a-kind projects often struggle to provide since it requires proof of an untested supply chain. Faced with the chicken and egg problem discussed in section 2.2, such bankable structures are challenging to secure. The need to develop bankable structures is considered to be an overwhelmingly strong requirement to unlocking investment, as shown in Survey 18.

Survey 18: Importance of bankable structures[169]



Source: Author's survey analysis

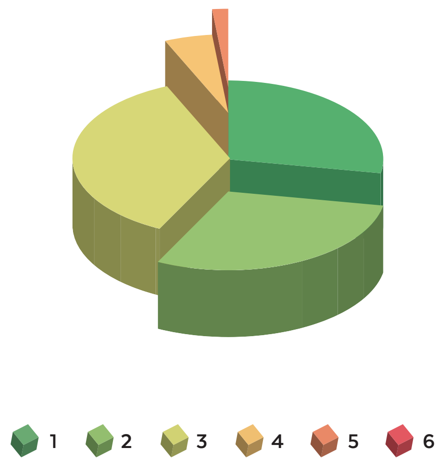
[169]Survey question – Where 1 is extremely important and 6 is not at all important, how important is it to develop relationships between producers, supply chain actors, off-takers, and lenders to improve coordination and help put together a bankable project

Banks often lack the technical capability to assess the risks of hydrogen projects, which are often first of a kind.

Banks have teams of investment professionals that are skilled in assessing the risks of projects. Since clean hydrogen is a relatively new field, there are few bankers that have the capability to accurately assess the real risks of clean hydrogen projects. Survey 19 shows how important this challenge is. A similar issue faced the offshore wind industry in the early 2010s, when a limited understanding of technology risk, policy risk, environmental risk, and economic risk made offshore wind an unattractive investment. Investing in a high-cost, high-risk sector when alternative investment opportunities were available meant that the cost of finance was very high for offshore wind.[171] In such environments, governments have a role to play in facilitating the investment environment.

Survey 19: Importance of upskilling bank risk assessors[170]

Bank risk assessors



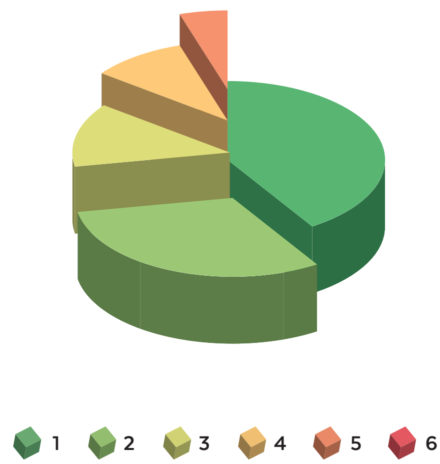
Source: Author's survey analysis

There is an opportunity for the UAE and UK to use innovative finance institutions like Green Investment Banks (GIBs) to overcome risks and mobilise private sector investment into hydrogen.

While GIBs can take many forms, they are all motivated by a public purpose to accelerate low-carbon, climate-resilient, and sustainable development. They are usually publicly owned, commercially operated entities that aim to scale-up investment in sustainable projects.[172] Using GIBs to provide finance and technical assistance to attract private investment into hydrogen projects is a popular idea among survey respondents, as seen in Survey 20.

Survey 20: Importance of Green Investment Banks[173]

Green Investment Banks



Source: Author's survey analysis

[170]Survey question – Where 1 is extremely important and 6 is not at all important, how important is it to upskill bankers on risk assessments for hydrogen projects to fairly and accurately assess risk and offer competitive financing terms

[173]Survey question – Where 1 is extremely important and 6 is not at all important, how important is it to establish public banks to provide financing and technical assistance that decreases risks and helps attract private investment

The UK Green Investment Bank pioneered this approach in 2012, and there is an opportunity for the UK Infrastructure Bank to now be used for hydrogen infrastructure.

The UK GIB was launched in 2012 with a capitalisation of £3 billion ($3.6 billion) and a mandate to mobilise private investment into offshore wind, waste and non-domestic energy efficiency.[174] It was sold to Macquorie Group in 2017 and renamed the Green Investment Group. It has been successful at mobilising finance towards technologies that were new and poorly understood. It has committed or arranged £25 billion ($30 billion) in investment, built 11 GW of projects, avoided 222 $MtCO_2e$ of emissions, and currently has 35 GW of projects under development.[175] The UK Infrastructure Bank was launched in 2021 with a similar purpose, to provide £22 billion ($26 billion) of infrastructure finance to tackle climate change and support regional growth.[176] The UK's Green Finance Institute has suggested that the UK Infrastructure Bank invest in hydrogen.[177]

The UAE's Masdar or the Emirates Development Bank could also develop Green Investment Bank functions to support hydrogen.

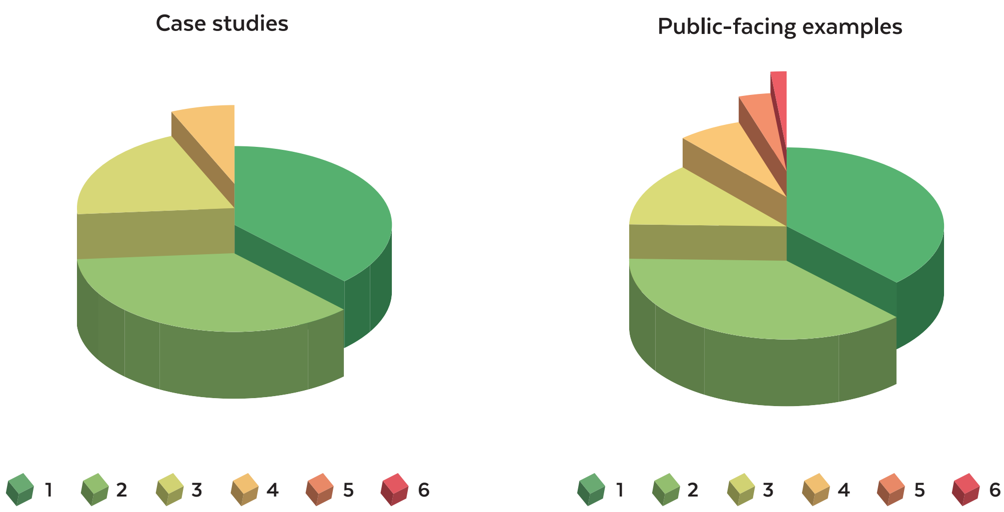
Since 2006, Masdar has invested in a 14 GW renewable energy portfolio in more than 40 countries worth over $20 billion (its share is about $9 billion).[178] Masdar also supports innovative finance. It launched a Revolving Credit Facility in 2018 to provide funding for local and international banks for investments into global clean energy and sustainable real estates, and also operates the Masdar Green Real Estate Investment Trust, a sustainable property portfolio.[179,180] Investment in Masdar from TAQA, Mubadala and ADNOC, members of the Abu Dhabi Hydrogen Alliance, makes Masdar a natural fit to offer hydrogen-focused technical assistance and innovative finance to reduce risks. The Emirates Development Bank is a financial enabler of the UAE's economic diversification and industrial transformation. It offers financial products to all sizes of business and plans to invest AED 30 billion ($8.2 billion) by 2025 into five key sectors, including manufacturing, technology and infrastructure.[181]

Risks can also be managed, and public confidence built, through case studies and public facing examples that show hydrogen's viability.

Seeing is believing when it comes totechnical viability, financial returns, safety perceptions and project implementability. Case studies and examples of success give investors and policymakers confidence that the technology's risks can be managed, that the supply chains are in place and that demand really exists. Examples of hydrogen that people can interact with, such as hydrogen buses, can encourage public support for the technology and assuage safety concerns. Survey respondents strongly support case studies as shown in Survey 21, and generally support public-facing examples.

[182]Survey question – Where 1 is extremely important and 6 is not at all important, how important is it to: Develop case studies of successful projects to generate confidence in the financial and technical viability of hydrogen projects (e.g. to investors, policymakers, consumers); Support highly visible examples of projects (e.g. hydrogen buses) to normalise hydrogen and raise confidence for stakeholders.

Survey 21: Importance of case studies and public-facing examples[182]

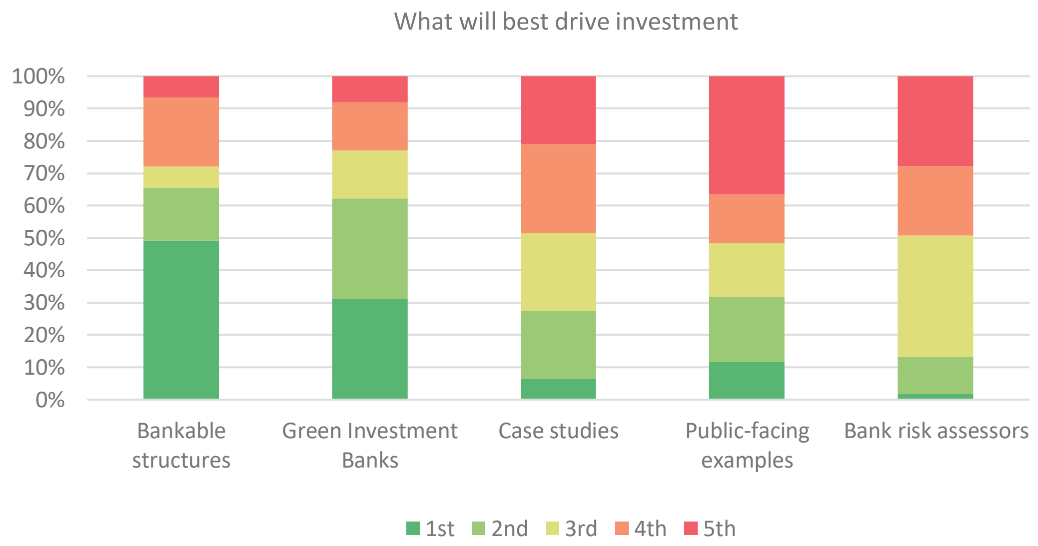


Source: Author's survey analysis

Bankable structures and green investment banks are considered most important to unlocking investment.

As shown in Survey 22, arranging bankable projects ranks highest; bankability is a precondition to unlocking finance. GIBs ranked second and are proven to help overcome financial and non-financial barriers and help to crowd in private sector investment. By providing technical assistance to risk assessors in banks, GIBs can also be a key tool to secure cheaper financing. While upskilling bank risk assessors ranked lowest priority, they still scored a considerable number of second and third choice selections. Many respondents are less enthusiastic about public-facing examples. This is potentially because current hydrogen investment decisions are made by businesses rather than the public, making public-facing examples less relevant to final investment decisions. It may also be because public-facing hydrogen use-cases like hydrogen buses, fuel cell vehicles and domestic heating sit at the bottom of the hydrogen hierarchy shown in Figure 6, whereas business-to-business use cases sit at the top.

Survey 22: Relative importance of different options to unblock investment[183]



Source: Author's survey analysis

Joint UAE-UK investment is already happening, but more is needed to achieve the volume of investment required to meet net zero.

A joint investment vehicle could be established, for example, a $10 billion UAE-UK hydrogen investment fund, to mobilise finance specifically into hydrogen. This could augment the UAE-UK Sovereign Investment Partnership announced in 2021, which will see the UAE invest £10 billion ($12 billion) over the next five years in three strategic priorities: energy transition, technology and infrastructure. This includes co-investments and co-development of Low-carbon Hydrogen Hubs, investment in Carbon Capture, Utilisation and Storage, and the creation of a decarbonised air corridor between the UK and the UAE.[184] In May 2022, ADNOC agreed to take a 25% stake in the design stage of bp's blue hydrogen project, H2Teesside, located in a UK Industrial cluster, which aims to develop two 500 MW production facilities. Masdar also signed an MOU to acquire a stake in bp's green hydrogen project, HyGreen Teesside, which will have a capacity of 60 MWe by 2025, growing to 500 MWe by 2030.[185] Despite these huge commitments, more joint investment must be mobilised for both countries' hydrogen ambitions to be realised.

[183] Survey question – Please rank the following from "top priority" (1) to "lowest priority" (5) with respect to what is both most effective and practical currently or in the near future: Bankable Structures; Bank risk assessors; Green Investment Banks; Case studies; Public-facing examples.

4.3. Building infrastructure and scaling up

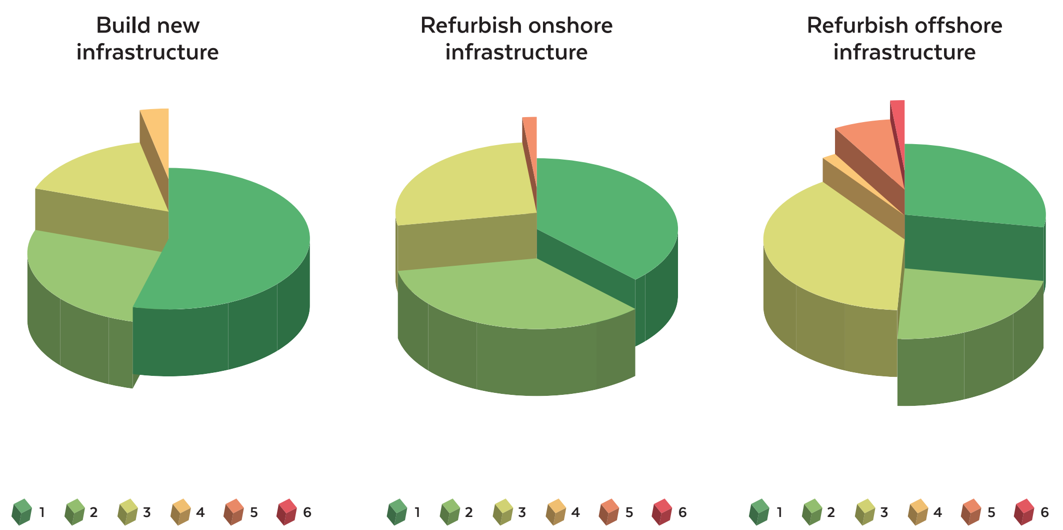
Infrastructure is needed to catalyse a hydrogen economy.

Transmission, distribution and storage infrastructure must connect supply sites with demand centres. Refuelling infrastructure is needed to enable transport use-cases. Integration with CCUS infrastructure, gas and electricity networks is also critical to enable hydrogen production and use and prepare a whole-systems approach to energy.

The needs of the UAE and UK will be met with a combination of new and repurposed infrastructure.

This includes new distributed and centralised storage facilities, new pipelines dedicated to hydrogen and carbon dioxide transport, and new electricity transmission infrastructure from greenfield renewable energy sites. It also includes repurposed land-based and undersea pipelines, electricity and gas network upgrades and upgrades to compressors and storage facilities. So-called "topside refurbishments" of offshore oil and gas platforms also have the potential to unlock different hydrogen production opportunities. Platforms could: host onsite blue hydrogen production collocated with CCS; host electrolysersfor onsite green hydrogen production collocated with offshore wind to avoid transmission losses; and/or host equipment to produce "clear" hydrogen from depleted oil and gas wells using novel technology.[186] Less support is expressed for refurbished offshore infrastructure, perhaps because it is not essential to kick-start the industry. Survey 23 shows strong support for new infrastructure and refurbished onshore infrastructure.

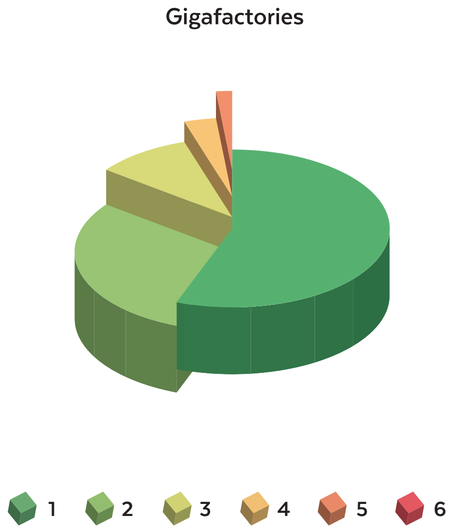
Survey 23: Importance of new and refurbished infrastructure[187]



Source: Author's survey analysis

[187] Survey questions – Where 1 is extremely important and 6 is not at all important, how important is it to: Build new hydrogen infrastructure (pipelines, storage facilities, electricity transmission lines for green hydrogen, etc.); Refurbish existing onshore infrastructure (e.g. facilities, pipelines, small pool storage) to accelerate hydrogen deployment and minimise stranded assets; Refurbish existing offshore infrastructure (e.g. oil and gas platforms, pipelines, offshore wind), to accelerate hydrogen deployment and minimise stranded assets.

Survey 24: Importance of gigafactories[191]



Source: Author's survey analysis

The UAE and UK are also looking to spur demand by making new and refurbished end-use equipment hydrogen ready.

For example, the UAE's Emirates Global Aluminium and GE are exploring the potential to operate its 5.2MW natural gas turbines with clean hydrogen.[192] The UK's Hy4Heat programme explored new and refurbished hydrogen appliances for domestic, commercial and industrial use. The extensive Hy4Heat programme also specified hydrogen quality and appliance certification standards, assessed the safe use of hydrogen in domestic buildings, developed metering solutions, and built hydrogen-fuelled demonstration homes.[193] While this option garnered some support, Survey 25 shows that this is not an overwhelming priority.

The UK's approach includes building new hydrogen and enabling infrastructure in industrial clusters, and repurposing existing gas transmission networks to connect them with a hydrogen backbone.

The UK Government's industrial clusters mission will co-locate hydrogen production, offshore wind, CCUS, ports and heavy industry to take advantage of infrastructure synergies within the cluster.[188] The utility National Grid is exploring the development of a hydrogen backbone that connects industrial clusters around the UK, potentially creating a pipeline network spanning 2,000 km. It would repurpose roughly a quarter of the UK's existing gas transmission network and would carry about 25% of the UK's current gas demand. The backbone would also seek to interconnect with the EU's proposed hydrogen transmission network.[189] This clustering approach, also known as a "hydrogen valley", could be explored and implemented in the UAE.

Survey 25: Importance retrofitting existing end-use equipment[190]

Source: Author's survey analysis

[190]Survey question – Where 1 is extremely important and 6 is not at all important, how important is it to establish large factories to produce hydrogen equipment (e.g. electrolyzers, fuel cells) to support production at a massive scale and lower cost.

[191]Survey question – Where 1 is extremely important and 6 is not at all important, how important is it to refurbish existing equipment that uses hydrogen (e.g. gas turbines, boilers) to accelerate demand for hydrogen.

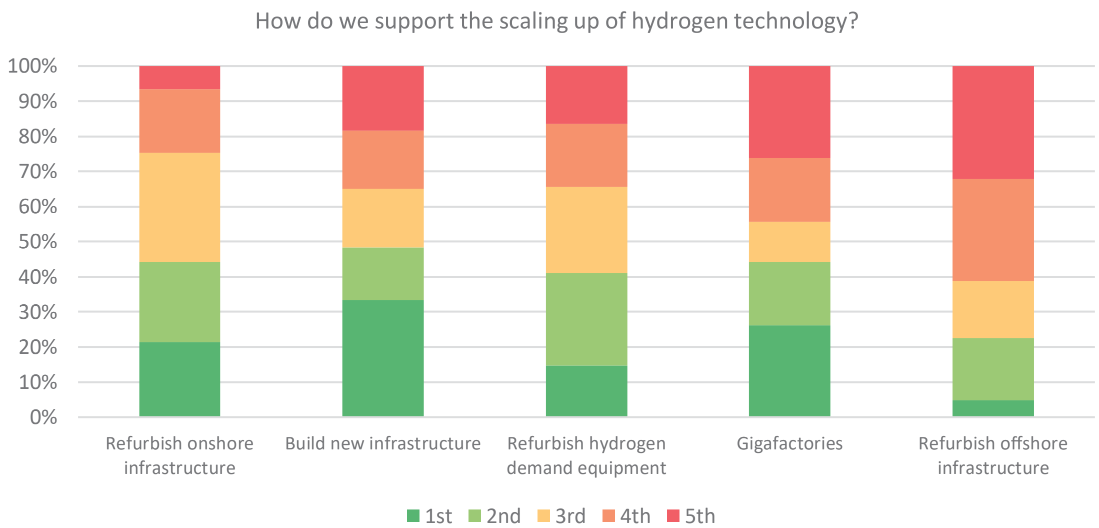
The commercial case for infrastructure investment is strongest when it will service large scale production and demand centres.

Large-scale production of both hydrogen and of the equipment that produces hydrogen brings down costs through economies of scale. "Gigafactories" with huge electrolyser production capacity have been announced in the UK and elsewhere. ITM Power completed construction of a 350MW PEM (Polymer Electrolyte Membrane) electrolyser plant in Sheffield in 2021 with plans to scale beyond 1 GW, which will cut the cost of electrolysers by up to 40% due to economies of scale and increased automation.[194] The perceived value of gigafactories to reduce costs through economies of scale is strong, as shown in Survey 24.

There is weak consensus on the most important approach to infrastructure needed to scale the market.

Survey 26 shows that respondents are less averse to refurbishing onshore infrastructure and more in favour of building new infrastructure. Respondents are almost evenly split when considering the importance of refurbishing hydrogen demand equipment, while gigafactories attract both extremes. Respondents are least favourable to refurbishing offshore infrastructure, perhaps because it is not critically needed to catalyse the market. Deeper analysis of the results shows a tendency for individual respondents to either favour new things (new infrastructure, new gigafactories) or to favour refurbishments.

Survey 26: Relative importance of different options to scale-up the market[195]



Source: Author's survey analysis

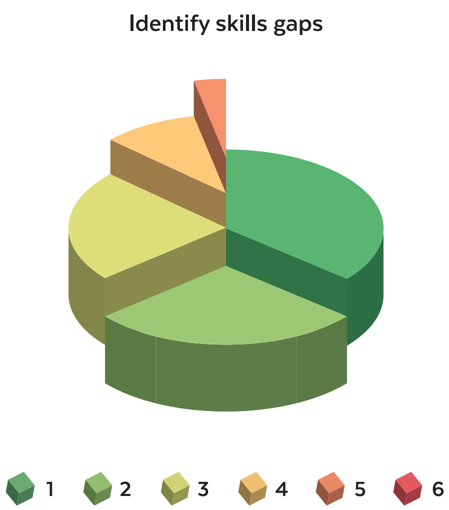
[195]Survey question – Please rank the following from top priority (1) to lowest priority (5): Build new infrastructure; refurbish onshore infrastructure; refurbish offshore infrastructure; refurbish hydrogen demand equipment; gigafactories.

4.4. Developing skills

Building the skills and capabilities of the hydrogen economy workforce is essential, starting by identifying needs.

The hydrogen industry is young and growing quickly and many of the jobs that will be created in a more advanced hydrogen economy do not yet exist.[196] Survey 27 shows the importance of assessing the needs, roles, and training requirements of the future workforce so that training programmes can be developed. In the UK, this need is being tackled by the Hydrogen Skills Partnership, which was launched to assess the jobs potential of a future hydrogen sector in the UK and to provide supply chain insights to identify new and emerging skills needs. It brings together partners from the private, public and academic sectors, including ScottishPower, ITM Power, Arcola Energy, Robert Gordon University, Energy Transition Zone Limited, Skills Development Scotland, Aberdeen University, North East Scotland College and the Hydrogen Accelerator (based at the University of St Andrews)[197]

Survey 27: Importance of identifying skills gaps[198]



Source: Author's survey analysis

Khalifa University is the UAE's centre of training and skills development for hydrogen.

Khalifa's Research and Innovation Center on CO2 and H2 (RICH) is the centrepoint for research, development, technology transfer and awareness raising about hydrogen. It is focused on educating highly skilled engineers to undergird the UAE's emerging hydrogen economy.

The UK's skills development landscape is growing.

A National Energy Skills Accelerator is being established in Aberdeen provide a 'one stop shop' for industry to access a wide range of energy courses, skills development programmes and R&D capabilities.[199] A National Hydrogen Research Innovation and Skills centre is also being established at the University of Sheffield with ITM Power, which will provide training and career development alongside industrial research.[200] Several UK universities have launched dedicated hydrogen programmes, including, among others:

- University of Birmingham's suite of programmes at PhD, Masters and Degree Certificate level from the Centre for Fuel Cell and Hydrogen Research[201]
- Cranfield University's programmes under the Hydrogen Research Network[202]
- University of Nottingham's PhD on Hydrogen Fuel Cells and their Applications[203]
- Imperial College London's courses under the hydrogen research theme of the Sustainable Gas Institute[204]
- University of Swansea Masters on Fuel Technology including hydrogen[205]

[198] Survey question – Where 1 is extremely important and 6 is not at all important, how important is it to stablish an understanding of the gaps in expertise related to the hydrogen sector, to help develop new training, courses and study programmes

There remains an opportunity to link up training and develop skills standards between UAE and UK, potentially by using UK satellite campuses in the UAE.

UK universities with hydrogen specialties such as the University of Birmingham and the University of South Wales (through Cymru H2 Wales)[206] also have campuses in Dubai. Khalifa University has research collaborations and student exchange programmes with China, South Korea, Russia, Italy, Saudi Arabia, and the United States, and would benefit from extending its collaboration with UK institutions. Universities and colleges may have an opportunity to develop aligned standards around technical and vocational training to facilitate a cross-border workforce. Survey 28 suggests that these opportunities garner moderate support.

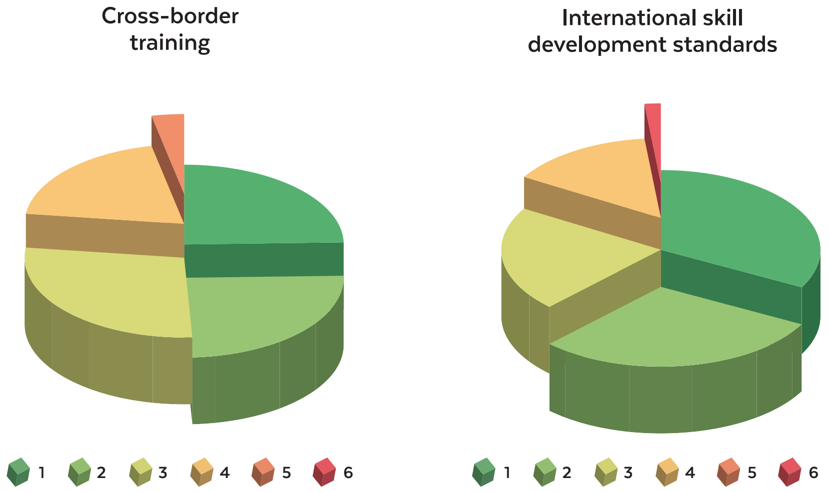
Retraining of oil and gas workers for the hydrogen economy would help support a just transition.

Transitioning to a low carbon future will lead to workforce shifts away from oil and gas in both the UK and UAE. Up to a third of oil and gas workers are actively looking for new jobs in the renewables sector and retraining these workers in the hydrogen sector can smooth the transition to a low carbon economy.[208] The recruitment and training firm Brunel has launched a retraining programme geared at oil and gas workforce that teaches the fundamentals of hydrogen production, its use along the complete value chain, as well as policy, legal and legislative topics.[209] Survey 29 shows strong support for retraining the oil and gas workforce for hydrogen.

Technical and vocational education and training (TVET) is especially important.

The need for hands-on education involving both academic and workplace training is crucial to develop a workforce where the needs and requirements of the job are continuously evolving. Survey 29 shows that both higher education and TVET are considered important when considered on their own, but when compared in Survey 30, TVET ranks considerably higher.

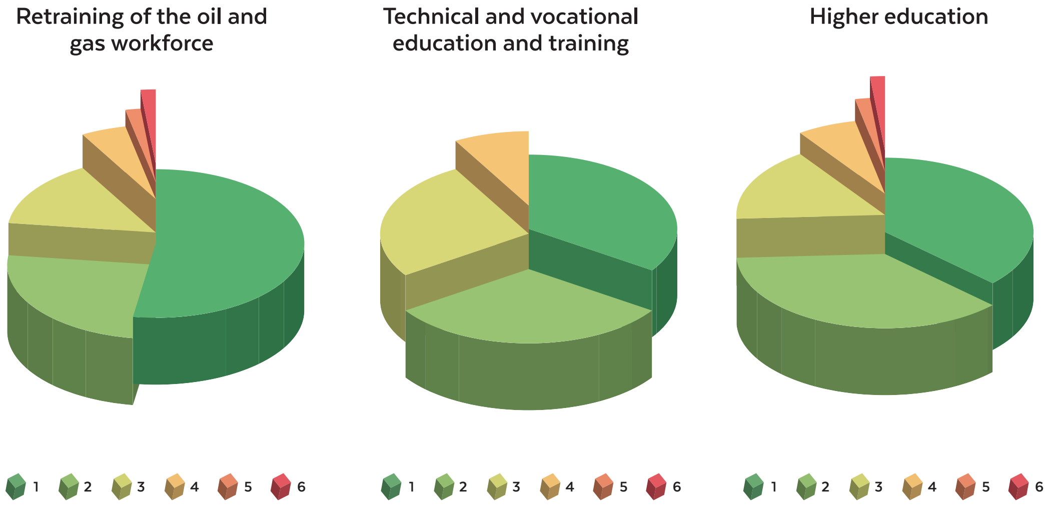
Survey 28: Importance of international training and skills standards[207]



Source: Author's survey analysis

[207]Survey questions – Where 1 is extremely important and 6 is not at all important, how important is it to: Develop international joint training programmes to prepare a globally-ready workforce and strengthen cross-border capabilities in the hydrogen sector (Cross-border training); Establish international norms and standards for workers in the hydrogen sector (International skills development standards).

Survey 29: Importance of different types of training and education[210]



Source: Author's survey analysis

Identifying skills gaps is a clear priority and filling the gaps through retraining and TVET is considered a good solution.

Comparing the relative importance of different needs to develop the skills and capabilities of the hydrogen workforce in Survey 30 shows that immediate training needs are considered more important than international collaboration and joint standards-setting. This may reflect the fact that hydrogen is still a nascent industry. Skills gaps first need to be identified then filled with practical training in a domestic environment before international skills exchange and joint educational standards are needed.

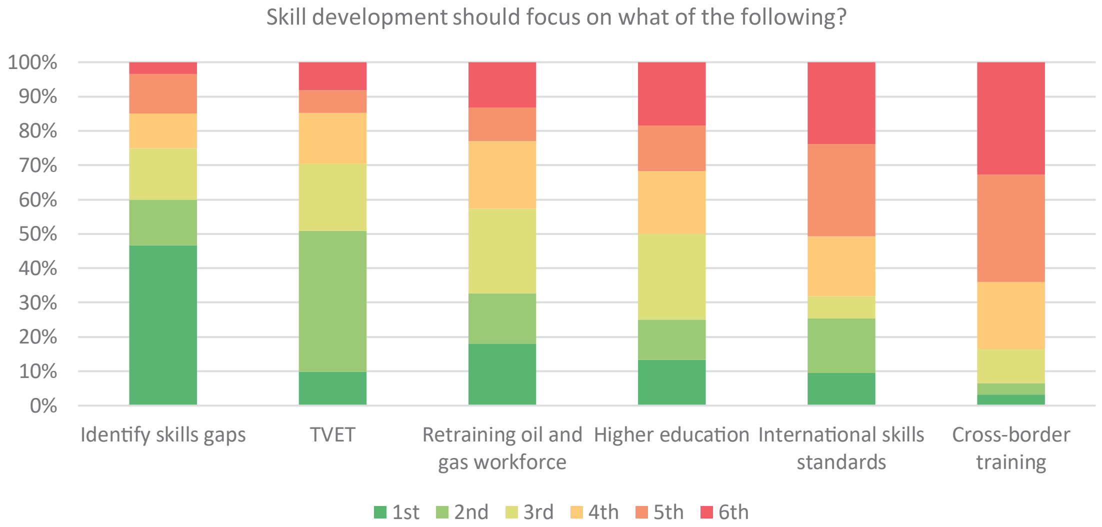
There is an opportunity for the UK and UAE to lead on skills standards and international training.

While Survey 30 shows that these are considered less important at the moment, establishing such standards and exchange programmes takes time. The hydrogen industry will rapidly grow from a national to an international sector, where skills and capabilities will need to be deployed around the world. The UAE and UK may have an opportunity to get out ahead of their peers by pioneering these activities through colleges and university programmes and by facilitating cross-border on-the-job training.

[210] Survey questions – Where 1 is extremely important and 6 is not at all important, how important is it to: Leverage existing skills in the oil and gas sector and adapt them to the hydrogen industry through retraining. This can help support a just transition (Retraining the oil and gas workforce); Develop non-academic technical education, practical training and apprenticeships to develop the applied skills and knowledge of the hydrogen workforce (TVET); Develop college and university programmes to advance the academic and research capability in the hydrogen sector (Higher education).

[211] Survey question – Please rank the following from "top priority" (1) to "lowest priority" (6) in terms of facilitating the skills and capabilities needed in the hydrogen industry Identify Skills Gaps; Technical and Vocational Education and Training; Higher Education; Retraining of the Oil and Gas Workforce; Cross-country Training; International Skill Development Standards

Survey 30: Relative importance of skills and capabilities needs for the hydrogen industry[211]



Source: Author's survey analysis

05

Pathways for the Future

This report highlights a number of priorities to accelerate the hydrogen industry.

Ensuring the low carbon credentials of clean hydrogen is absolutely essential to making hydrogen a real solution to combat climate change. The UK showed leadership in establishing a national low carbon hydrogen standard, and the UAE could consider adopting it as a first step to promulgating an internationally recognised standard. Since both countries plan on making hydrogen from low carbon electricity and gas, it makes sense to join forces to establish this as a global norm.

Supporting demand is critical to kick-start the market

Directive policies that encourage demand are important, especially in hard-to-abate sectors. The UAE and UK are both focusing on the industry and transport sectors as drivers of domestic demand, creating space for complementary business opportunities. Governments have a role in developing the right macroconditions that put hydrogen on a level playing field with other energy technologies, namely through carbon pricing and detailed policies that outline hydrogen's role in achieving net zero commitments. Models like Germany's H2Global could be emulated in both the UAE and UK to overcome price barriers and manage market friction between producers and consumers.

The UAE and UK have opportunities to deepen innovation partnership and capitalise on complementary positions regarding early- and late-stage innovations and demonstrations.

The UK's early-stage innovation capabilities complement the UAE's later-stage scale-up focus. Strengthening links through pilot projects, joint research centres and testing facilities could unlock value in both countries. Forming a joint hydrogen platform for exchange between disciplines and sectors could help maximise 'learning by interacting' and accelerate innovation and cost reductions.

Efforts on joint investments and infrastructure development should be redoubled to meet the scale of the decarbonisation challenge.

With the global hydrogen pipeline at just 40% of what is required to achieve net zero, there remains open space for ambitious countries like the UAE and UK to move quickly and capture market share. The two countries could build on recent announcements to form even bigger investment partnerships, tapping the capital in the UAE's sovereign wealth funds and UK investors' appetite for international diversification. Complementary technical capabilities in large-scale infrastructure, including CCS, could also be leveraged.

Linking hydrogen businesses with education and training institutions in both countries will help ensure a prepared workforce.

Building links between the UAE and UK can help identify skills gaps and develop appropriate training programmes to fill them. While it may be early for cross-border training and international skills standards, both countries could identify the types of TVET that needs strengthening and how to best retrain the oil and gas workforce.

By working together, the UAE and UK can harness hydrogen's enormous economic potential and lead the global low carbon transition.

The two countries already have a special hydrogen relationship which can be strengthened to create greater alignment, facilitate business and innovation exchange, and accelerate the industry. Together, the two countries can become influential players in this emerging market.

Annex 1: **MOUs & bilateral agreements**

Agreements with the UK

Country	Type	Description	Link
Belgium	Technology, Partnership	The UK and Belgium have signed a memorandum of understanding (MOU) to work closely on the path towards decarbonisation and future energy interconnection. This memorandum of understanding deepens the UK and Belgium's bilateral relationship and enables closer working on important energy priorities including: multipurpose electricity interconnection offshore wind low carbon hydrogen carbon capture, usage and storage	https://hydrogen-central.com/uk-belgium-energy-cooperation-hydrogen/
UK (with Italian and German firms)	Partnership	The collaboration, in line with the UK government's ten point plan for green industrial revolution, will investigate the technical and commercial feasibility to work together on future low carbon project initiatives in the region. Eni UK currently owns and operates the oil and gas fields in Liverpool Bay, feeding gas extracted from the fields into the Uniper owned Connah's Quay power station in Flintshire. The MOU will support Uniper's investigations into future opportunities for blue and green hydrogen production at Uniper's site, capturing any CO2 produced as a by-product from the process.	https://www.eni.com/en-IT/media/press-release/2021/06/eni-hk-uniper-partnering-decarbonisation-north-wales-energy-sector.html
South Korea	Technology, Partnership	The UK and South Korea have signed a memorandum of understanding that will support the co-operation of the countries' respective government departments in working to deliver net zero emissions. BEIS permanent secretary Sarah Munby met with the Ministry of Trade, Industry and Energy Vice Minister Jin-Kyu Park on 24 September in order to enhance discussions between the two countries on energy, science, business and new technologies. The BEIS-MOTIE Industry and Energy Dialogue will act as a steering board for all existing bilateral collaboration between the UK and the Republic of Korea, including the Science, Technology and Innovation Partnership and the Civil Nuclear Dialogue.	https://www.gov.uk/government/publications/uk-and-south-korea-memorandum-of-understanding-mou-to-enhance-industrial-and-energy-cooperation

Country	Type	Description	Link
South Korea	Investment	UK fuel cell manufacturer Intelligent Energy (IE), South Korean partner Hogreen Air, and South Korea's largest manufacturer of electric buses and trucks Edison Motors sign MOU for fuel cell technology. During the H2World 2021 conference in Ulsan, South Korea on Friday 5 November, a memorandum of understanding (MOU) was signed by Jun-seong Weon (Director, Edison), Greg Harris (Sales Director, IE) and Seong-ho Hong Hong (CEO, Hogreen Air) at the stand of the British Embassy, Seoul. The MOU between the three parties aims to expand the hydrogen fuel cell market for motive applications in South Korea and shows the cooperation between the three companies to focus on integrating Intelligent Energy's fuel cells into a range of Edison vehicles and supporting Hogreen Air's collaboration with Edison Motors on unmanned aerial vehicles.	https://www.intelligent-energy.com/news-and-events/company-news/2021/11/19/intelligent-energy-signs-mou-with-south-korean-partner-hogreen-air-and-south-koreas-largest-manufacturer-of-electric-buses-and-trucks-edison-motors/
Norway	Investment, Partnership	Shell and Norsk Hydro have signed a memorandum of understanding to jointly produce and supply hydrogen produced from renewable electricity. The ambition is to use the hydrogen to help decarbonise Hydro's and Shell's own operations, and to supply customers in heavy industries, the maritime sector and road transport. It will be produced in hubs centred around Hydro and Shell's own business, and where they see strong potential for scaling production for customers in heavy industry and transport.	https://renews.biz/73523/shell-and-norsk-hydro-sign-green-hydrogen-mou/
Canada	Technology, Partnership	Accelerating to Net Zero with Hydrogen Blending Standards Development in the UK, Canada and the US Hydrogen is expected to play a critical role in the move to a net-zero economy. However, large-scale deployment is still in its infancy. Exciting pilot projects are being conducted and explored in the UK, Canada and US states such as California to determine the technical feasibility of blending hydrogen into existing natural gas systems. There is increasing interest around permitting significant percentage blends of hydrogen into gas networks, which would enable the carbon intensity of gas supplies to be reduced, create a new demand for hydrogen and, with the use of separation and purification technologies downstream, support the transportation of pure hydrogen to markets.	https://renews.biz/73523/shell-and-norsk-hydro-sign-green-hydrogen-mou/
Saudi Arabia	Technology	The Business Secretary Greg Clark has signed a Memorandum of Understanding (MoU) on Clean Energy with Saudi Arabia's Minister of Energy, Industry and Mineral Resources Khalid A Al-Falih. The MoU, signed at the Cabinet Office on Wednesday (7 March), commits the UK and Saudi Arabia to work closer than ever before on developing technologies that will reduce harmful carbon emissions while growing their respective economies.	https://www.gov.uk/government/news/uk-and-saudi-arabia-sign-memorandum-of-understanding-on-clean-energy

Country	Type	Description	Link
Mauritania	Technology	Mauritania has signed a memorandum of understanding (MoU) with UK oil and gas firm Chariot for a green hydrogen project of up to 10GW. The Project Nour agreement covers feasibility studies for one offshore and two onshore areas covering 14,400km². Chariot would use the areas to develop 10GW of solar and wind capacity to feed electrolysers producing green hydrogen.	https://www.windpowermonthly.com/article/1728892/planned-10gw-green-hydrogen-project-include-africas-first-offshore-wind-farm

Agreements with the UAE

Country	Type	Description	Link
France	Technology	Emirates Nuclear Energy Corporation (ENEC) has signed a memorandum of understanding (MoU) with France's EDF for cooperation on research and development (R&D) in the nuclear energy sector and the potential for collaboration in the production of green hydrogen from nuclear power. The MOU was signed at the UAE-France nuclear cooperation event E-Fusion, which was held in Dubai on 29-30 June 2021. The MoU sets out a path to develop the strategic partnership between ENEC and EDF through the sharing of expertise and advancements in the nuclear sector.	https://energy-utilities.com/uae-signs-nuclear-mou-with-france-s-edf-news113052.html
Germany	Technology, Investment	Mubadala Investment Company (Mubadala) and Siemens Energy have signed a Memorandum of Understanding (MOU) with the intention of creating a strategic partnership to drive investment and development of advanced technology, manufacture of equipment, and green hydrogen and synthetic fuel production.	https://www.mubadala.com/en/news/mubadala-and-siemens-energy-sign-mou-accelerate-green-hydrogen-capabilities-abu-dhabi
India	Partnership	Abu Dhabi's renewable energy company Masdar and Indian conglomerate firm Reliance Industries want to explore opportunities for collaboration in green hydrogen, which is a priority for the UAE and India.	https://www.offshore-energy.biz/uae-and-india-to-collaborate-on-clean-energy-and-green-hydrogen/
Israel	Investment, Technology	Energroup Limited, which specializes in sustainable investments and aims to stimulate private investment to promote the transition to a green economy with the development of Green Hydrogen plants, has signed a memorandum of understanding to develop blue and green hydrogen generation in Israel. Under the agreement, signed with the Israel Electric Corporation, the two parties will collaborate on the sourcing, development, implementation and operation of green and blue hydrogen projects.	https://www.offshore-energy.biz/uae-and-india-to-collaborate-on-clean-energy-and-green-hydrogen/

Country	Type	Description	Link
Italy	Investment, Partnership	As part of the agreement, the two companies will carry out a number of assessment activities, including technical and economic feasibility studies to explore potential projects and solutions to foster and promote hydrogen development in the UAE, and elsewhere globally. The MOU was signed by Musabbeh Al Kaabi, Chief Executive Officer of UAE Investments at Mubadala Investment Company (Mubadala), and Marco Alverà, Chief Executive Officer at Snam. The MOU reinforces the confidence of both Mubadala and Snam in the commercial and technological potential of the hydrogen industry, as well as its capacity to accelerate the energy transition.	https://www.snam.it/en/Media/Press-releases/2021/Snam_Mubadala_MoU_hydrogen_UAE.html
Japan	Partnership	This MOU is an agreement that both parties will collaborate in establishing a hydrogen-based society and pursuing the efficient use of water and electricity. The MOU will also provide for the exploration of whether or not potential hydrogen production that utilizes renewable energy is technically and commercially viable. Under the MOU, both parties will jointly implement research, development, and proofs of concept, as well as share their respective expertise and know-how in the areas of renewable energy, hydrogen production, supply and distribution.	https://www.marubeni.com/en/news/2020/release/20200120_2E.pdf
Malaysia	Partnership	Petroliam Nasional Bhd (Petronas) in a statement today said it had signed two Memoranda of Understanding (MoU) with United Arab Emirates (UAE)-based Abu Dhabi National Oil Company (ADNOC) and Masdar to pursue collaborations across the energy value chain. According to the national oil and gas (O&G) company, discussions between the parties began following Yang di-Pertuan Agong Al-Sultan Abdullah Ri'ayatuddin Al-Mustafa Billah Shah's five-day special visit to the UAE in December last year at the invitation of the Crown Prince of the Emirate of Abu Dhabi, Sheikh Mohamed Zayed Al Nahyan	https://www.theedgemarkets.com/article/petronas-inks-mous-abu-dhabi-national-oil-co-masdar
Morocco	Partnership	The International Renewable Energy Agency (IRENA) and the Ministry of Energy, Mines and Environment (MEME) of the Kingdom of Morocco have today agreed to strengthen joint collaboration to advance knowledge in renewable energy and to accelerate the energy transition. Specifically, IRENA and Morocco will work closely to advance the national green hydrogen economy as the country aims to become a major green hydrogen producer and exporter.	https://www.irena.org/newsroom/pressreleases/2021/Jun/Morocco-and-IRENA-Partner-to-Boost-Renewables-and-Green-Hydrogen-Development

Country	Type	Description	Link
Netherlands	Partnership	The UAE Ministry of Energy and Infrastructure and the Dutch Ministry for Foreign Trade and Development Cooperation have signed a Memorandum of Understanding (MoU) on hydrogen energy. The MOU was signed by Suhail bin Mohammed Al Mazrouei, Minister of Energy and Infrastructure, and the Dutch Minister for Foreign Trade and Development Cooperation, Liesje Schreinemacher, at the Netherlands Pavilion at Expo 2020 Dubai. As part of their Joint Economic Committee, the UAE and the Netherlands have been in structured dialogue to identify common interests & create a partnership for decarbonisation of the energy sector and increasing the use of clean hydrogen.	https://www.wam.ae/en/details/1395303032269
Russia	Technology	The UAE Ministry of Industry and Advanced Technology (MoIAT) signed a memorandum of understanding (MoU) with the Ministry of Industry and Trade of the Russian Federation to bolster industrial collaboration in hydrogen fuel technology. In line with their common objective to develop sustainable and reduced or emission-free energy sources, as well as achieve a carbon-neutral industrial sector while ensuring its continued growth, the collaboration will explore ways of supporting the production, storage, and transportation of hydrogen fuel.	https://www.zawya.com/en/business/uae-and-russia-sign-mou-on-hydrogen-technology-iraol311
Russia	Partnership	The UAE's Ministry of Industry and Advanced Technology and Russia's Ministry of Industry and Trade signed a memorandum of understanding (MoU) to collaborate on hydrogen develop-ment, particularly in the production, storage and transportation of the fuel. Under the agreement, the two countries will collaborate in the manufacture of equipment used in the production, liquefaction and use of raw hydrogen and fuel mixtures that use hydrogen as a main element.	https://www.iea.org/policies/14745-uae-and-russia-agreement-to-collaborate-on-hydrogen-development
South Korea	Technology	Nexonstar (South Korea) & Everise Construction (Abu Dhabi - UAE) have signed a cooperation Memorandum of Understanding (MOU) to jointly promote the green hydrogen production and application systems in the Middle East region. Nexonstar's water electrolysis green hydrogen production system is one of the world's most efficient green hydrogen production system, and based on its technology, Everise will provide the services to build Green Hydrogen production plant, on site type Green Hydrogen refueling station and Self-cycling energy Hydrogen Power system in the Middle East.	https://www.khaleejtimes.com/kt-network/nexonstar-and-everise-construction-signs-mou-to-promote-green-hydrogen-system-cooperation-in-middle


HYDROGEN
zero emission

References

1. UNFCCC. (2022). The Paris Agreement. https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
2. UK Government. (2021). UK's path to net zero set out in landmark strategy. https://www.gov.uk/government/news/uks-path-to-net-zero-set-out-in-landmark-strategy
3. UAE Government. (2021). UAE Net Zero 2050. https://u.ae/en/information-and-services/environment-and-energy/climate-change/theuaesresponsetoclimatechange/uae-net-zero-2050
4. UNFCCC. (2020). Second Nationally Determined Contribution of the United Arab Emirates. https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/United%20Arab%20Emirates%20Second/UAE%20Second%20NDC%20-%20UNFCCC%20Submission%20-%20English%20-%20FINAL.pdf
5. UK Government. (2021). UK enshrines new target in law to slash emissions by 78% by 2035. https://www.gov.uk/government/news/uk-enshrines-new-target-in-law-to-slash-emissions-by-78-by-2035
6. WAM. (2021). UAE announces Hydrogen Leadership Roadmap, reinforcing Nation's commitment to driving economic opportunity through decisive climate action. https://www.wam.ae/en/details/1395302988986
7. HMG. (2021). UK Hydrogen Strategy. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1011283/UK-Hydrogen-Strategy_web.pdf
8. OPEC. (2021). UAE facts and figures. https://www.opec.org/opec_web/en/about_us/170.htm
9. Dubai Future Foundation. (2021). Hydrogen: From hype to reality. https://www.dubaifuture.ae/wp-content/uploads/2021/10/Hydrogen-From-Hype-to-Reality-EN-v1.0.pdf
10. HMG. (2021). UK Hydrogen Strategy. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1011283/UK-Hydrogen-Strategy_web.pdf
11. IEA. (2021). Global hydrogen review 2021. https://iea.blob.core.windows.net/assets/5bd46d7b-906a-4429-abda-e9c507a62341/GlobalHydrogenReview2021.pdf
12. World Bank. (2022). Total greenhouse gas emissions (ktCO2e). https://data.worldbank.org/indicator/EN.ATM.GHGT.KT.CE
13. BEIS. (2021). 2021 UK Provisional Greenhouse Gas Emissions. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1064921/2021-uk-ghg-provisional-figures-statistical-summary.pdf
14. Broadleaf. (2022). Resource material: The colours of hydrogen. https://broadleaf.com.au/resource-material/the-colour-of-hydrogen/
15. IEA. (2021). Global Hydrogen Review 2021. https://iea.blob.core.windows.net/assets/5bd46d7b-906a-4429-abda-e9c507a62341/GlobalHydrogenReview2021.pdf
16. Howarth, RW, Jacobson, MZ. How green is blue hydrogen? Energy Sci Eng. 2021; 9: 1676– 1687. https://doi.org/10.1002/ese3.956
17. Hydrogen Council. (2021). Hydrogen decarbonization pathways: A life-cycle assessment. https://hydrogencouncil.com/wp-content/uploads/2021/01/Hydrogen-Council-Report_Decarbonization-Pathways_Part-1-Lifecycle-Assessment.pdf
18. BEIS. (2022). The UK Low Carbon Hydrogen Standard. https://www.gov.uk/government/publications/uk-low-carbon-hydrogen-standard-emissions-reporting-and-sustainability-criteria
19. 20 grams of carbon dioxide equivalent per megajoule (Lower Heating Value)
20. Khalifa University. (2022). Research and Innovation Center on CO2 and Hydrogen. https://www.ku.ac.ae/rich
21. ISO. (2022). Stages and resources for standards development. https://www.iso.org/stages-and-resources-for-standards-development.html
22. Qamar Energy. (2021). The UAE's role in the global hydrogen economy. (2021). https://qamarenergy.com/sites/default/files/The%20UAE's%20Role%20in%20the%20Global%20Hydrogen%20Economy.pdf
23. EWEC. (2020). Abu Dhabi Power Corporation Announces Lowest Tariff for Solar Power in the World. https://www.ewec.ae/en/media/press-release/abu-dhabi-power-corporation-announces-lowest-tariff-solar-power-world

24. IRENA. (2015). Renewable energy prospects: United Arab Emirates. https://www.irena.org/-/media/-Files/IRENA/Agency/Publication/2015/IRENA_REmap_UAE_report_2015.pdf

25. UK Government. (2022). Offshore wind. https://www.great.gov.uk/international/content/investment/sec-tors/offshore-wind/

26. UK Government. (2022). British Energy Security Strategy. https://www.gov.uk/government/publications/brit-ish-energy-security-strategy/british-energy-security-strategy#renewables

27. BEIS. (2022). Solar photovoltaic deployment. https://www.gov.uk/government/statistics/solar-photovolta-ics-deployment

28. Solar Energy UK. (2021). Lighting the way making net zero a reality with solar energy. https://solarener-gyuk.org/wp-content/uploads/2021/06/Lighting-the-way-report.pdf

29. Climate Change Committee. (2022). Update to Parliament. https://www.theccc.org.uk/wp-content/up-loads/2022/06/Progress-in-reducing-emissions-2022-Report-to-Parliament.pdf

30. Energy UK. (2022). Nuclear generation. https://www.energy-uk.org.uk/our-work/generation/nuclear-generation

31. Emirates Nuclear Energy Corporation. (2022). Barakah Nuclear Energy Plant. https://www.enec.gov-.ae/barakah-plant/

32. OPEC. (2021). UAE facts and figures. https://www.opec.org/opec_web/en/about_us/170.htm

33. BP. (2021). Statistical review of world energy. https://www.bp.com/en/global/corporate/energy-economics/stat-istical-review-of-world-energy.html

34. Proton. (2022. Our process. https://proton.energy/our-process/

35. UAE Ministry of Energy and Infrastructure. (2021). UAE Hydrogen Leadership Roadmap. Personal communica-tion 30 March 2022.

36. IEA. (2021). Hydrogen. https://www.iea.org/reports/hydrogen

37. IEA. (2021). Global Hydrogen Review 2021. https://iea.blob.core.windows.net/as-sets/5bd46d7b-906a-4429-abda-e9c507a62341/GlobalHydrogenReview2021.pdf

38. Note: The Hydrogen Council's 2050 estimate was revised in 2021 to 620 Mt comprising 22% of final energy demand for hydrogen. Hydrogen Council (2021). Hydrogen for net zero. https://hydrogencouncil.com/wp-content/up-loads/2021/11/Hydrogen-for-Net-Zero_Full-Report.pdf

39. Energy Transitions Commission. (2021). Making the hydrogen economy possible: Accelerating clean hydrogen in an electrified economy. https://energy-transitions.org/wp-content/up-loads/2021/04/ETC-Global-Hydrogen-Report.pdf

40. WAM. (2021). UAE announces Hydrogen Leadership Roadmap. https://www.wam.ae/en/details/1395302988986

41. UK Government. (2022). Hydrogen investor roadmap. https://assets.publishing.service.gov.uk/government/up-loads/system/uploads/attachment_data/file/1067408/hydrogen-investor-roadmap.pdf

42. European Commission. (2022). REPowerEU: A plan to rapidly reduce dependence on Russian fossil fuels and fast forward the green transition. https://ec.europa.eu/commission/presscorner/detail/en/IP_22_3131

43. UK Government. (2021). UK Hydrogen Strategy. https://assets.publishing.service.gov.uk/government/up-loads/system/uploads/attachment_data/file/1011283/UK-Hydrogen-Strategy_web.pdf

44. Scottish Government. (2020). Scottish Government Hydrogen Policy Statement. https://www.gov.scot/publica-tions/scottish-government-hydrogen-policy-statement/documents/

45. Crown Estate Scotland. (2022). ScotWind offshore wind leasing delivers major boost to Scotland's net zero aspirations. https://www.crownestatescotland.com/news/scotwind-off-shore-wind-leasing-delivers-major-boost-to-scotlands-net-zero-aspirations

46. Edie. (2021). Scotland outlines plans to double onshore wind capacity by 2030, ramp up regenerative agriculture. https://www.edie.net/news/11/Scotland-outlines-plans-to-dou-ble-onshore-wind-capacity-by-2030--ramp-up-regenerative-agriculture/#:~:text=On%20onshore%20wind%2C%20Scotland%20currently,up%20to%20an%20additional%2012GW

47. SNP. (2022). Massive investment in Scotland's offshore wind. https://www.snp.org/massive-investment-in-scot-lands-off-shore-wind/#:~:text=The%2017%20new%20offshore%20wind,in%20construction%20or%20advanced%20development

48. IRENA. (2022). Geopolitics of the Energy Transformation: The Hydrogen Factor. https://www.irena.org/publica-tions/2022/Jan/Geopolitics-of-the-Energy-Transformation-Hydrogen

49. IRENA. (2022). Geopolitics of the Energy Transformation: The Hydrogen Factor. https://www.irena.org/publications/2022/Jan/Geopolitics-of-the-Energy-Transformation-Hydrogen

50. UK Government. (2021). United Kingdom – United Arab Emirates Joint Communiqué: a Partnership for the Future. https://www.gov.uk/government/news/united-kingdom-united-arab-emirates-joint-communique-a-partnership-for-the-future

51. Mubadala. (2021). UAE to Invest £10 Billion In Priority UK Industries https://www.mubadala.com/en/news/uae-and-uk-launch-sovereign-investment-partnership

52 UAE Ministry of Foreign Affairs and International Cooperation. (2021). Joint Communiqué: a Partnership for the Future. https://www.mofaic.gov.ae/en/mediahub/news/2021/9/17/17-09-2021-uae-joint-statement

53. bp. (2021). bp, ADNOC and Masdar to form strategic partnership to provide clean energy solutions for UK and UAE. https://www.bp.com/en/global/corporate/news-and-insights/press-releases/bp-adnoc-and-masdar-to-form-strategic-partnership-to-provide-clean-energy-solutions-for-uk-and-uae.html

54. EV Volumes. (2022). Global EV sales for 2021. https://www.ev-volumes.com

55. M. Dijk, & M. Yarime. The emergence of hybrid-electric cars: Innovation path creation through coevolution of supply and demand. Technological Forecasting & Social Change 77 (2010) 1371–1390.

56. https://www.sciencedirect.com/science/article/pii/S004016251000106X

57. Survey questions – Where 1 is extremely important and 6 is not at all important, how important is it to: Stimulate demand, e.g. through public procurement policies, carbon pricing, decarbonisation regulations (Stimulate demand); Support hydrogen consumers, e.g. through policies that decrease up-front costs of equipment that uses hydrogen or by subsidizing hydrogen costs (Support hydrogen consumers)

58. Survey questions – Where 1 is extremely important and 6 is not at all important, how important is it to: Develop a hydrogen hierarchy and focus policy initiatives at “high-value” / “hard-to-abate” sectors (e.g. fertiliser, steel, shipping & aviation, chemicals) (Directed policy approach); Create a level playing field that encourages a low-carbon future (e.g. remove fossil fuel subsidies and put a price on carbon) and let markets and prices determine where and how hydrogen is used (Free market approach)

59. UAE Government. (2021). UAE Net Zero 2050. https://u.ae/en/information-and-services/environment-and-energy/climate-change/theuaesresponsetoclimatechange/uae-net-zero-2050

60. UK Government. (2021). UK's path to net zero set out in landmark strategy. https://www.gov.uk/government/news/uks-path-to-net-zero-set-out-in-landmark-strategy

61. OECD. (2021). Carbon pricing in the United Kingdom. https://www.oecd.org/tax/tax-policy/carbon-pricing-united-kingdom.pdf

62. OECD. (2016). Effective Carbon Rates. Pricing CO2 through Taxes and Emissions Trading Systems. https://read.oecd.org/10.1787/9789264260115-en?format=pdf

63. IRENA. (2020). Green hydrogen: A guide to policymaking. https://irena.org/publications/2020/Nov/Green-hydrogen

64. Survey questions –Where 1 is extremely important and 6 is not at all important, how important is it to: Add additional policy detail around the national net zero targets that have been announced to specify how hydrogen is expected to fit into the decarbonisation plan and build confidence in the future market; Encourage more corporate net-zero targets to send demand signals to hydrogen stakeholders about their potential interest in hydrogen; Apply a carbon price to greenhouse gas emissions to strengthen the commercial case for low-carbon hydrogen as an alternative to higher-carbon fuels like natural gas, coal or petrol;

65. Dubai Future Foundation. (2021). Hydrogen: from hype to reality. https://www.dubaifuture.ae/wp-content/uploads/2021/10/Hydrogen-From-Hype-to-Reality-EN-v1.0.pdf

66. Liebreich Associates. (2021). The clean hydrogen ladder. https://www.linkedin.com/pulse/clean-hydrogen-ladder-v40-michael-liebreich/

67. Ueckerdt, Falko & Bauer, Christian & Dirnaichner, Alois & Everall, Jordan & Sacchi, Romain & Luderer, Gunnar. (2021). Potential and risks of hydrogen-based e-fuels in climate change mitigation. Nature Climate Change. 11. 1-10. 10.1038/s41558-021-01032-7. https://www.researchgate.net/publication/351376346_Potential_and_risks_of_hydrogen-based_e-fuels_in_climate_change_mitigation

68. TAQA. (2021). TAQA Group, Emirates Steel to Enable the Region's First Green Steel Manufacturing. https://www.taqa.com/press-releases/greensteel/

69. Chemanager. (2021). Fertiglobe Collaborates on Green Hydrogen in UAE. https://www.chemanager-online.com/en/news/fertiglobe-collaborates-green-hydrogen-uae

70. Adnoc. (2021). Fertiglobe Joins TA'ZIZ as Partner in World-Scale Blue Ammonia Project in Ruwais. https://www.adnoc.ae/news-and-media/press-releases/2021/fertiglobe-joins-taziz-as-partner-in-world-scale-blue-ammonia-project-in-ruwais

71. HMG. (2021). Industrial Decarbonisation Strategy. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/970229/Industrial_Decarbonisation_Strategy_March_2021.pdf

72. BEIS. (2021). Industrial Fuel Switching competition. https://www.gov.uk/government/publications/industrial-fuel-switching-competition

73. BEIS. (2022). Industrial Hydrogen Accelerator Programme. https://www.gov.uk/government/publications/industrial-hydrogen-accelerator-programme

74. HMG. (2021). Industrial Decarbonisation Strategy. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/970229/Industrial_Decarbonisation_Strategy_March_2021.pdf

75. DFF. (2021). Hydrogen: From hype to reality. https://www.dubaifuture.ae/wp-content/uploads/2021/10/Hydrogen-From-Hype-to-Reality-EN-v1.0.pdf

76. UK Department for Transport. (2020). UK embraces hydrogen-fuelled future as transport hub and train announced. https://www.gov.uk/government/news/uk-embraces-hydrogen-fuelled-future-as-transport-hub-and-train-announced

77. City of London. (2021). Cleaner buses. https://www.london.gov.uk/what-we-do/environment/pollution-and-air-quality/cleaner-buses

78. UK Government. (2021). UK Hydrogen Strategy. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1011283/UK-Hydrogen-Strategy_web.pdf

79. First Aberdeen. (2021). Hydrogen buses. https://www.firstbus.co.uk/aberdeen/plan-journey/zero-emission-mission/hydrogen-buses

80. BEIS. (2021). Apply for the Red Diesel Replacement competition Phase 1. https://www.gov.uk/government/publications/red-diesel-replacement-competition

81. IATA. (2020). Fact sheet 7: Liquid hydrogen as a potential low carbon fuel for aviation. https://www.iata.org/contentassets/d13875e9ed784f75bac90f000760e998/fact_sheet7-hydrogen-fact-sheet_072020.pdf

82. Fuel Cells and Hydrogen 2 Joint Undertaking, Hydrogen-powered aviation – a fact-based study of hydrogen technology, economics, and climate impact by 2050, Publications Office, 2020, https://data.europa.eu/doi/10.2843/766989

83. TotalEnergie. (2022). United Arab Emirates: TotalEnergies joins Masdar and Siemens Energy in initiative to drive green hydrogen development and produce Sustainable Aviation Fuel. https://totalenergies.com/media/news/press-releases/united-arab-emirates-totalenergies-joins-masdar-and-siemens-energy

84. Survey questions – Where 1 is extremely important and 6 is not at all important, how important is it to: Encourage domestic demand for hydrogen to kick-start the industry at home (e.g. through grants, loans, local or regional strategies and local trials); Use government procurement of public assets (e.g. buses, ferries, fleets) to kickstart demand for hydrogen and raise awareness about hydrogen in the public sphere.

85. Survey question – Please rank the following from "top priority" (1) to "lowest priority" (5) in terms of encouraging the development of a clean hydrogen industry: Carbon pricing, Corporate net zero targets, National net zero targets, Local demand focus, Public procurement.

86 Survey question: Where 1 is extremely important and 6 is not at all important, how important is it to support hydrogen producers by stimulating supply, e.g. through public offtake agreements, production subsidies, guarantees, tax measures

87 Survey question: Where 1 is extremely important and 6 is not at all important, how important is it to provide public credit guarantees to reduce the risks of lending to hydrogen producers

88 Green Finance Institute. (2022). Green finance guarantee facility. https://www.greenfinanceinstitute.co.uk/programmes/green-finance-guarantee-facility/

89 UK Export Finance. (2020). Export Development Guarantee. https://www.gov.uk/guidance/export-development-guarantee#clean-growth

90 UK Export Finance. (2021). UKEF backs landmark £430 million green transition loan for Wood Plc. https://www.gov.uk/government/news/ukef-backs-landmark-430-million-green-transition-loan-for-wood-plc

91 UK Government. (2022). Capital claim allowances. https://www.gov.uk/capital-allowances/first-year-allowances

92. Survey question – Where 1 is extremely important and 6 is not at all important, how important is it to encourage Enhanced Oil Recovery using CCS to create a market for captured carbon, thereby reducing the cost of blue hydrogen

93. Research and markets. (2021). Oxygen Global Market Report 2021: COVID-19 Impact and Recovery to 2030. https://www.researchandmarkets.com/reports/5323078/oxygen-global-market-report-2021-covid-19-impact

94. Allied market research. (2018). Carbon Black Market Outlook – 2026. https://www.alliedmarketresearch.com/carbon-black-market

95. Energy Transition. (2021). CCS Seduction IV: A new dawn for the oil industry goes Nova. https://energytransition.org/2021/01/ccs-seduction-iv-a-new-dawn-for-the-oil-industry-goes-nova/

96. SPS International. (2021). UAE plans to boost output by 30% through development in enhanced oil recovery (EOR). https://www.sps-ich.com/2015/11/uae-plans-boost-output-30-development-enhanced-oil-recovery-eor/
97. Forbes. (2021). Address blue hydrogen feedback. https://www.forbes.com/sites/rrapier/2021/09/04/addressing-blue-hydrogen-feedback/?sh=5301db497851
98. IRENA. (2021). Green hydrogen supply: A guide to policy making. https://irena.org/-/media/Files/IRENA/Agency/Publication/2021/May/IRENA_Green_Hydrogen_Supply_2021.pdf
99. NREL. (2010). A Policymaker's Guide to Feed-in Tariff Policy Design. https://www.nrel.gov/docs/fy10osti/44849.pdf
100. Low Carbon Contracts Company. (2022). Contracts for Difference. https://www.cfdallocationround.uk/
101. BEIS. (2022). Consultation outcome: Design of a business model for low carbon hydrogen. https://www.gov.uk/government/consultations/design-of-a-business-model-for-low-carbon-hydrogen
102. Survey questions – Where 1 is extremely important and 6 is not at all important, how important is it to: Provide subsidies to hydrogen producers per unit of hydrogen sold (Feed-in Tariff); Provide subsidies per unit of hydrogen sold equivalent to the difference between supply prices (production and transport) and demand prices (the wholesale price or "strike price" for hydrogen) (Contracts for Difference). BEIS. (2022). Consultation outcome: Design of a business model for low carbon hydrogen. https://www.gov.uk/government/consultations/design-of-a-business-model-for-low-carbon-hydrogen
103. H2Global. (2022). How to deliver on the EU Hydrogen Accelerator. http://files.h2-global.de/H2Global_How-to-deliver-on-the-EU-Hydrogen-Accelerator.pdf
104. H2Global Stiftung. (2022). The H2Global mechanism. https://www.h2-global.de/project/h2g-mechanism
105. Survey question – Where 1 is extremely important and 6 is not at all important, how important is to: Provide government-backed long-term offtake agreements to provide certainty to producers and reduce risks for lenders (Offtake agreements); Similar to the Contracts for Difference (CfD) approach, provide subsidies equivalent to the difference between supply prices and demand prices, but discover supply prices and demand prices through a double-auction. The government effectively becomes the primary off-taker and the primary wholesaler by buying and selling large pools of hydrogen (German H2Global model).
106 European Commission. (2022). Commission launches consultations on the regulatory framework for renewable hydrogen. https://ec.europa.eu/info/news/commission-launches-consultation-regulatory-framework-renewable-hydrogen-2022-may-20_en
107 Survey question: Please rank the following from "top priority" (1) to "lowest priority" (6) in terms of facilitating the development of a clean hydrogen industry. Credit Guarantees, Offtake Agreements, Feed-in-Tariffs, Contracts for Difference, German "H2Global" Model, Enhanced Oil Recovery
108 ADQ is a holding company with portfolio companies including Abu Dhabi Ports, Abu Dhabi Airports, Etihad Rail, Etihad Steel, Abu Dhabi National Energy Company (TAQA) and Emirates Nuclear Energy Corporation (ENEC), Agthia and others.
109 WAM. (2021). Ministry of Energy and Infrastructure joins 'Abu Dhabi Hydrogen Alliance'. https://wam.ae/en/details/1395302913342
110. Mubadala. (2022). TAQA, ADNOC & Mubadala Enter Binding Agreements for Acquisition of Masdar Stake. https://www.mubadala.com/en/news/taqa-adnoc-mubadala-enter-binding-agreements-acquisition-masdar-stake
111. Masdar. (2021). Masdar leads initiative to support development of Abu Dhabi's green hydrogen economy. https://news.masdar.ae/en/press%20Release?rsuWw+EzkpcdKH4JI-BOmfO3fzCPnRBu2jCfP90BKc5ilBa7S4ZPypgBaB/QjqwA7
112. DEWA. (2021). Under the patronage and presence of Ahmed bin Saeed Al Maktoum

Dubai inaugurates Green Hydrogen project at Mohammed bin Rashid Al Maktoum Solar Park. https://www.dewa.gov.ae/en/about-us/media-publications/latest-news/2021/05/green-hydrogen-project
113. MENA Hydrogen Alliance. (2022). https://dii-desertenergy.org/mena-hydrogen-alliance/
114. Survey question – Where 1 is extremely important and 6 is not at all important, how important is it to support coordination among the supply chain to facilitate integration across the sector.
115. BEIS. (2021). The grand challenge missions. https://www.gov.uk/government/publications/industrial-strategy-the-grand-challenges/missions
116. UK Government. (2021). What is the industrial cluster mission? https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/803086/industrial-clusters-mission-infographic-2019.pdf
117. These are: UK Hydrogen and Fuel Cell Association, Hydrogen UK, Scottish Hydrogen & Fuel Cell Association, HyCymru Wales, Midlands Hydrogen and Fuel Cell Network, Hydrogen East, North West Hydrogen Alliance, UK H2 Mobility
118. These are: British Compressed Gases Association, EnergyUK, Renewables UK, Decarbonised Gas Alliance, REA (Associates for Renewable Energy and Clean Technology), Oil & Gas UK, Energy Intelligence Centre

119. Clean H2 Limited. (2022). Personal communication. http://www.cleanh2limited.com/
120. Hy4Heat. (2022). https://www.hy4heat.info/
121. Catapult Network. (2021). Accelerating a UK hydrogen economy. https://catapult.org.uk/wp-content/uploads/2021/04/9384_Accelerating-a-UK-Hydrogen-Economy-1.pdf
122. National Composites Centre. (2022). Hydrogen innovation initiative. https://www.nccuk.com/what-we-do/hydrogen/hydrogen-innovation-initiative/
123. Survey question – Please rank the following from "top priority" (1) to "lowest priority" (6) in terms of facilitating the development of a clean hydrogen industry. Directive policy approach; Free market approach; Stimulating demand; Stimulating Supply; Support hydrogen consumers; Support the supply chain.
124. Energy Transitions Commission. (2021). Making the hydrogen economy possible. https://energy-transitions.org/wp-content/uploads/2021/04/ETC-Global-Hydrogen-Report.pdf
125. IEA. (2021). Global hydrogen review. https://iea.blob.core.windows.net/assets/5bd46d7b-906a-4429-abda-e9c507a62341/GlobalHydrogenReview2021.pdf
126. Survey questions – Where 1 is extremely important and 6 is not at all important, how important is it to: Direct investments towards innovation for electrolysers to drive down the cost of green hydrogen (electrolyser focus); Support innovation for "turquoise" hydrogen (i.e. methane pyrolysis / plasma pyrolysis / gas-to-graphene) using gas and renewable electricity as inputs to produce low carbon hydrogen without needing CCS. (Turquoise hydrogen).
127. IEA. (2021). Global hydrogen review. https://iea.blob.core.windows.net/assets/5bd46d7b-906a-4429-abda-e9c507a62341/GlobalHydrogenReview2021.pdf
128. A. Elia, M. Kamidelivand, F. Rogan, B. Ó Gallachóir. Impacts of innovation on renewable energy technology cost reductions, Renewable and Sustainable Energy Reviews, Volume 138, 2021, 110488, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2020.110488.
129. IEA. (2020). Energy Technology Perspectives 2020. Special report on clean energy innovation. https://iea.blob.core.windows.net/assets/04dc5d08-4e45-447d-a0c1-d76b5ac43987/Energy_Technology_Perspectives_2020_-_Special_Report_on_Clean_Energy_Innovation.pdf
130. World Intellectual Property Organization. (2021). Global Innovation index 2021: 14th edition. https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2021.pdf
131. World Intellectual Property Organization. (2022). Global Innovation Index. https://www.wipo.int/publications/en/series/index.jsp?id=129
132. World Intellectual Property Organization. (2021). Global Innovation Index 2020: United Arab Emirates. https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2020/ae.pdf
133. WIPO. (2022). Global Innovation Index 2021. https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2021.pdf
134. Scotland's Hydrogen Accelerator. (2022). Homepage. https://h2-accelerator.org/
135. National Grid. (2020). Hydrogen: Testing the heating fuel of the FutureGrid. https://www.nationalgrid.com/uk/stories/journey-to-net-zero-stories/hydrogen-testing-heating-fuel-futuregrid
136. Catapult Network. (2021). Accelerating a UK hydrogen economy. https://catapult.org.uk/wp-content/uploads/2021/04/9384_Accelerating-a-UK-Hydrogen-Economy-1.pdf
137. TERC. (2022). About us. https://terc.ac.uk/
138. IDRIC. (2020). Homepage. https://idric.org/
139. Khalifa University. (2022). RICH. https://www.ku.ac.ae/rich
140. Masdar. (2021). Masdar leads initiative to support development of Abu Dhabi's green hydrogen economy. https://news.masdar.ae/en/press%20Release?rsuWw+EzkpcdKH4JlBOmfO3fzCPnRBu2jCfP90BKc5ilBa7S4ZPypgBaB/QjqwA7
141. Net Zero Technology Centre. (2022). Net Zero Technology Centre announces new TechX Accelerator Strategic Partnership with ADNOC. https://www.netzerotc.com/news-events/news/news/2022/net-zero-technology-centre-announces-new-techx-accelerator-strategic-partnership-with-adnoc/
142. Survey questions – Where 1 is extremely important and 6 is not at all important, how important is it to: Establish accelerators to support innovators develop new technology, build business skills and bring technology to market; Establish large-scale national testing centres so that new technology can be tested and validated.
143. A. Elia, M. Kamidelivand, F. Rogan, B. Ó Gallachóir. Impacts of innovation on renewable energy technology cost reductions, Renewable and Sustainable Energy Reviews, Volume 138, 2021, 110488, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2020.110488.
144. Blackstone Resilience. (2022). Hydrocarbon engineering (HE) sustainable production of green energy from water. Personal communication.

145. A. Elia, M. Kamidelivand, F. Rogan, B. Ó Gallachóir. Impacts of innovation on renewable energy technology cost reductions, Renewable and Sustainable Energy Reviews, Volume 138, 2021, 110488, ISSN 1364-0321, https://-doi.org/10.1016/j.rser.2020.110488.

146. IRENA. (2022). Geopolitics of the Energy Transformation: The Hydrogen Factor. https://www.irena.org/publications/2022/Jan/Geopolitics-of-the-Energy-Transformation-Hydrogen

147. Survey questions – Where 1 is extremely important and 6 is not at all important, how important is it to: Support investment into early-stage innovations that prioritises the development of new technologies and new methods; Direct investment towards pilot projects to test new technologies, build learning and provide a safe testing environment before scaling up.

148. DEWA. (2022). Green hydrogen project. https://www.dewa.gov.ae/en/about-us/media-publications/latest-news/2022/03/green-hydrogen

149. Bee'ah Group. (2022). Bee'ah energy. https://www.beeahgroup.com/services/beeah-energy/

150. Innovate UK. (2022). Innovate UK funded projects since 2004. https://www.ukri.org/publications/innovate-uk-funded-projects-since-2004/

151. EMEC. (2021). Personal communication.

152. EMEC. (2022). Hydrogen projects. https://www.emec.org.uk/projects/hydrogen-projects/

153. BEIS. (2022). Net zero innovation portfolio. https://www.gov.uk/government/collections/net-zero-innovation-portfolio

154. BEIS. (2018). Low Carbon Hydrogen Supply Competition. https://www.gov.uk/government/publications/hydrogen-supply-competition

155. BEIS. (2022). Industrial Hydrogen Accelerator Programme. https://www.gov.uk/government/publications/industrial-hydrogen-accelerator-programme

156. BEIS. (2021). Industrial Fuel Switching Competition. https://www.gov.uk/government/publications/industrial-fuel-switching-competition

157. BEIS. (2021). Green Distilleries Competition. https://www.gov.uk/government/publications/green-distilleries-competition

158. BEIS. (2022). Hydrogen BECCS Innovation Programme. https://www.gov.uk/government/publications/hydrogen-beccs-innovation-programme

159. Survey question: Please rank the following from "top priority" (1) to "lowest priority" (6) with respect to innovation to advance the hydrogen sector: Electrolyser Focus; Pilot projects; National Test Centres; Hydrogen accelerators; Turquoise" hydrogen; Early-stage research

160. Hydrogen Council. (2021). Hydrogen investment pipeline grows to $500 billion in response to government commitments to deep decarbonisation. https://hydrogencouncil.com/en/hydrogen-insights-updates-july2021/

161. IEA. (2021). Global hydrogen review 2021. https://www.iea.org/reports/global-hydrogen-review-2021/executive-summary

162. IRENA. (2020). Investment needs. https://www.irena.org/financeinvestment/Investment-Needs

163. Adnoc. (2020). H.H. Sheikh Mohamed bin Zayed Commends ADNOC's Agility and Resilience at SPC Meeting. https://www.adnoc.ae/news-and-media/press-releases/2020/hh-sheikh-mohamed-bin-zayed-commends-adnocs-agility-and-resilience-at-spc-meeting

164. Engie. (2021). ENGIE and Masdar form US$5 billion strategic alliance to drive UAE's green hydrogen economy. https://www.engie.com/en/journalists/press-releases/engie-and-masdar-form-us-5-billion-strategic-alliance-to-drive-uae-s-green-hydrogen-economy

165. The National. (2021). Abu Dhabi's Kizad to develop $1bn green ammonia plant. https://www.thenationalnews.com/business/energy/abu-dhabi-s-kizad-to-develop-1bn-green-ammonia-plant-1.1229632

166. The National. (2021). Taqa and Abu Dhabi Ports to develop 2 gigawatt green ammonia facility. https://www.thenationalnews.com/business/energy/2021/07/07/-taqa-and-abu-dhabi-ports-to-develop-2-gigawatt-green-ammonia-facility/

167. UK Government. (2021). UK Hydrogen Strategy. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1011283/UK-Hydrogen-Strategy_web.pdf

168. Renews. (2021). UK green hydrogen opportunity valued at '£23bn in 2030'. https://renews.biz/73222/uk-green-hydrogen-opportunity-valued-at-23bn-in-2030/

169. Survey question – Where 1 is extremely important and 6 is not at all important, how important is it to develop relationships between producers, supply chain actors, off-takers, and lenders to improve coordination and help put together a bankable project

170 Survey question – Where 1 is extremely important and 6 is not at all important, how important is it to upskill bankers on risk assessments for hydrogen projects to fairly and accurately assess risk and offer competitive financing terms

171. International Economic Development Council. (2010). Analysis of the offshore wind energy industry. https://www.iedconline.org/clientuploads/Downloads/edrp/IEDC_Offshore_Wind.pdf

172. Natural Resources Defense Council. (2020). State of Green Banks 2020. https://www.nrdc.org/sites/default/files/state-green-banks-2020-report.pdf

173. Survey question – Where 1 is extremely important and 6 is not at all important, how important is it to establish public banks to provide financing and technical assistance that decreases risks and helps attract private investment

174. UK National Archives. (2011). Financing the UK Green Investment Bank. https://webarchive.nationalarchives.gov.uk/ukgwa/20120717011339/http://bis.gov.uk/policies/business-sectors/green-economy/gib/detail

175. Macquarie. (2022). Green Investment Group. https://www.greeninvestmentgroup.com/en.html

176. UKIB. (2022). Homepage. https://www.ukib.org.uk/

177. Green Finance Institute. (2021). The role of a UK National Infrastructure Bank in a green recovery. https://www.greenfinanceinstitute.co.uk/wp-content/uploads/2020/12/GREEN-FINANCE-INSIGHTS-PAPER.pdf

178. Masdar. (2022). Overview. https://masdar.ae/en/Masdar-Clean-Energy/Overview

179. Masdar (2018). Masdar Signs Region's First Green Revolving Credit Facility to Drive Sustainability Goals. https://news.masdar.ae/en/news/2018/11/28/09/48/masdar-signs-regions-first-green-revolving-credit-facility-to-drive-sustainability-goals

180. Masdar. (2022). Masdar green REIT. https://masdar.ae/en/masdar-city/business-at-masdar-city/masdar-green-reit

181. EDB. (2022). Homepage. https://www.edb.gov.ae/en

182. Survey question – Where 1 is extremely important and 6 is not at all important, how important is it to: Develop case studies of successful projects to generate confidence in the financial and technical viability of hydrogen projects (e.g. to investors, policymakers, consumers); Support highly visible examples of projects (e.g. hydrogen buses) to normalise hydrogen and raise confidence for stakeholders.

183. Survey question – Please rank the following from "top priority" (1) to "lowest priority" (5) with respect to what is both most effective and practical currently or in the near future: Bankable Structures; Bank risk assessors; Green Investment Banks; Case studies; Public-facing examples.

184. UAE Ministry of Foreign Affairs and International Cooperation. (2021). Joint Communiqué: a Partnership for the Future. https://www.mofaic.gov.ae/en/mediahub/news/2021/9/17/17-09-2021-uae-joint-statement

185. bp. (2022). Abu Dhabi's ADNOC and Masdar to join bp's UK hydrogen projects. https://www.bp.com/en/global/corporate/news-and-insights/press-releases/abu-dhabis-adnoc-and-masdar-to-join-bps-uk-hydrogen-projects.html

186. Proton. (2022). Homepage. https://proton.energy/

187. Survey questions – Where 1 is extremely important and 6 is not at all important, how important is it to: Build new hydrogen infrastructure (pipelines, storage facilities, electricity transmission lines for green hydrogen, etc.); Refurbish existing onshore infrastructure (e.g. facilities, pipelines, small pool storage) to accelerate hydrogen deployment and minimise stranded assets; Refurbish existing offshore infrastructure (e.g. oil and gas platforms, pipelines, offshore wind), to accelerate hydrogen deployment and minimise stranded assets.

188. BEIS. (2021). The grand challenge missions. https://www.gov.uk/government/publications/industrial-strategy-the-grand-challenges/missions

189. National Grid. (2022). Making plans for a hydrogen 'backbone' across Britain. https://www.nationalgrid.com/stories/journey-to-net-zero-stories/making-plans-hydrogen-backbone-across-britain

190 Survey question – Where 1 is extremely important and 6 is not at all important, how important is it to establish large factories to produce hydrogen equipment (e.g. electrolyzers, fuel cells) to support production at a massive scale and lower cost.

191 Survey question – Where 1 is extremely important and 6 is not at all important, how important is it to refurbish existing equipment that uses hydrogen (e.g. gas turbines, boilers) to accelerate demand for hydrogen.

192 EGA. (2021). EGA and GE to develop roadmap to decarbonise UAE aluminium giant's GE gas turbines, including by switching to hydrogen. https://www.ega.ae/en/media-releases/2021/november/ega-and-ge-release

193 Hy4Heat. (2022). Homepage. https://www.hy4heat.info/

194 Recharge. (2021). Green hydrogen: ITM Power's new gigafactory will cut costs of electrolysers by almost 40%. https://www.rechargenews.com/energy-transition/green-hydrogen-itm-power-s-new-gigafactory-will-cut-costs-of-electrolysers-by-almost-40-/2-1-948190

195 Survey question – Please rank the following from top priority (1) to lowest priority (5): Build new infrastructure; refurbish onshore infrastructure; refurbish offshore infrastructure; refurbish hydrogen demand equipment; gigafactories.

196 Bezdek, R. H. (2019). Journal of Renewable Energy and Environmental Sustainability. The hydrogen economy and jobs of the future. https://www.rees-journal.org/articles/rees/full_html/2019/01/rees180005s/rees180005s.html

196 Bezdek, R. H. (2019). Journal of Renewable Energy and Environmental Sustainability. The hydrogen economy and jobs of the future. https://www.rees-journal.org/articles/rees/full_html/2019/01/rees180005s/rees180005s.html

197 Scottish Power. (2021). Hydrogen skills partnership launch. https://www.scottishpower.com/news/pages/hydrogen_skills_partnership_launch.aspx

198 Survey question – Where 1 is extremely important and 6 is not at all important, how important is it to stablish an understanding of the gaps in expertise related to the hydrogen sector, to help develop new training, courses and study programmes.

199 North East Scotland College. New National Energy Skills Accelerator to be established in Aberdeen to support the UK energy transition. https://www.nescol.ac.uk/new-national-energy-skills-accelerator-to-be-established-in-aberdeen-to-support-the-uk-energy-transition. https://www.nescol.ac.uk/new-national-energy-skills-accelerator-to-be-established-in-aberdeen-to-support-the-uk-energy-transition

200. University of Sheffield. (2021). University of Sheffield and ITM Power announce green hydrogen Gigafactory and hydrogen research and training centre. https://www.sheffield.ac.uk/news/university-sheffield-and-itm-power-announce-green-hydrogen-gigafactory-and-hydrogen-research-and

201. University of Birmingham. (2022). Birmingham Centre for Fuel Cell and Hydrogen Research. https://www.birmingham.ac.uk/research/activity/chemical-engineering/energy-chemical/fuel-cells/index.aspx

202. Cranfield University. (2022). Hydrogen research network. https://www.cranfield.ac.uk/research/rio/hydrogen-research-network

203. University of Nottingham. (2022). Hydrogen Fuel Cells and their Applications. https://www.prospects.ac.uk/universities/university-of-nottingham-3928/faculty-of-engineering-12355/courses/hydrogen-fuel-cells-and-their-applications-46216

204. Imperial College London. (2022). Hydrogen. https://www.imperial.ac.uk/sustainable-gas-institute/research-themes/hydrogen/

205. University of Swansea. (2022). Fuel Technology, MSc by research. https://www.swansea.ac.uk/postgraduate/research/engineering-applied-sciences/chemical/msc-by-research-fuel-technology/

206. Cyrmu H2 Wales. (2022). Homepage. http://www.h2wales.org.uk/index.html

207. Survey questions – Where 1 is extremely important and 6 is not at all important, how important is it to: Develop international joint training programmes to prepare a globally-ready workforce and strengthen cross-border capabilities in the hydrogen sector (Cross-border training); Establish international norms and standards for workers in the hydrogen sector (International skills development standards).

208. Energy Voice. (2021). Brunel launches hydrogen course to retrain oil workers. https://www.energyvoice.com/renewables-energy-transition/311602/brunel-hydrogen-course/

209. Brunel. (2022). The World's First Accredited Hydrogen Education Program is Here. https://www.brunel.net/en/renewables/hydrogen/hydrogen-education-program

210. Survey questions – Where 1 is extremely important and 6 is not at all important, how important is it to: Leverage existing skills in the oil and gas sector and adapt them to the hydrogen industry through retraining. This can help support a just transition (Retraining the oil and gas workforce); Develop non-academic technical education, practical training and apprenticeships to develop the applied skills and knowledge of the hydrogen workforce (TVET); Develop college and university programmes to advance the academic and research capability in the hydrogen sector (Higher education).

210. Survey question – Please rank the following from “top priority” (1) to “lowest priority” (6) in terms of facilitating the skills and capabilities needed in the hydrogen industry Identify Skills Gaps; Technical and Vocational Education and Training; Higher Education; Retraining of the Oil and Gas Workforce; Cross-country Training; International Skill Development Standards

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