Creating a market for hydrogen

Examining the levers that could unlock the hydrogen market in Europe and beyond

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Introduction

Hydrogen is a powerful, disruptive and evolving force that can help decarbonise almost every sector of the economy and increase the flexibility of modern energy systems. European governments have positioned themselves as key backers of this emerging energy carrier, as part of the green recovery from the coronavirus pandemic, and companies have begun announcing large pathfinder and development projects. Europe's potential market size means it will set the agenda in the hydrogen era. Currently however, hydrogen faces significant barriers of economics and business models, requiring incentives and government coordination to achieve commercial scale and maturity. Governments, investors, companies and consumers need a clear view on how they can benefit from the hydrogen opportunity.

In this report we consider:

- How will hydrogen scale up and what future markets will emerge?
- What role will the EU Hydrogen Strategy and the upcoming UK hydrogen strategy play in enabling the transition to a net-zero carbon integrated economy?
- What policy, legal and regulatory frameworks are required to support a fast-growing, cost-effective, reliable and low-carbon hydrogen industry?

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Executive summary

- Hydrogen is a powerful energy vector, identified by the European Commission as integral to meeting the Paris Agreement's goals on decarbonisation in the sectors of heavy industry, long-range transport, and home heating.
- This has led to the emergence of an abundance of national-level and EU-level strategies on hydrogen, targeting rapid, decisive development of hydrogen technologies to enable a coordinated transition towards a net zero-carbon economy.
- 'Blue' hydrogen from fossil fuels with carbon capture, use and storage (CCUS) will play an essential transitional role towards wide-scale adoption of renewable-derived 'green' hydrogen.
- Hydrogen demonstrates significant potential as a versatile energy carrier. Hydrogen electricity storage capabilities can balance the intermittent production profile of renewables and support the operation of nuclear power plants struggling with overproduction of electricity during periods of low demand.
- Further research and innovation is required to implement hydrogen technologies commercially in other end-uses, such as home heating, maritime/shipping and aviation.
- Differences across scope, scale, legal frameworks and policy drivers raise the question: how can the EU and UK collaborate with hydrogen pioneers like Japan, Norway, Australia, South Korea, the Gulf region and (now) the UK, to advance its regional ambitions?
- In the near-term, hydrogen use will have to be prioritised in sectors where it is nearing competitiveness with natural gas or where limited alternatives are available.
- Vertical integration, long-term contracts, dedicated infrastructure (for transport and distribution), availability of energy inputs, tailored financial support, creation of demand, and an overarching enabling policy environment will be crucial to the early development of a European hydrogen industry.
- From government strategy, comes law and regulation and it is this legal framework (European and non-European) that will need to be developed in a coherent manner to encourage cross-jurisdictional development of hydrogen as a genuine and sustainable alternative to fossil fuel heat and transport fuel.

> "In the integrated energy system of the future… large-scale deployment of clean hydrogen at a fast pace will be key for the EU to achieve a higher climate ambition. It will foster sustainable growth and jobs, which will be critical in the recovery from the COVID-19 crisis."
>
> A Hydrogen Strategy for a Climate-Neutral Europe, July 2020

Key drivers and challenges

Three key factors are driving Europe's revived interest in hydrogen. First, a new wave of climate activism post-2010 and the Paris Agreement of 2015 has led companies and governments to assume responsibility for their impact on climate change. The EU, Norway and UK have pledged to be carbon-neutral by 2050 or even earlier. An attitude of urgent climate action has arisen in capital and financial markets, reflected in the adoption of several sustainable finance regulations, such as the Equator Principles, by the bloc.

Secondly, it has become apparent that renewable electricity and electric vehicles, the main pillars of European climate policy to date, only go so far to decarbonisation. Long-distance transport, home heating, seasonal electricity storage, and heavy industry all require other solutions.

Thirdly, the 'European Green Deal' on a sustainable economy and post-COVID-19 recovery puts strong emphasis on developing new sustainable technologies and employment. Other important industrial countries, notably Japan and Australia, have their own well-advanced hydrogen strategies. Hydrogen is also foreseen to bolster energy security, by diversifying from fossil fuel imports to a mix of domestically-produced hydrogen and imports from a diversified range of suppliers.

According to several European carbon-abatement strategies – the European Green Deal, the EU Strategy for Energy System Integration, and the recent Hydrogen Strategy for a Climate-Neutral Europe – the sector has ripened to a pre-commercialisation phase where it is now ready to play an essential role in decarbonising the economy.

However, acting on such strategies requires unique pathways and support mechanisms, many of which are yet to be defined.

The European hydrogen strategy faces two major challenges to becoming reality. First, supply costs for both blue and green hydrogen have to fall to come closer to fossil fuel prices, to the point where carbon costs under the Emissions Trading System (ETS) are sufficient to close the gap. That will require research and technological innovation but, more importantly, widespread deployment and economies of scale and manufacturing.

Secondly, a business and regulatory model has to emerge that can coordinate the very large investments required along the value chain, from storage to transport, to use.

The EU Hydrogen Strategy Factsheet[1]		
2020 - 2024		– Install 6GW of clean H_2 electrolysers – Produce 1 million tonnes of clean H_2
2025 - 2030		– Install 40 GW of clean H_2 electrolysers – Produce 10 million tonnes of clean H_2 – Achieve an integrated H_2 energy system
2030 -		– Deploy green, clean H_2 on a large-scale across all hard-to-decarbonise sectors

"Setting a 2050 net-zero carbon target based on clean hydrogen sounds wonderful, but the reality of doing it is difficult. On the demand side, it isn't an easy switch over. The difficult to decarbonise areas are industry, transport, and heat. It is difficult not only because it is expensive, but because existing policies are insufficient to underpin it."

Dr. Tony Smith, PEEL Environmental, former BP, ExxonMobil

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Comparing the marketability of green, blue and grey hydrogen

Substantial amounts of hydrogen are already used in industrial and chemical processes in Europe. Nearly all of this hydrogen is made from fossil fuels without CCUS, hence being carbon-intensive, or 'grey'. A simplistic solution would be to electrify all such processes with zero-carbon sources of power like renewables or nuclear. However, this is technically unfeasible in some cases, such as those needing high-temperature heat which cannot currently be produced electrically[2], those that use hydrogen as a feedstock (such as ammonia/fertilisers and refineries), or those such as steelmaking which require a reducing agent.

> "Hydrogen is certainly more than an energy carrier. For many industries, such as refineries or fertilizer production, hydrogen is a key feedstock. In those sectors, transition from 'grey' through 'blue' to 'green' hydrogen is a critical step on the carbon reduction path."
>
> Zbigniew Kozłowski, Partner, DWF

Additional promising areas of hydrogen use are in home heating, where hydrogen could be blended into the existing gas grid. Current peak heating demand in northern Europe can occur at times of low renewable output and have short but very high peaks, making electrical heating or heat-pumps costly. Long-distance transport in lorries, ships and aeroplanes is also hard or impossible to power with batteries; hydrogen or a derivative fuel such as ammonia or synthetic hydrocarbons are preferable because of higher energy density and greater compatibility with existing infrastructure and designs.

> "Hydrogen is key for the green transition in Europe. Therefore, many projects related to research and development of green hydrogen might qualify for important public economic support (grants or loans) provided by the EU Recovery and Resilience Facility."
>
> Gerard Perez Olmo, Partner, DWF

Hydrogen can be used not only for industrial and transport applications, and district heating, but also for electricity grid balancing and energy buffering. During periods where renewable energy generation exceeds load or nuclear power plants struggle with overproduction, electricity can be converted into hydrogen, which can be used for storage, as a backup and provide buffering functions.

> "A variety of hydrogen applications may interlink and create synergies between different sectors and energy markets. This will require developing a true hydrogen economy with a full value chain of supply, infrastructure, and demand."
>
> Zbigniew Kozłowski, Partner, DWF

Current EU carbon-abatement strategies for such sectors focus almost exclusively on the uptake of green hydrogen, or hydrogen produced via electrolysis of water with low-carbon electricity from renewables (and sometimes nuclear), as shown in Table 1.

Feedstock	Route	Process	
Natural Gas	Steam reforming or autothermal reforming	Separation with CCUS	Product - Fuel Cell grade H_2
Coal	Gasification	Separation with CCUS → Purification	
Renew-ables	Electrolysis of water	Purification → Compression	
Nuclear	Thermo-chemical pyrolysis	Removal of solid carbon	

Table 1 Routes for low-carbon hydrogen production [3]

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This brings to fore a critical challenge. In its drive to decarbonise Europe with hydrogen, the EU will have to decarbonise hydrogen production in a cost-effective manner. Currently the cost of clean, 'green' hydrogen is still 3-10 times higher than that of grey, while 'blue' hydrogen, or hydrogen produced from fossil fuels with carbon capture and storage (CCS) is twice that of grey (Table 2). Note that \$1.7/kg H_2 is equivalent to almost \$15/MMBtu or €43.1/MWh, with gas at the TTF hub for December 2020 delivery, the peak period, priced at €14/MWh. Therefore 'blue' hydrogen is currently more than four times as expensive as natural gas per unit of energy; the cheapest 'green' hydrogen is more than six times costlier.

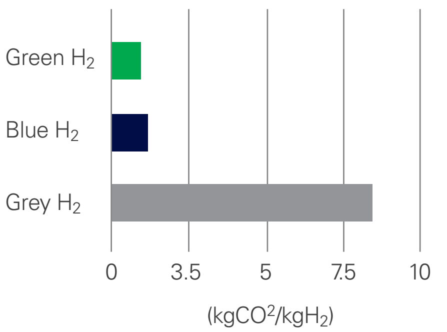

Figure 1 CO^2 emissions per technology [4]

Method	Process	Cost (US\$/kgH_2)
Steam Methane Reforming (Fossil Fuels)	No CCUS	1.7
Steam Methane Reforming (Fossil Fuels)	With CCUS	2.3
Electrolysis (Renewables)	Alkaline 5c, 100% load	3.5
Electrolysis (Renewables)	Polymer electrolyte membrane, 100% load	5.4
Electrolysis (Renewables)	Solid Oxide Electrolyser Cell, 100% load	16.7

Table 2 Hydrogen production costs in Europe [5]

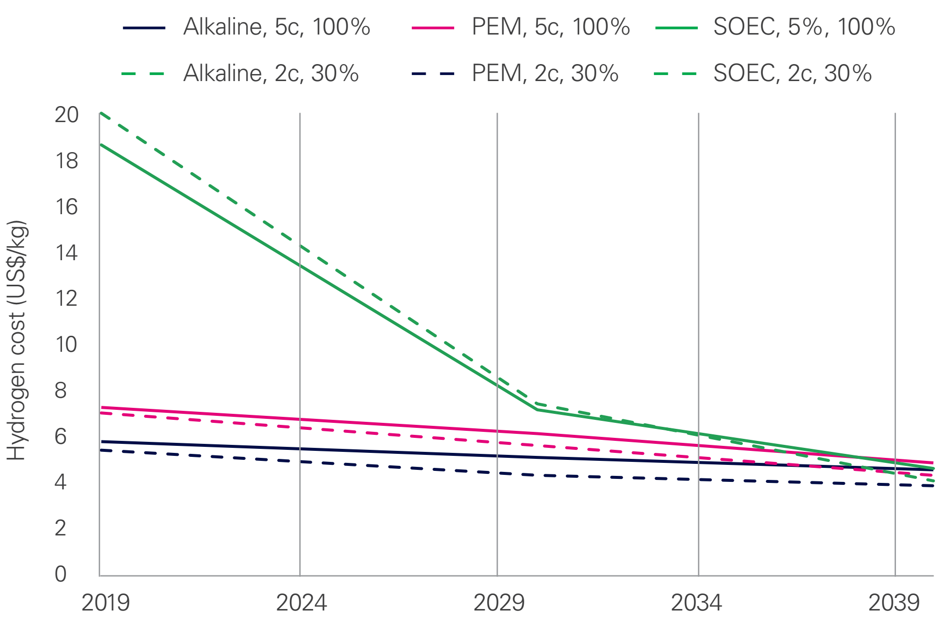

Figure 2 Cost of hydrogen production from electrolysis [6]

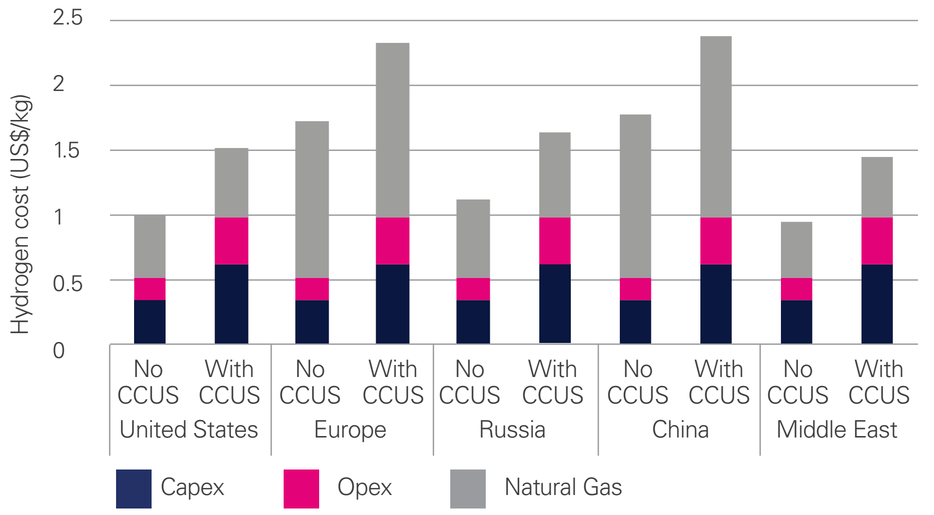

Figure 3 Cost of hydrogen production using natural gas [7]

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Hydrogen from electrolysis in the table 2 assumes 100% load factors for the electrolysers. Using cheap off-peak renewable energy, the electricity cost for electrolysers can be reduced, but with lower load factors leading to higher overall production costs (Figure 2). Therefore 'green' hydrogen needs to be produced from renewables with high availability and low costs, possibly a combination of offshore wind and solar. Feeding electrolysers with electricity produced in nuclear power plants is also an option, in particular during periods of low demand for electricity (e.g. during the night).

Both production methods for decarbonised hydrogen are expected to play a major role in meeting the EU's future energy needs, even though 'blue' hydrogen seems to have been downplayed in the EU's hydrogen strategy. Blue hydrogen, however, has the advantages of bigger scale and lower cost over the next decade, before enabling a phased adoption of 'green' hydrogen thereafter. A large part of current industrial applications could be decarbonised relatively easily, with minimal disruption to supply chains, by increasing the cost efficiency of 'blue' hydrogen production technologies.

Without dedicated drivers and regulation, however, 'blue' hydrogen would be unable to fulfil its role as a transition step until green hydrogen can be produced in sufficient quantities at significantly lower cost than at present. Achieving this would require an integrated, full value-chain approach, of which 'blue' hydrogen, or low-carbon hydrogen would support the rapid reduction of emissions from existing hydrogen production.

Project	Hydrogen source	Partners	Size
Lingen refinery, Germany	Wind	BP, Ørsted	50 → 500 MW
Hollandse Kust, Netherlands	Offshore wind	Shell, Eneco	200 MW, 22 kt/yr
NorthH2, Netherlands	Offshore wind	Shell, Gasunie, Groningen Seaports	750 MW, 800 kt/yr
Puertollano, Spain	Solar PV	Iberdrola, Fertiberia	20 MW
HyGreen, France	Solar	Engie, Air Liquide, DLVA	750 MW, 12 kt/yr
Hyport Ostend, Belgium	Wind	DEME, PMV, Port of Ostend	50 MW, 100 kt/yr
H2H Saltend, UK	Autothermal reformer of gas	Equinor	125 kt/yr

Table 3 Selected European hydrogen production projects[8]

Value chain development

From the 1950s onwards, the European gas business built up a commercially complex value chain, supported by very extensive infrastructure, and long-term contracts based on oil-indexation, from producing fields within Europe and in the Soviet Union and Algeria, import pipelines and liquefied natural gas terminals, to users in industry, power generation and buildings.

The hydrogen value chain is potentially even more complicated, because of the differing sources of supply, transport methods (liquefied hydrogen, ammonia, organic carriers) and end uses (power, heating, industry, synthetic fuels and mobility), and the opportunity for transitioning natural gas infrastructure to hydrogen.

Scaling up the hydrogen value chain will be one of the biggest drivers of cost reductions in the production, storage, transport, and distribution of hydrogen, and the manufacturing of associated infrastructure and system components, narrowing the cost gap between natural gas and hydrogen.

Technological breakthroughs for reducing electrolyser costs for renewable hydrogen production might not develop fast enough to deliver the expected sharp drop in low-carbon hydrogen costs over the next decade. While this is recognised in the EU's Hydrogen Strategy, it has not, yet, led to the required investments along the value chain. A rapid development of regulation to provide the foundation for investment decisions by the private sector is essential to encourage large-scale investment and growth of this sector.

European hydrogen policy therefore needs to synchronise the development of hydrogen production and imports with the creation of markets and end-users. Bridging the existing cost gap between hydrogen and natural gas would be a logical first step in developing the hydrogen value chain. It would also enable a more transitional role for 'blue' hydrogen towards net-zero carbon.

This could be achieved through mechanisms such as carbon pricing, contracts-for-difference, direct subsidies, mandates, or special quotas. Current and forecast European emissions trading prices are not enough on their own to make hydrogen cost-competitive with fossil fuels, and will need initially to be supplemented with other mechanisms.

The inclusion of CCUS in hydrogen production from natural gas raises the required natural gas input by about 10%, and the overall cost of the produced hydrogen by about 35-50%, or about US$ 0.5/kg. As noted previously, this results in 'blue' hydrogen costs of US$ 2.3/kgH_2, equivalent to about US$ 18.2/MMBtu of natural gas, which is rather exorbitant in current terms. With SMR emissions around 8.4 kgCO^2e/kgH_2, the cost premium for 'blue' over 'grey' hydrogen equates to a carbon price of about US$ 60/tonne, above current EU emissions trading system (ETS) levels of €33/tonne (~US$ 40/tonne), but within the range of anticipated future carbon prices, which Reuters forecasts at about €50/tonne (US$ 60/tonne) by 2030.[9]

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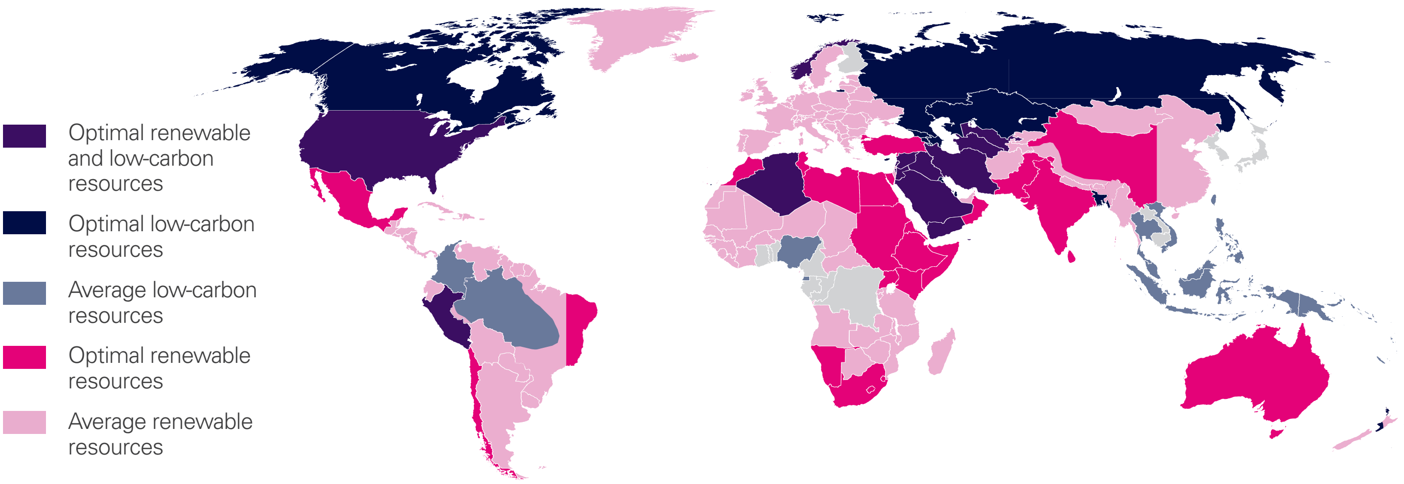

Country/ Region	H_2 Production Potential
US	Favourable PV and wind conditions, cheap natural gas
Chile	Favourable PV/wind hybrid conditions
EU	Likely to be a high-demand location RE constrained due to varying load curves, limited space availability CCUS constrained by public acceptability
Middle East	High PV/wind hybrid potential Cheap natural gas Abundant geological storage for CCUS

Country/ Region	H_2 Production Potential
Japan/ Korea	Space and resource constraints, likely hydrogen/ammonia importer
China	Large investments in hydrogen economy, potential to be self-sufficient
Australia	Potential for large-scale PV farms with favourable load profiles
Russia	Cheap natural gas, significant hydropower and nuclear capacity; existing pipelines to Europe

Table 4 EU hydrogen production potenial is constrained necessitating development of the entire value chain[10]

A carbon tax and a cap-and-trade system for 'blue' hydrogen could, therefore, enable a shift in comparative advantage, as the price of produced hydrogen would increase in jurisdictions where implemented, diverting towards 'blue' hydrogen produced in jurisdictions with no carbon compliance costs, including non-EU regions like the Middle East, that have a wealth of natural gas.

This creates "carbon leakage", which could ultimately enhance carbon reduction efficiency of CCUS systems, and improve their cost-effectiveness. Increasing future carbon prices create additional "carbon leakage" as natural gas prices decline due to the lowered demand for conventional energy sources from countries with carbon pricing policies, impacting their imports. The effect on competitiveness can be mitigated, to an extent, through either a tax on natural gas (or other fossil fuel) imports from countries with no carbon tax (i.e. EU's proposed carbon border tax)[11], or an allowance requirement for such imports.

Mechanism	Description
Carbon Taxation	– Already used in the UK (as a carbon floor price) and in Scandinavia – Can introduce increasing carbon floor price to EU ETS – Can furnish a predictable price incentive – Easier and quicker to implement and administer; relying on already existing administrative structures – Low-carbon H2 exports to regions without carbon prices can receive tax credit equal to CO2 costs
Cap-and-trade	– Already in operation (EU ETS) – More certainty about the amount of emissions to be reduced – Politically viable when applied on utility-scale power plants; used in the US, EU and China's ETS pilots
Contract-for-difference (CfD)	– Project-related subsidy payments based on the price gap to the high-carbon equivalent when investing in low-carbon hydrogen – Subsidy funding can be determined through auctions
Carbon surcharges	– Can help "refinance" other policy mechanisms through a special surcharge on carbon content of high-carbon hydrogen products (such as 'grey' hydrogen products) – Can offset cost disadvantage of low-carbon products
Performance standards	– Standard for maximum embedded carbon emissions of H2-derived materials (e.g. fertilisers, steel, fuels), possibly falling over time
Quota for Green H2	– Mandates natural gas providers to sell certain share of green hydrogen – Guarantees demand for low-carbon hydrogen – Ensures expansion of power-to-x technologies

Table 5 Policy instruments to bridge cost gap between natural gas and hydrogens[12]

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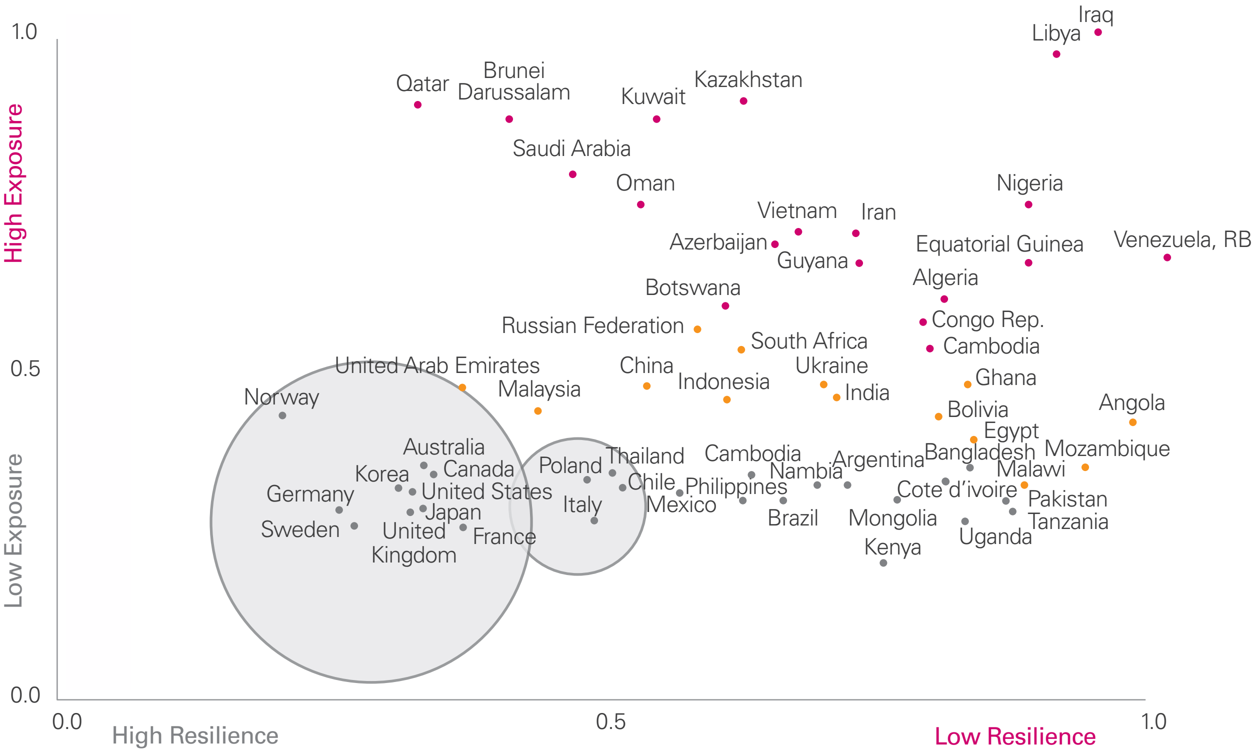
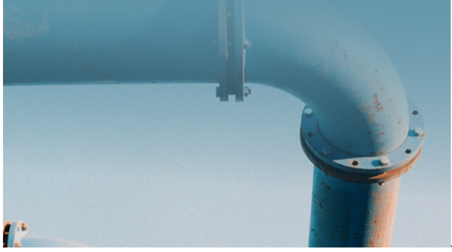


Figure 4 European countries fare well in resilience to carbon pricing mechanisms[13]

"In the UK, the recently-established Hydrogen Advisory Council (HAC) will oversee a range of workstreams to support the development of hydrogen in industry. Unique carbon pricing solutions, such as hybrid systems, will be an integral focus."

Darren Walsh, Partner, DWF



Hybrid systems, that combine carbon taxation alongside a cap-and-trade-system, can avoid the drawbacks of both in achieving hydrogen cost competitiveness with natural gas.

Carbon taxation is typically designed to increase over time, while a cap-and-trade system has volatile prices which are sensitive to economic health, but should also increase as allowances are reduced. Hybrid systems, like in the UK, can combine the EU ETS with a "carbon floor price", giving certainty of a minimum level of carbon pricing. Cap-and-trade systems can have safety valves, such as the Market Stability Reserve (MSR) in the EU ETS, where extra allowances are released to dampen price spikes or the surplus of allowances is removed from the market to increase the price.

The recently-released EU taxonomy[14], part of the EU Action Plan, identifies core technical criteria for orienting capital flows towards hydrogen investment to achieve growth markets. Hydrogen has been identified as a one of the several components towards sustainable development of, mainly, the manufacturing (as 'green' hydrogen) and transportation (as hydrogen fuel cells) sectors. Under thetaxonomy criteria, production of hydrogen from non-renewable sources has to emit not more than 5.8 tCO^{2}e per tonne of hydrogen, while hydrogen produced from electrolysis should use 58 MWh or less of electricity per tonne of hydrogen produced. Average carbon intensity of the electricity used for hydrogen production should not be above 100 gCO^{2}e/kWh, a level which will fall over time.

Guarantees of origin and contracts-for-difference (CfDs) could drive low-carbon hydrogen growth under these criteria, by enabling the 'low-carbon' element of 'blue', and the 'renewable' element of 'green' hydrogen to be competitively traded. For hard-to-decarbonise sectors like heavy industry, including fertilisers, steel, chemicals, cement, and aviation and shipping, CfDs could be the best solution to implement minimum carbon emission reduction standards and sustainability criteria to achieve clean hydrogen market growth.

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Carbon CfDs will enable a shift in attitude that will encourage financing Capex as well as Opex for low-carbon hydrogen. Financing CfDs will be a challenge, which could create unique opportunities. One might be a special ETS system dedicated to hydrogen. This could be in the form of a directive from the European Commission, but implementation would have to be necessitated at the national level to achieve success."

Emilia Makarewicz, Head of Hydrogen Development, Polenergia SA

Price uncertainties of investing in low-carbon technologies in niche sectors has arguably minimised uptake of hydrogen. At the national level, a CfD could be implemented on the terms of typical "spread trading", wherein the government would agree with the low-carbon hydrogen investor on a strike price over a carbon market price, with any difference between the two payable either to the investor (if the market price is lower than the strike price), or the government (if the market price is higher). This could help correct the regulatory risk associated with price uncertainties of investing in hydrogen for hard-to-decarbonise sectors, and improve long-term market growth.

A CfD model could therefore avoid applying backstops or guaranteed purchase of natural gas, as consumers would be exposed to high payment under such a system. However, for this to be effective, it would have to be implemented on a national strategy level, unlike a European-level guideline system, which may not be as detailed.

For example, the German government is planning to offer a pilot carbon contracts-for-difference programme for the hard-to-decarbonise sectors steel and chemical industries as part of its national hydrogen strategy[15]. In the UK, a recent study commissioned by the Department for Business, Energy & Industrial Strategy (BEIS) found that CfD-style backing could unleash a wave of low-carbon hydrogen as a form of a revenue stabilisation mechanism that reduces investor cost of capital.[16]

Most hydrogen technologies have a niche status, but hold significant potential for achieving economies of scale and improving the technology further via learning and R&D. Fuel cell stacks for passenger vehicles will exhibit higher learning rates due to a scale-up in other segments, such as electrification (from renewables and batteries).

'Green' hydrogen can benefit from higher learning rates for alkaline and polymer electrolyte membrane (PEM) electrolysis technology. Learning rate estimates for PEM are high as the technology is newer, meaning it has higher cost-reduction potential. PEM electrolyser manufacturing may also benefit from improvements in the PEM fuel cell production. The EU already has international strength in technologies needed to supply fuel cell manufacturing. Although the electrolyser sector is still small, European manufacturers are regarded as innovative and "ready to scale up their efforts." A scale-up in hydrogen usage will not only result in reductions in equipment costs, but will also lead to improved utilisation of capex.

H_2 development in a nascent and inconsistent market

The European Commission's Hydrogen Strategy for a Climate-Neutral Europe struggles to identify clean hydrogen as part of an overall sector that is still nascent, even though it recognises it requires unique market conditions to support growth as a priority area.

A major reason behind this is the difference in policy, support, development, market size, business models, and technological readiness between different EU member countries. Almost all EU member states have included plans for clean hydrogen development in their National Energy and Climate Plans for 2021-2030 submitted to the European Commission under Regulation EU/2018/1999 on the governance of the energy union and climate action. Fourteen member states have mentioned hydrogen in the context of their alternative fuels infrastructure national policy frameworks.

"Although the electrolyser sector is still small, European manufacturers are innovative and ready to scale up their efforts. The EU is considered a global leader in electrolysis, in all technology types, from component supply to final integration capability, with little competition being able to match its depth and breadth."

Karol Lasocki, Partner, DWF

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Hydrogen, therefore, is distributed much more than indicated by region-wide stratagems, with several countries already having their own national hydrogen agendas. These include Germany, the Netherlands, Spain, Portugal, France and Poland (draft), and, outside the bloc, the UK, Norway and Iceland.

Ranking Matrix

Highest	5	4	3	2	1	Lowest

		Germany	Netherlands	UK	France	Norway
Production	Blue H_2	2	3	4	1	5
	Green H_2	5	5	3	4	2
Major end uses	H_2 Networks	4	4	4	1	1
	H_2 Energy Storage	1	2	1	1	1
	Industrial Heat	1	2	2	1	1
	Industrial Feedstock	1	4	1	4	1
	Power Generation	1	2	2	1	1
	Household heating	4	4	4	1	1
	Heavy Vehicles	1	2	5	5	5
	Passenger Vehicles	1	2	4	2	4
	Export	1	5	1	1	1
Policy and support	Infrastructure	4	5	3	3	2
	Long-term Contracts	3	2	2	2	3
	Funding	3	3	3	2	3
	Market Regulation	3	2	3	2	3
Overall Ranking		2.3	3.1	2.8	2.0	2.3

Table 6 Comparison of factors core to an integrated H_2 economy across European countries

Table 6 highlights the level of importance accorded to core factors in selected European countries' national hydrogen strategies. These include several sub-facets under the core themes of hydrogen production methods, hydrogen end uses, and policy and support mechanisms.

It is clear that renewable hydrogen is the favourite among most European countries, save Norway and the UK, both of course important hydrocarbon producers with large carbon dioxide storage space in the North Sea. Their national strategies and recent activity indicate a growing role for 'blue' hydrogen as an essential step towards a low-carbon future, which in turn will lead the transition to a net zero-carbon future.

Case study 1: Norway

Blue hydrogen more worthy of pursuit than green

Norway's state oil company Equinor regards the development of blue hydrogen as currently more worth pursuing than green hydrogen. It has put into motion a project in the UK to develop one of the world's first "at-scale" facilities to produce blue hydrogen, the Saltend H2H project (see Table 3) expected to mature toward an FID during 2023, with first potential production by 2026. According to the firm, blue hydrogen will remain cheaper than green in the medium term. According to CFO Lars Bacher, "for green hydrogen to actually work, it requires an overcapacity in renewables", which in of itself is a separate challenge, requiring renewable subsidies. Phase-1 of the project will comprise a 600 MW auto thermal reformer with carbon capture technology, the largest plant of its kind in the world, to convert natural gas to 125 kt/y hydrogen. This is Norway's second step into CCS this year, the first being an FID on Northern Lights, the EU's first commercial-scale carbon transportation and storage project off the coast of Norway, which could establish Norway as a centre for blue hydrogen in the region.

Case study 2: UK

Funding boost directed to blue hydrogen in favour of green

The UK announced a US$ 36.5 M boost in funding for its hydrogen projects as part of a nation-wide carbon abatement programme, with most of the funding directed to blue hydrogen in favour of green, which the UK sees as likelier to develop at GW scale versus green, which is still at MW scale. HyNet North West, a low-carbon blue hydrogen project comprising the development and deployment of a 100 kNm3/hr hydrogen production and supply facility has received the bulk of funding, at US$ 9.9 M, followed by Scotland's Acorn project focussed on reforming natural gas at the St. Fergus natural gas terminal by capturing CO^2. The third beneficiary is Cranfield University's HyPER project which is pursuing bulk blue hydrogen production by utilising sorbent enhanced steam reforming. Cleaning up emissions from industry and housing remains a major challenge for the UK, which can be achieved by "trialling technologies" that enable the transition to a low-carbon future.

This stands in contrast to hydrogen activity in Germany, where 'green' hydrogen has become synonymous with the country's climate policies. Germany, not unlike the Netherlands, prefers a rapid transformation to an entirely non-fossil future, while Norway and the UK have shown preference for a transition to a low-carbon future.

Overall, the five assessed countries lack attention on hydrogen in industrial heat, power generation and storage. This is a potential weakness in terms of the pace of developing sufficient end-uses versus creating supply.

Even though the EU Hydrogen Strategy acknowledges that low-carbon hydrogen production is integral to the transition towards large-scale adoption of net zero-carbon hydrogen, it is intended to be a temporary measure to reduce emissions in the short/mid-term and scale up the market.

Major reasons are so-called "controversies" surrounding the use of CCUS and its costs, as well as the ultimate dependence of 'blue' hydrogen on natural gas, which is subject to commodity price fluctuations and geopolitical risks.

Europe has been one of the lesser-impacted regions from gas supply reductions during the coronavirus pandemic, but cancellation/deferment of cargoes from traditional suppliers during a period of weak oil and gas demand remains a cause of concern.

"Installing the infrastructure and stimulating offtake of 'blue' hydrogen might serve 'green' hydrogen well in the future by scaling up the market."

Karol Lasocki, Partner, DWF

Case study 3:

Storing and transmitting hydrogen through gas network

Poland

Polish Oil and Gas Company (PGNiG) has recently started work on projects aimed at the implementation of hydrogen use for power generation and automotive applications. Hydrogen – Clean Fuel for the Future is PGNiG's new hydrogen program consisting of several projects ranging from green hydrogen production, through hydrogen storage and distribution, to industrial power generation applications. Within the framework of the InGrid – Power to Gas project the company plans to examine the possibilities of storing and transmitting hydrogen through the gas network. The green hydrogen production facility will be located in Odolanów, which is expected to come on stream in 2022. PGNiG intends to use electricity generated by PV panels for the purpose of hydrogen production. The facility will enable testing of the whole process from production to delivery of green hydrogen to customers. It will allow the company to run tests by injecting a mixture of natural gas and hydrogen into an on-site model gas network, storing hydrogen and carrying it by tanker to the station in Warsaw. The company envisages using hydrogen for power generating units on an industrial scale, involving turbines in CHP plants running on properly designed natural gas and hydrogen blends to produce heat and electricity.

The PGNiG Central Measurement and Testing Laboratory plans to expand its analytics capabilities to become the first laboratory in Poland and one of the few in Europe providing a hydrogen purity testing service. Upon accrediting it, the lab will test alternative fuels for PGNiG, as well as third parties on a commercial basis.

A comparison of policy mechanisms and regulations

R&D spending on hydrogen in the EU has picked up since 2016 after a sharp fall in 2012, with focus on hydrogen -based passenger transportation in favour of other end uses now demanding a transition from technological demonstration projects into large-scale adoption and standardisation. For light transport, electric vehicles now seem favoured over hydrogen, which will be focused more on heavy and long-range transport.

However, other end uses, such as home heating, maritime/shipping and aviation, power generation, and industry (including alternate industry) remain relatively niche and underexplored. This creates a unique challenge for public funding dedicated to hydrogen – how should it be prioritised between technological development and demonstration projects on the one hand, and large-scale deployment to bring down costs on the other hand?

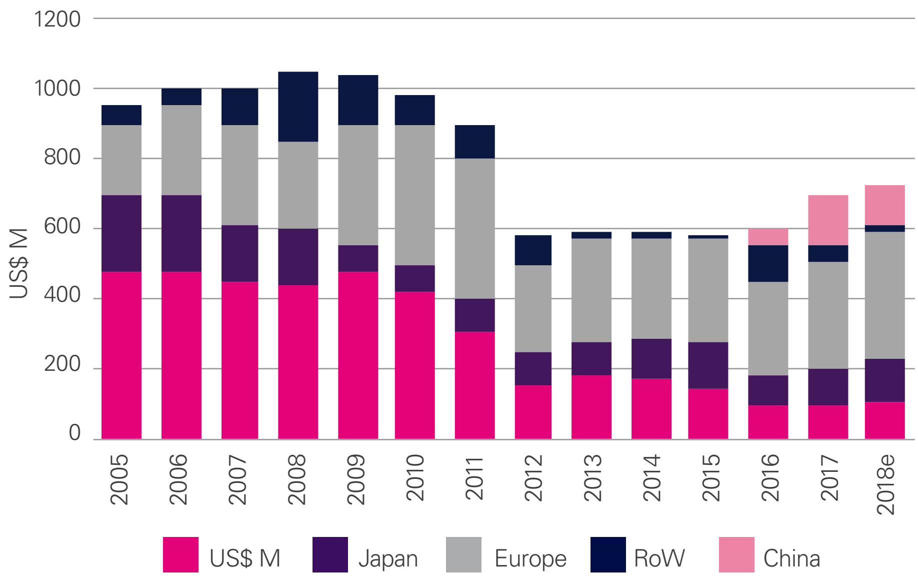

Figure 5 Government R&D Budget into Hydrogen [17]

Creating a market for hydrogen

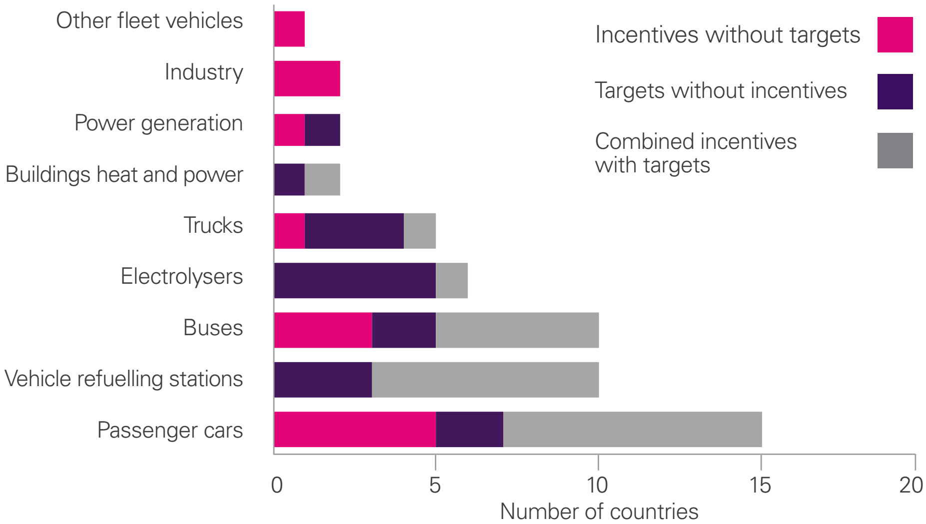

Figure 6 Current Policy Support for Hydrogen Deployment [18]

Required regulatory framework tools need to be combined with financial incentives until such a time that low-carbon hydrogen technology becomes cost-competitive to support demonstration and deployment.

Public funding will play a crucial role in scaling up hydrogen production and use between different end-uses. However, this cannot be achieved without dedicated policy drivers that enable and mandate clean and efficient hydrogen use. These can include certification systems that guarantee low-carbon, and in the future, carbon-free, hydrogen supply for hard-to-decarbonise sectors of the economy.

Other mechanisms include vertical integration, long-term contracts (to provide a hedge on hydrogen prices for the offtaker while advancing carbon abatement goals), dedicated infrastructure (for transport and distribution), availability of energy inputs, and an overarching enabling policy environment that maintains the competitiveness of European industries.

A specialised focus on hydrogen supply infrastructure could help dictate the viability of transition pathways (from 'grey', to 'blue', to 'green'), by connecting centres of demand with the right support mechanisms. Elements of the existing pan-European gas infrastructure could be repurposed to provide the infrastructure for local needs like home and industrial heating, as well as large-scale cross-border transport of hydrogen.

Hydrogen could be imported as ammonia. Ammonia is much easier to liquefy for tanker transport, and can also be transported by pipeline. At the destination, it may either be used directly (it can be burnt directly in gas turbines), or reconverted to hydrogen. However, this may struggle to be competitive in destination markets, given the high transport costs and inflexibility.

Other sectors could benefit from hydrogen in the manufacture and export of decarbonised products. These include iron and steel, cement, methanol, fertiliser, synthetic methane and synthetic liquid fuels. That may be a more attractive route because of the higher density of most of these products, and because it would localise more of the value creation.

Power-to-X and e-fuel applications could potentially become new hydrogen markets in sectors like aviation, shipping, chemical, and petrochemicals, where alternative options to decarbonise are either limited, lacking, or costly. Launching demonstration projects from public funding at sites where hydrogen production and hydrogen commodity production, i.e. e-fuels and other synfuels, can be combined will eliminate the cost for hydrogen transport, benefitting scale-up. Converting existing users of grey hydrogen is an obvious place to start with tangible projects. The partnership between BP and Danish utility Ørsted to supply green hydrogen from wind power to the former's refinery in Lingen in Germany is an example[19].

The Hydrogen Strategy for a Climate-Neutral Europe puts particular emphasis on developing hydrogen clusters – so-called 'Hydrogen Valleys'. This idea relies on local production of hydrogen based on decentralised renewable energy sources and local demand, transported over short distances. In such locations hydrogen can be used not only for industrial and transport applications, and electricity balancing, but also for district heating. The Polish draft hydrogen strategy assumes foundation of five 'Hydrogen Valleys until 2030.

Designing integrated hydrogen networks can combine hydrogen utilisation with complementary solutions, and achieve further economies of scale. The Port of Rotterdam in the Netherlands is one such example, as is the Port of Newcastle in Australia.

"At the moment, the European Commission's Renewable Energy Directive (2009/28/EC) explicitly includes hydrogen as a means of meeting the target for renewables in the transport sector. It also allows hydrogen produced from installations connected to the grid to be statistically accounted for as 100% renewable, even if the overall electricity mix has low shares of renewable energy, provided that certain conditions are met."

Karol Lasocki, Partner, DWF

Creating a market for hydrogen

Case study 4:
Port of Rotterdam's hydrogen network

Netherlands

The Port of Rotterdam in the Netherlands is currently developing a public hydrogen network to serve Rotterdam's industrial and power sector by connecting producers and users. A green hydrogen plant being developed by Shell will transport hydrogen via pipeline to Shell's refinery in Pernis, which will be developed by the Port of Rotterdam alongside other partners. In the near future, the pipeline is expected to be hooked up to the national hydrogen network developed by the Dutch national natural gas infrastructure and transportation company, Gasunie. The Port's hydrogen network is an example of combining hydrogen utilisation with complementary solutions to achieve economies of scale.

Case study 5:
Port of Newcastle's hydrogen production facility

Australia

The Port of Newcastle is another example. According to Simon Byrnes, Chief Commercial Officer at the Port of Newcastle in Australia, the Port will establish a hydrogen production facility to feed hydrogen to Australia's NSW region, one of the largest consumers of hydrogen currently, on the sidelines of its operations as the world's largest coal exporting port. "The initial stage of our project will target domestic supply, which is gradually scalable", says Byrnes. "In the future, we are planning to develop a large-scale renewable and hydrogen complex that could not only export hydrogen, but also import hydrogen transport options."

"There is a strong tendency towards hydrogen over electric for transport in Australia, as it can cover large distances. For this, we expect our Port to play a pivotal role in the growth of the transportation, including the heavy transportation market, using hydrogen fuel."

Simon Byrnes, Chief Commercial Officer, Port of Newcastle

Cross border collaborative approaches

The scale of the EU's hydrogen ambitions are likely to be too large to be met from domestic production alone. Traditional energy partners, notably Norway, North Africa, Russia and the Gulf, have their own hydrogen production potential and ambitions, as do energy exporters such as Australia. Some of these countries are likely to be highly competitive hydrogen producers because of the excellence of renewable resources and/or hydrocarbons and geology.

Norway, North Africa and Russia are linked to Europe by gas pipeline that could be repurposed to carry hydrogen. Germany already sees opportunity in collaboration with Russia, and is working on a joint plan of action on hydrogen development, wherein Russian hydrogen would be transported to Germany to assist in its Energiewende (energy transition).

As discussed above, for more distant suppliers, hydrogen may be supplied to Europe in the form of ammonia (which can be used directly to support the phase-out of coal power plants by burning pure ammonia, or dissociated back to hydrogen), or as decarbonised derivative products such as steel or synthetic plastics and fuels. These will likely be more economic delivery methods than shipping pure hydrogen.

These options raise a variety of issues to consider:

- Assurance of the low-carbon nature of imported hydrogen or related products and the sustainable character of its supply chain (the proposed EU carbon border tax seems to fit this aim);
- European energy security, reliability and diversification of imports (as with current imports of oil and natural gas);
- Trade policy, protectionism and compatibility with WTO requirements;
- Technological cooperation on hydrogen production (novel electrolysers, CCUS) and hydrogen related industrial processes;
- Construction or repurposing of infrastructure;
- Business models and commercial arrangements, likely based on existing pipeline gas/LNG frameworks but with significant differences;
- Promotion of government-to-government cooperation and partnerships with European business.

"Renewables seem the logical choice in replacing fossil fuels but leave a gap in the market. Hydrogen is the best fuel to fill that gap. Australia will become a major clean hydrogen player due to two enormous assets: land and sunshine."

Alan Finkel, Australia Chief Scientist, OCS, Department of Industry, Innovation & Science

Conclusion

The right enabling policy support mechanisms will serve to expand the European hydrogen market by reducing demand uncertainties, scaling applications with the highest learning rates (or highest cost improvement per dollar invested), designing transport and distribution networks that maximise utilisation, as well as complementary solutions with spill over effects. For example, hydrogen infrastructure at ports and airports can be used for refuelling, heating, and power.

Reducing demand uncertainty will attract greater investment. As discussed previously, the EU has contemplated the use of carbon contracts for difference (CCfDs), a logical, market-based mechanism that would promote blue hydrogen production much more easily initially, due to the lower cost of blue hydrogen production today, with green hydrogen having to rely on more direct support schemes until costs reduce sufficiently.

> "The EU hydrogen market is still relatively underdeveloped on the global scale. Existing European energy regulation is moving swiftly and decisively towards encouraging open, liquid markets, while hydrogen requires further attention and regulation to encourage further private sector investment on a large scale."
>
> Darren Walsh, Partner, Head of Power, DWF

Scaling applications with the highest learning rates is a natural cost improvement for investment. According to the Hydrogen Council, scaling fuel cell vehicle production from 10,000 to 200,000 units can reduce unit costs by as much as 45%, irrespective of any major technological breakthroughs, due to the improvement in manufacturing learning rates.

Providing financial instruments can further leverage investment with the support of public guarantees to mitigate the risk for early movers. The EU Hydrogen Strategy acknowledges that developing the whole value chain of supply, infrastructure, and demand will drive scale-up of hydrogen, but this might be more appropriate for a mature market. The European hydrogen market is still relatively underdeveloped on a global scale, and not regulated, in the manner that gas and electricity internal markets are. Existing rules for gas and electricity markets therefore, are not currently conducive to developing a competitive hydrogen legislative framework, which requires its own set of unique rules to transition from a nascent to mature market.

However, at DWF, we are seeing clients take the initiative by kick-starting the hydrogen market in the UK. Co-location of electrolysers with solar PV or on-shore wind farms are coming to market with vigour; and we are delighted to be supporting these first-movers in this exciting new market. Hydrogen-fuelled buses with national infrastructure to re-fuel them are being developed by our clients with binding supply obligations in place with a number of the main UK transport authorities. These arrangements are happening in real time and rather than merely discussing options and strategy, we are front and centre of the hydrogen revolution. This is no longer a market opportunity, but a visible and real business which our clients are grasping and helping shape as they make bold investment decisions now.

The hydrogen sector is at a crucial juncture. Its success is, in turn, vital to Europe's chances of meeting its climate and energy goals effectively and affordably.

Policymakers and investors should bear in mind four key points.

1. A critical point for decision-making: Decisions made today will have long-term ramifications for shaping the hydrogen industry, not just in Europe but worldwide, given the likely importance of the European market.
2. Building scale with local benefits: As with renewables, the industry needs to build scale quickly to bring down costs. European hydrogen ambitions imply a rapid expansion of domestic production as well as imports. Yet European governments also want the benefits of hydrogen technology development and associated employment to be secured locally. That requires addressing issues of infrastructure, regulation and innovation.
3. Value-chain coordination: Coordination along the value-chain will be critical, as production, imports, transport, storage and use of hydrogen all need to be synchronised. Vertically-integrated companies or consortia may be appropriate, especially initially. But governments, both national and supranational, have a key role in ensuring such coordination, including with external suppliers. Hydrogen therefore has cross-cutting dimensions across trade policy, industrial and technology policy, regional development and international relations.
4. Regulation for a nascent market: Regulations need to be flexible and appropriate for a nascent market. They need to recognise the significant risks being borne by hydrogen pioneers. And they should be focussed on the end-goal of low-emission, reliable and cost-effective energy services, not overly prescriptive between different 'colours' of hydrogen or different end-use sectors.

Darren Walsh
Partner, Head of Power, UK

About DWF

DWF is a leading global provider of integrated legal and business services, with more than 30 global locations and over 4,000 people. We became the first Main Market Premium Listed legal business on the London Stock Exchange in March 2019.

We have three offerings – Legal Advisory, Mindcrest and Connected Services. Our ability to seamlessly combine any number of these services to deliver bespoke solutions for our clients is our key differentiator. Delivered through our global teams across eight core sectors, our Integrated Legal Management approach delivers greater efficiency, price certainty and transparency for our clients without compromising on quality or service.

DWF's team of energy specialists helps its clients to adapt to regulatory reforms, rethink their strategies, optimise efficiencies across the value chain and find new agile ways to tackle emerging challenges. We offer a complete range of services in areas such as regulatory, environmental, finance, corporate, construction, insurance, technology and transport law and dispute resolution.

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