SHORE CAPITAL
CAPITAL MARKETS

Sustainability Advisory Group ESG 21st March 2022

The Shore Capital Sustainability Advisory Team aims to provide a regular newsletter to corporate clients, with the intention of highlighting our insights into areas of corporate sustainability that are of key interest and debate. The topics will range across aspects of ESG, regulation, reporting and emerging stock market themes.

We provide a dedicated resource for corporates on sustainability and ESG issues. Working with management, we can identify key strategic objectives, implement suitable frameworks, and help on stewardship activities – increasing engagement with all stakeholders.

Please get in touch.

Author

Ling Sin Fai Lam
0 7780 704 898
ling.sinfailam@shorecap.co.uk

Hydrogen

Opportunities for scaling up in the UK

Hydrogen production at scale is not a new process. Around 0.7Mt is both produced and consumed in the UK annually [1], with the majority produced using methane reforming without carbon capture, utilisation and storage (CCUS). At present, most of the hydrogen produced in the country is largely used as a feedstock for industrial processes, for example in oil refining and the production of ammonia for fertilisers.

Hydrogen produces no carbon emissions at the point of combustion, giving rise to opportunities for the fuel to play a significant role in the decarbonisation of the UK's energy system. But there are challenges along the entirety of the hydrogen value chain, in the production, supply, storage and transportation of hydrogen, up to the point of combustion.

Hydrogen presents a huge opportunity for the UK to develop innovative technologies along the value chain and an opportunity for UK companies to play a leading role. This note aims to inform:

- **Business owners on key market dynamics such as government policy to identify innovative solutions and future revenue development linked to the hydrogen economy and**
- **Asset managers on the identification of value chain drivers outside of pure-play hydrogen that will most clearly benefit from the transition to a hydrogen economy.**

- Hydrogen is key to the UK meeting its statutory commitment to achieving net zero by 2050. The UK's hydrogen pathway includes a twin-pronged approach incorporating both blue and green hydrogen indicating the continued relevance of the UK's natural gas industry.
- The adoption of hydrogen requires systemic changes to the UK's existing energy system. Opportunities through innovations, policy interventions and investments along the entirety of the hydrogen value chain (production, networks and storage, and end-use). Conversely, multi-decade asset lifecycles expose companies to the threat of locked-in GHG emissions, stranded assets and technology obsolescence.
- Cost considerations vary depending on production technology: Capex profiles for blue and green hydrogen are unique, with key technology requirements of CCUS and electrolysis technologies respectively. Operating cost considerations focus on natural gas costs for blue hydrogen and renewable electricity costs for green hydrogen.
- Cost parity trajectory varies between end-use deployment. The market for hydrogen-related equipment and technologies is highly complex and fragmented but these technologies offer corporate opportunities to grow or future-proof their business models.

Hydrogen and UK's decarbonisation strategy

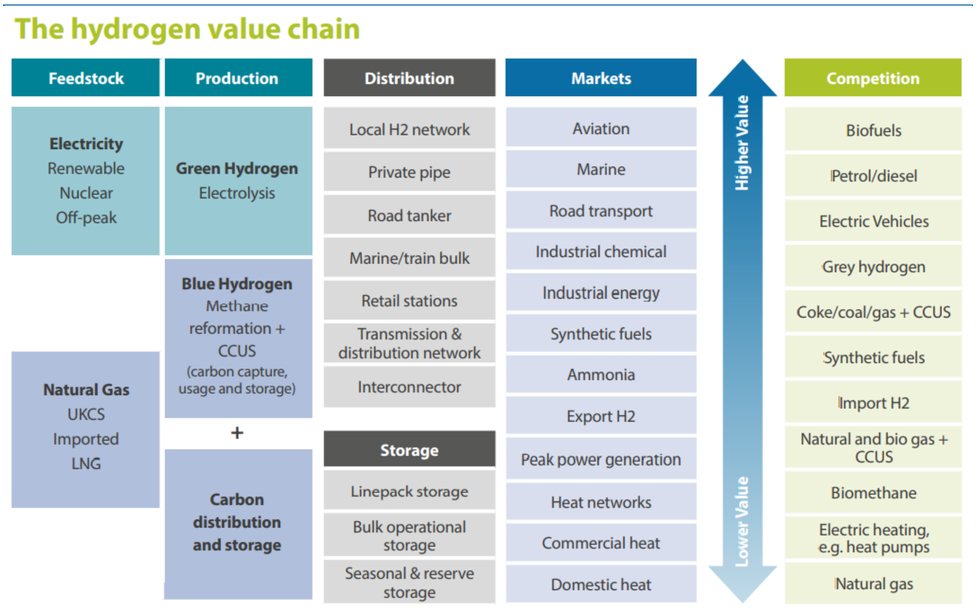
Low-carbon hydrogen key to achieving net zero in the UK, although business model and regulation unclear.

Low-carbon hydrogen has been identified as key to meeting the UK's statutory binding commitment to achieve net zero by 2050. The UK Government's Ten Point Plan for a Green Industrial Revolution targets 5GW of low-carbon hydrogen production capacity for use across the economy by 2030. Rapid and significant scale-up in low-carbon hydrogen production will be required as there is virtually no low-carbon hydrogen produced or used currently to supply energy.

The UK has the potential to become a global leader on hydrogen – the country's geography, geology, infrastructure and expertise make it particularly suited to rapidly developing a low-carbon hydrogen economy.

The hydrogen chain is complex with multiple distribution channels, markets and competitors. Thus, it is thus important to take each stage in the value chain individually as the issues are unique. From an upstream perspective, investors need to recognise the technological and feedstock options available for production. Downstream end-use markets are distinct with different value propositions for hydrogen products, and added to that, low-carbon hydrogen may be competing with a wide range of other low-carbon solutions.

Figure 1: The hydrogen value chain



Source: Regen Hydrogen Insight Paper, Regen

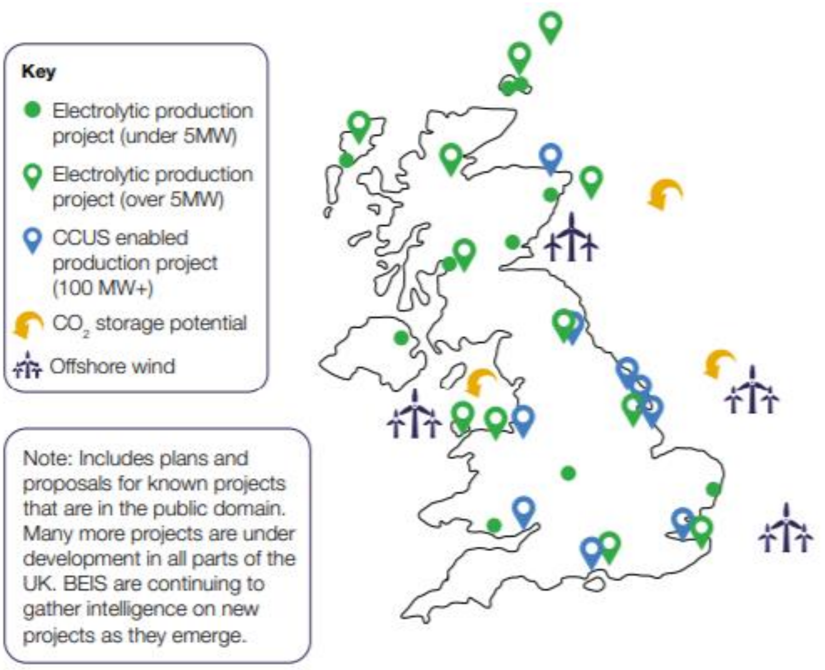
Deployment of hydrogen in the UK

Early deployment of hydrogen technology and infrastructure will be in industrial clusters by the coast, with important links to CO_2 storage sites such as disused oil and gas fields. The UK Government aims to establish CCUS in four industrial clusters by 2030 at the latest, supporting its ambition to capture 10Mt/CO_2 per annum. These industrial clusters will serve as significant potential demand centres for low-carbon hydrogen.

Clusters in the UK are located close to the coast due to proximity to disused oil and gas fields which serve as potential CO_2 storage sites.

Being located by the coast close to existing offshore wind assets also allows the industry to benefit from the UK's position as the largest global offshore wind generator.

Figure 2: Proposed UK electrolytic and CCUS-enabled hydrogen production projects



Source: UK Hydrogen Strategy, BEIS

Clusters are important for the development of nascent industries such as hydrogen as this focus can:

- Accelerate economies of scale and de-risk the production of hydrogen by providing greater certainty on hydrogen off-take and at the same time as decarbonising existing grey hydrogen production.
- Minimise the initial need for investments in large-scale long-distance pipeline and transport infrastructure.
- Accelerate and support the development of new end-use applications for hydrogen.
- Promote early development of storage infrastructure.
- Support collaborative development of the hydrogen industry that would benefit the entire value chain.

Hydrogen production pathways

Almost all UK hydrogen production is currently through emissions-intensive natural gas reforming and coal gasification without CCUS, which has a carbon footprint of 10-12 kgCO_2e per kg of hydrogen. Using hydrogen produced from unabated fossil fuels as an alternative to the fossil fuels themselves offers very limited environmental benefits and may even lead to higher global emissions.

The UK's hydrogen pathway includes the twin-pronged adoption of both blue and green hydrogen technologies, indicating the continued relevance of the UK's natural gas industry

Not all hydrogen production methods are zero carbon and may rely on carbon capture to deliver a net zero outcome. It is expected that no single hydrogen production method will dominate future markets, providing greater flexibility and resilience to the system. Two main low-carbon production routes have been highlighted as integral to the UK's hydrogen strategy to deliver the level of hydrogen needed to meet net zero rapidly and at scale: fossil fuels coupled with CCUS (blue hydrogen) or water electrolysis (green hydrogen).

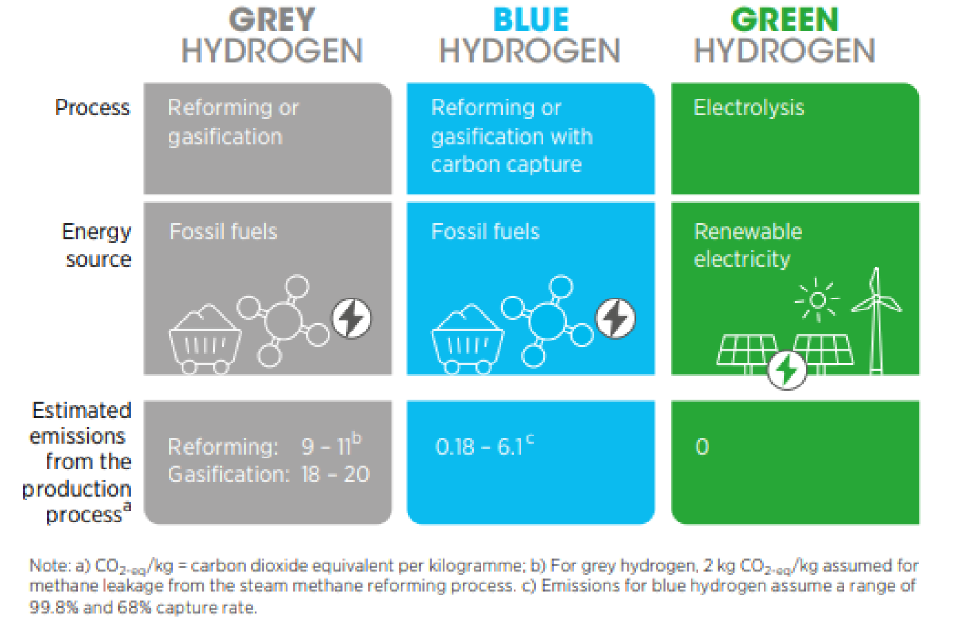
Grey hydrogen, sometimes referred to as black or brown hydrogen, is produced with fossil fuels using steam methane reforming (SMR) or coal gasification. This technology is not considered in the transition to net zero as the process entails substantial CO2 emissions.

Blue hydrogen, the combining of grey hydrogen with CCUS, is viewed as an early-stage transition technology. About 75%[5] of hydrogen is currently produced from natural gas, and the large-scale deployment of the technology could accelerate the growth of the hydrogen market and reduce the pressure on near-term renewable energy capacity installation rate to produce green hydrogen. However, the technology is not perfect and carbon emissions cannot be eliminated entirely.

Green hydrogen is considered the only fully sustainable technology for producing the element and is produced from renewable energy. The most established technology option for producing green hydrogen is water electrolysis fuelled by renewable electricity and produces no carbon emissions. Green hydrogen from water electrolysis has been gaining momentum as the technology allows the exploitation of synergies from sector coupling and providing flexibility to the power system.

Often, both blue hydrogen and green hydrogen are classed as low-carbon hydrogen. The UK is currently in the process of assessing and comparing options for a UK low carbon hydrogen standard that defines low carbon hydrogen.

Figure 3: Colour-code typology of hydrogen production



Source: Geopolitics of the energy transition: The hydrogen factor, IRENA

At present, blue hydrogen is still the main low-carbon hydrogen production method and will likely remain so in the short to medium term because production costs are lower than for lower-carbon green hydrogen technologies. CCUS is attractive because it can reduce emissions from existing production capacity quickly through retrofits and can enable large-scale dispatchable hydrogen production.

However, this technology is not perfect and the CO_2 emissions reduction potential for blue hydrogen is limited to 85-95% at best [5]. Upstream emissions also impact the lifecycle footprint of hydrogen produced from fossil fuels and CCUS. Additionally, the use of this technology restricts the extent to which carbon emissions can be reduced, since high capture rates have associated economic penalties.

Electrolysis, which produces green hydrogen from electricity and water, has the potential to generate carbon-free hydrogen if renewable or nuclear electricity is used, but the process can also result in very high emissions if the electricity source is of high carbon intensity.

There are various electrolyser designs. Alkaline polymer electrolyte (APE) and polymer electrolyte membrane (PEM) electrolysers are already commercial, whereas solid oxide electrolyser cells (SOECs) are at the precommercial stage and anion exchange membranes (AEMs) are the very early stage of development.

Key production barriers include:

- Production cost: Relative immaturity of low-carbon hydrogen technologies.
- Technological and commercial risk: Low-carbon hydrogen technologies have not been proven at scale in the UK.

- **Demand uncertainty**: Limited use of hydrogen in the UK at present, with producers having no certainty if their supply will be matched by market demand.
- **Lack of market structure**: No regulated market for the fuel.
- **Distribution and storage barriers**: The lack of sufficient carbon capture and storage and hydrogen transmission infrastructure.
- **Policy and regulatory uncertainty**: The lack of a clear and consistent long-term policy and regulatory framework for low carbon hydrogen adds risk to the investment process.

Hydrogen networks and storage

Most hydrogen is used directly worldwide, as end-user costs rise rapidly if it cannot be used in a gaseous state close to where it is produced. Converting hydrogen into another medium is costly to store, although conversion to other chemical compounds such as ammonia and liquid organic hydrogen carriers (LOHCs) are the options currently being considered. Gaseous hydrogen pipelines, liquefied hydrogen, ammonia and LOHC trailers are the most likely to be used in the UK.

Salt caverns and compressed gas tanks have been established as the most cost-effective ways to store hydrogen, in a scenario of a fully developed hydrogen economy where a substantial amount of the product will need to be stored. In the UK, four large salt deposits are currently being explored for their potential to store hydrogen in Teesside, East Yorkshire, Cheshire and under the East Irish Sea, with a total estimated storage capacity of 322TWh.

Injecting hydrogen into the gas grid or fully replacing natural gas with hydrogen has multiple benefits that include the utilisation of existing gas distribution networks, the viability of the gas distribution network as a storage medium for renewable electricity during times of low demand, and the cost advantage of transporting hydrogen in large quantities via pipes compared with transporting the energy equivalent in electricity.

There is currently limited transmission, distribution and storage infrastructure for hydrogen, as hydrogen use is small-scale and the hydrogen is often produced and used in the same location. Transmission and distribution include both pipeline and non-pipeline (e.g. through road transport) distribution methods, as well as the potential for blending into the gas grid. Storage covers above-ground vessels, underground storage, and the infrastructure allowing pressurisation, liquification or conversion to so called 'hydrogen carriers' (e.g. ammonia). There is a range of barriers to infrastructure being established:

- **Supply and demand uncertainty**: Lack of certainty on the size and location of distribution and storage infrastructure required, which could lead to stranded assets.
- **Cost and funding uncertainty**: Lack of clarity on the commercial frameworks and ownership structures that will apply to building and operating distribution and storage infrastructure.
- **Regulatory uncertainty**: Currently no established regulatory framework for hydrogen distribution and storage.
- **Safety and feasibility testing**: Outside of current industrial uses, distribution and storage of hydrogen has not been fully safety-tested at scale.

Hydrogen a solution for 'hard to abate' segments of the market.

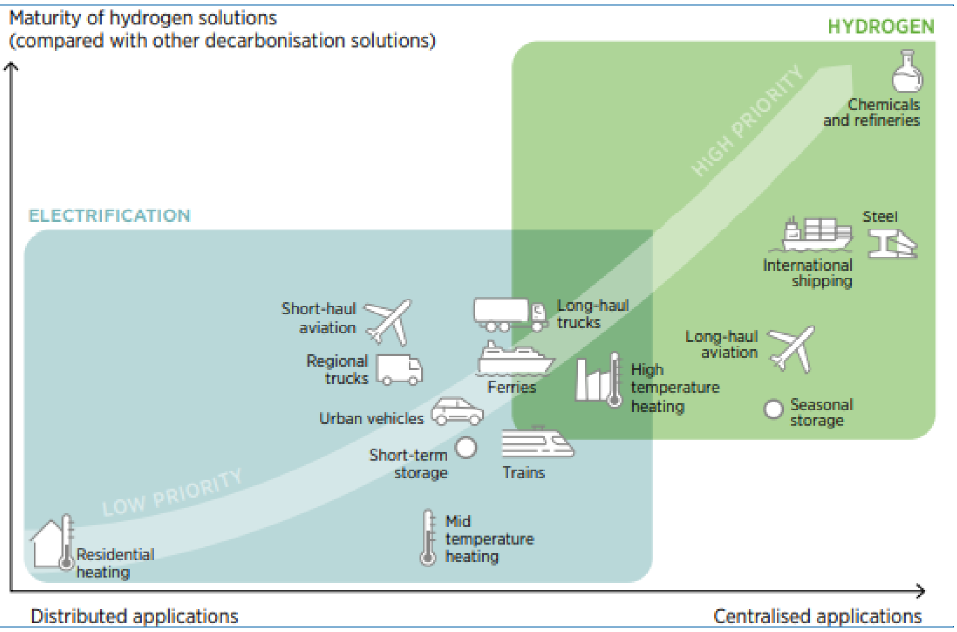
Hydrogen end-use

Currently, hydrogen is mostly used as a feedstock for industrial processes, for example in oil refining and the production of ammonia for fertilisers. Most consumption occurs near the point of production, but it is typically converted into ammonia for transportation since ammonia stores almost twice as much energy per unit as liquid hydrogen.

Hydrogen could be the solution to many of the hardest parts of the transition to net zero. This includes demands such as:

- Transport where greater ranges, as well as weight and volume considerations, mean that high energy density of fuel is essential (e.g. HGVs and shipping).
- Industrial sectors that are difficult to electrify due to a requirement for high-grade heat or chemical considerations (e.g. glass, steel and ceramics).
- Heating solutions that minimise change to homes or behaviours (e.g. homes unsuitable for heat pumps without significant insulation).

Figure 4: Maturity map of hydrogen solutions



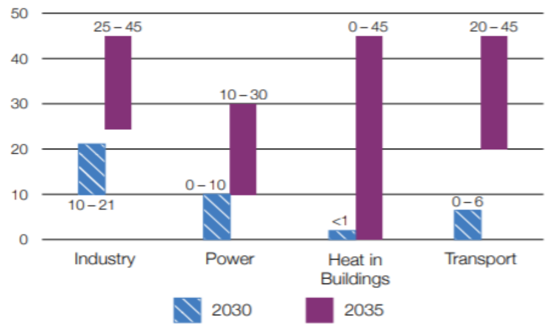
Source: Geopolitics of the energy transition: The hydrogen factor, IRENA

Barrier to hydrogen end-use broadly apply to new users across all end-use sectors, but the relative importance of each barrier and the extent to which they prevent hydrogen uptake varies depending on the end-use sector.

- User cost: The cost of low-carbon hydrogen is higher than that of fossil fuels or high-carbon hydrogen, so hydrogen can be more expensive for users than high-carbon alternatives. Users will face upfront costs of transitioning to hydrogen, including investment in new equipment, such as boilers or fuel cells: these can be more expensive than conventional equipment as they do not benefit from economies of scale or mature supply chains.

- **Technological and commercial risk**: There are risks associated with switching to low-carbon hydrogen as most technologies have not yet been commercially demonstrated.
- **Supply uncertainty**: There is no commercially available low-carbon hydrogen in the UK, so potential users of hydrogen cannot be sure they will have a secure supply.
- **Lack of market structure**: End-users of hydrogen may be more likely to be dependent on a small number of suppliers.
- **Distribution and storage barriers**: Hydrogen end-use requires infrastructure to transport and store hydrogen from the production facility to the end-users.
- **Policy and regulatory uncertainty**: The lack of a long-term policy and regulatory framework for low-carbon hydrogen could deter investors from switching to hydrogen.
- **Safety and feasibility testing**: The safety and technical case for low-carbon hydrogen use at scale has not been established for many end-uses.
- **Consumer awareness and acceptance**: Consumers may not be aware of the option of using it or may not be willing to do so.

Figure 5: Illustrative hydrogen demand in 2030 and 2035



Considering the delta between the anticipated demand of hydrogen from Heat in Buildings in 2030 and 2035, could this point to the largest end-user opportunity?

Note: Figures do not include blending into the gas grid.

Source: UK Hydrogen Strategy, BEIS

Costs required to deploy hydrogen

Looking at the hydrogen value chain split, the production of hydrogen accounts for the largest share of investments. End-application investments have a higher share in mature projects due to funding being needed for fuel cells and on-road vehicle platforms.

Companies tend to target their investments in the hydrogen space towards three specific areas: future investments of Hydrogen Council members trend heavily towards capex investments (80%) followed by spending on R&D or M&A activities[8].

Capital expenditure requirements

Three main hydrogen production technologies considered include:

- **Blue hydrogen**: Steam methane reforming with CCUS.
- **Green hydrogen**: PEM, Alkaline and SOCE.
- **Grey / blue hydrogen**: Gasification (of various feedstocks).

Figure 6: Capex requirements for the three main production technologies

Technology	Capex Requirements
Steam methane reforming with CCUS	• reformer unit • power island (steam turbine) • balance of plant, civil works (building and foundations) • electricity (where relevant) • gas grid connection • CO_2 dehydration & compression unit • SMR plants: unit for CO_2 removal from flue gas • ATR plants: air separation unit
Electrolysis	• electrolyser system (the stack) • balance of plant (drier, cooling, de-oxo and water de-ionisation equipment) • civil works (building and foundations) • electricity grid connection
Gasification	• gasifier • syngas treatment unit • air separation unit • shift conversion unit • acid gas removal unit • sulphur recovery unit • CO_2 drying & compression unit • methanator unit to convert residual carbon oxides

Source: Hydrogen production costs, BEIS, Shore Capital Markets

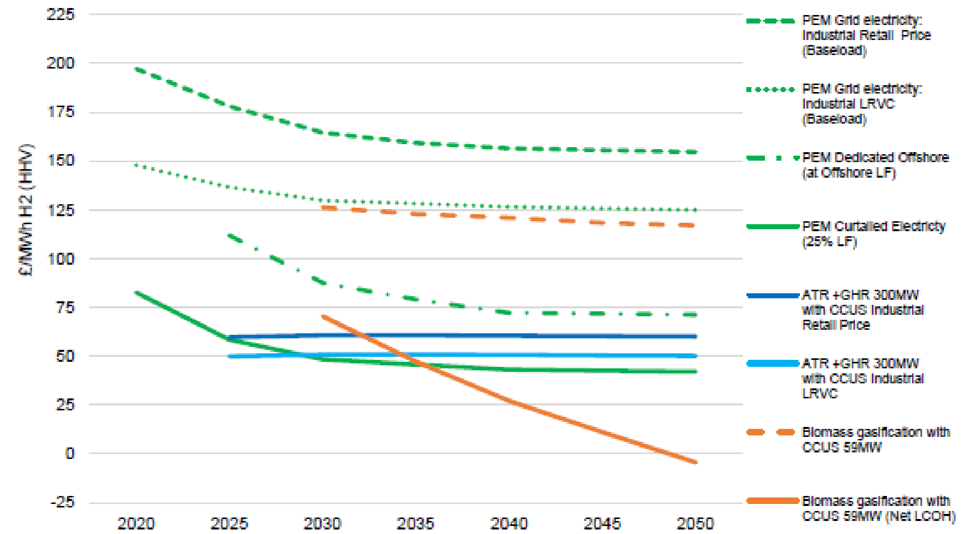
Costs of deploying hydrogen production technologies

At present, CCUS-enabled methane reformation technologies are the lowest-cost hydrogen production technology. However, over time and depending on fuel price assumptions, different electrolysis configurations are coming down in cost and in some cases become cost competitive with CCUS-enabled methane reformation technologies.

PEM using only curtailed electricity could become cost competitive from 2025 onwards, although the use of curtailment in the short term is likely to be limited, due to limited build-out in the power sector, limiting the production of hydrogen.

Biomass gasification with CCUS is relatively high cost, but the value associated with the negative emissions assumed for this analysis results in rapidly declining and even negative costs through to 2050.

Figure 7: Comparison of LCOH estimates across different technology types at central fuel prices commissioning from 2020 to 2050, £/MWh H_2, higher heating value (HHV)



Source: Hydrogen Analytical Annex, BEIS

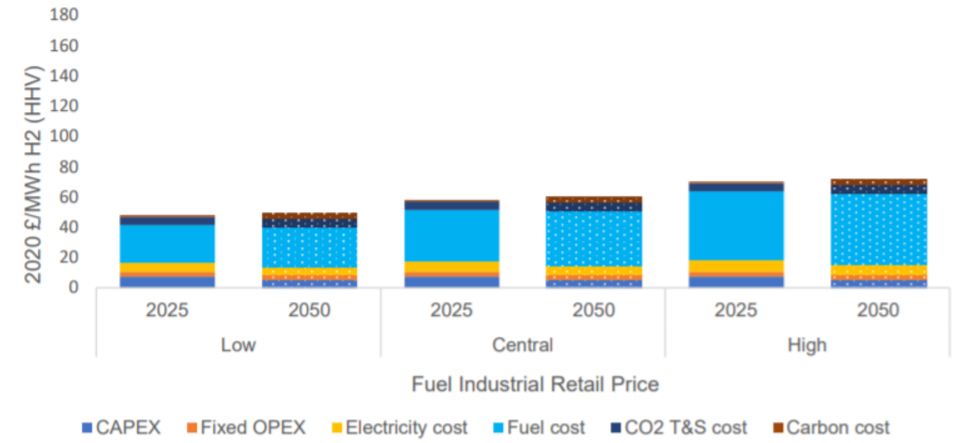
Blue hydrogen

Blue hydrogen is sometimes portrayed as a safe bet, because it allows producer countries to monetise natural gas resources and pipelines that might otherwise become stranded.

Main driver(s) of costs: Fuel costs, making overall production costs very sensitive to changing fuel prices (as illustrated).

Cost-reduction potential: Scope for economies of scale and modest capex and opex reductions over time through technological learning, although the overall potential is limited given fuel costs and carbon costs (expected to rise over time).

Figure 8: LCOH for an illustrative 1000MW ATR plant with CCUS



Note: Autothermal reforming (ATR) is the reforming of natural gas

Source: Hydrogen Analytical Annex, BEIS

Levelised cost of hydrogen (LCOH) is calculated as the discounted total costs incurred during the lifetime of an asset or project over the total discounted hydrogen volumes generated.

Green hydrogen

Countries and regions with high renewable potential and a low levelised cost of electricity (LCOE) can use their resources to become major producers of green hydrogen.

Main driver(s) of costs: Scenarios indicate that accessing grid electricity and paying the industrial retail price for it is the most expensive option, whilst using dedicated renewables (excluding private wire costs) and curtailed electricity are less costly, although limited by available supply. If plants can access lower grid electricity prices it would become a more cost-effective option.

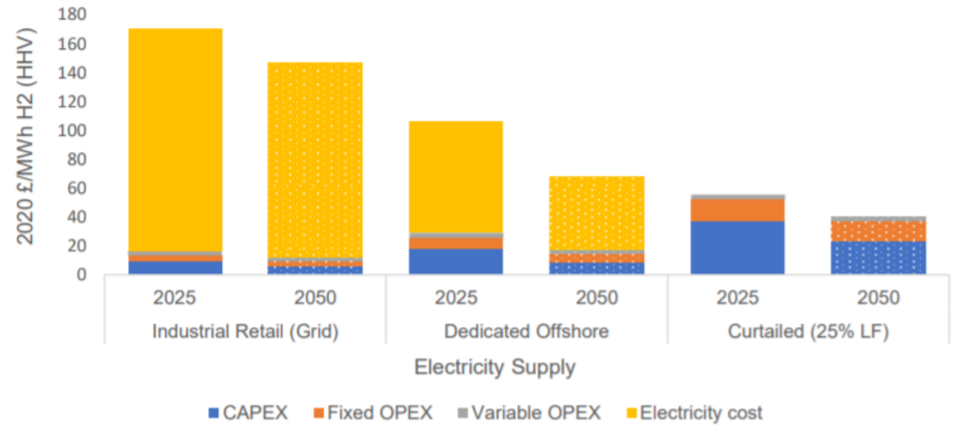
Cost-reduction potential: Capex and opex make up a larger proportion of the levelised costs in the 2020s; this proportion is lower in 2050, reflecting efficiency improvements through technological learning.

Industrial retail: Using electricity from the grid allows hydrogen producers to run at a constant, maximum load factor,

Dedicated offshore: Electricity from dedicated offshore electricity generation sources.

Curtailed: Using wasted electricity as input (i.e. where electricity supply exceeds demand or due to localised network constraints).

Figure 9: LCOH for an illustrative 10MW PEM electrolyser



Note: Proton exchange membrane (PEM), a technology used in the electrolysis of water for the production of hydrogen.

Source: Hydrogen Analytical Annex, BEIS

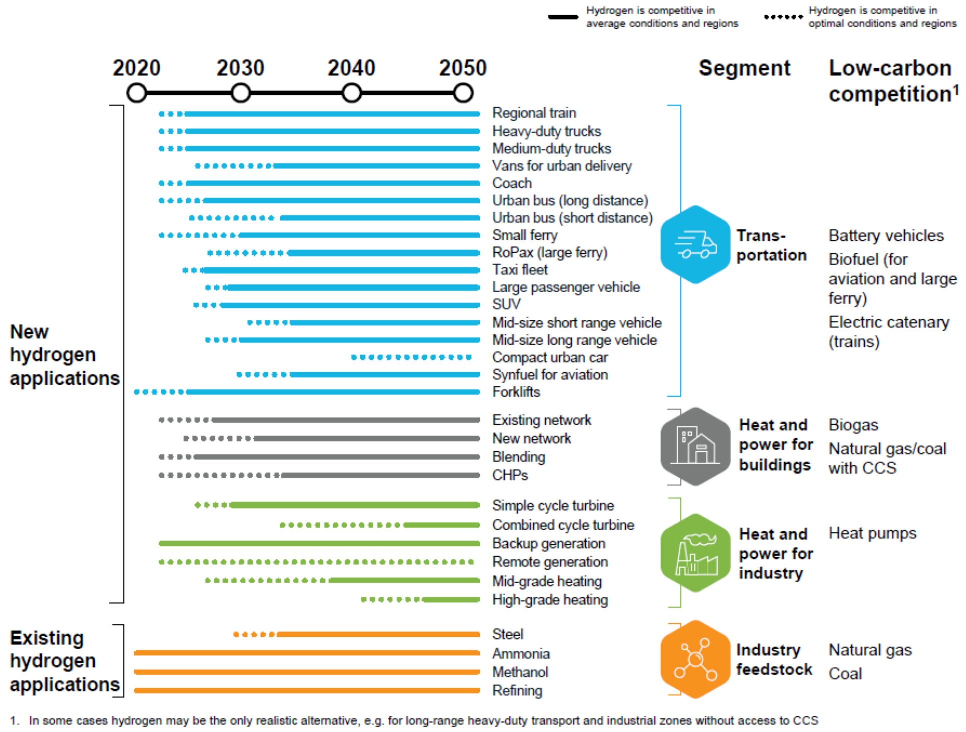
Cost of deploying end-use hydrogen technologies

Hydrogen is best suited to decarbonise 'hard to abate' applications where direct electrification with renewable energy is not feasible. For hydrogen to be viable as a low-carbon energy source, it will need to be cost competitive against low-carbon alternatives for companies to see the potential for hydrogen within their industries.

There are multiple opportunities for involvement in hydrogen and from the wide range of industries. The chart below illustrates cost competitiveness of hydrogen technologies in end-use sectors within a global context. Similar cost considerations for the UK market can be derived, although the break-even timing depends heavily on regional specific energy prices, infrastructure readiness and policy framework. This provides an idea on how the value chain might develop and when hydrogen is likely to be cost competitive for a specific application.

The risk of stranded assets exists in segments of the value chain with multi-decade asset lifecycles; operators that fail to future-proof their assets face locking-in GHG emissions and technology obsolescence in the journey to net zero.

Figure 10: Cost competitiveness trajectories of hydrogen applications



Source: Path to hydrogen competitiveness, Hydrogen Council

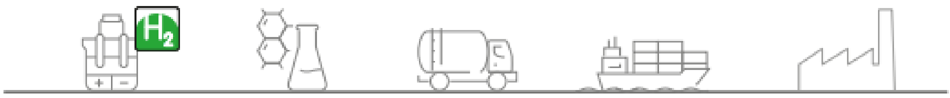
Opportunities

Innovation

The market for hydrogen-related equipment and technologies is highly complex and fragmented and the market has struggled due to the lack of technology, infrastructure and investments. The transition of the hydrogen economy is now expected to accelerate at scale. Two key pieces of technological equipment, electrolysers and fuel cells, are more mature than technologies in other parts of the value chain and offer the greatest opportunities to capture value and establish industry leadership.

Fuel cells hold significant potential for aiding in the development of zero-emissions heavy-duty vehicles. The scalability and affordability of renewable energy systems, as well as advancements in electrolysers, allow for green hydrogen production.

Figure 11: Estimated global market potential for hydrogen equipment and components, 2050



PRODUCTION	TRANSFORMATION	TRANSPORTATION	END USE	
USD **60-65** bn	USD **35-40** bn	USD **25-30** bn	USD **80-90** bn	
			Transport	Industry
USD 50-60 bn for electrolysers, including balance of plant	USD 21-25 bn for ammonia	USD 5-7 bn for storage	USD 21-25 bn for fuel cells	USD 16-20 bn for iron reduction and electric-arc furnace
		USD 5-7 bn for compression	USD 11-15 bn for onboard storage	USD 11-15 bn for equipment
		USD 2-5 bn for pipelines	USD 8-10 bn for combustion engines	USD 8-10 bn for heat and power generation
USD 5-7 bn for capture technology	USD 16-20 bn for carbon-based compounds (*e.g.* methanol, synfuels, LOHC)	USD 11-15 bn for other distribution	USD 3-6 bn for fueling stations	

Source: Ludwig et al. (2021)

Business Opportunities

The transition to a new energy carrier requires a series of investments and enhancements not only in energy supply and distribution, but also in end-use technologies. Opportunities for corporates exist across the value chain in innovation or adoption. The former brings about the potential for clear competitive advantage through the development of technology or services associated with the hydrogen value chain. The latter covers opportunities for corporates to adopt or invest in off-the-shelf solutions into their operating models.

For each of the sectors listed below, we have looked at the opportunities available to them in terms of "Innovation Opportunities" or "Adoption Opportunities".

Figure 13: Opportunities by sector

Sector	Innovation opportunity	Adoption opportunity	Commentary
Oil and gas	●	●	Big oil has substantial experience in developing assets and have collectively pledged billions of dollars towards sustainable hydrogen production. Grey or blue hydrogen, created from natural gas, is seen as option for transition rather than going full on renewable, avoiding the potential for stranded natural gas assets. Hydrogen presents a logical growth opportunity for the sector due to the sector's gas capabilities and emerging renewable energy capabilities. UK refineries, which already use large volumes of hydrogen, are best placed to provide an offtake market to blue hydrogen, and exist in close proximity to energy intensive industries,
Resources	●		At present, there is sufficient geological supplies of most minerals and metals required for hydrogen technologies (e.g. platinum group metals in PEMs). Markets could tighten with rapidly rising demand and long lead times in mining and refining projects.
Gas networks / heating	●	●	Adoption of hydrogen is a natural extension of a utility's business of building and owning assets, allowing utility players to utilise existing natural gas infrastructure (potentially carbon capture) and maintain relevance in future decarbonisation strategies. Five of the leading gas players in the UK (Cadent, National Grid, NGN, SGN and Wales & West Utilities) formed the Energy Networks Association, which has proposed a £900 million plan, for a UK hydrogen/biomethane gas network.
Capital goods	●		Increased demand for green hydrogen will benefit technology manufacturers with electrolysis know-how or related renewable generation offerings. Energy and utilities already are already among the most important end markets.
Heavy industry		●	Industrial steelmakers have stated that hydrogen has a key role within their long-term decarbonisation strategies. Technology for iron and steel production using hydrogen-based furnaces, and turbines for electrolysis for high-temperature heat applications, or for industrial feedstock, are already in existence today. Due to long life cycles of industrial heat, process and power assets, decisions on whether to commit to hydrogen are being made today.
Industrial chemicals and gas		●	Industrial gas companies will look to adapt to some of the new opportunities created in the sustainable hydrogen market through low carbon feedstock. Existing use cases for hydrogen may be among the first green hydrogen opportunities to be financeable, because the offtake picture will be clearer and easier to model. The case for green or blue ammonia depends heavily on lowering costs and policy requirements, since fertilizers are a global commodity, highly sensitive to raw material costs and the sales price for farmers.
Transport		●	Major heavy-duty vehicle manufacturers have started taking steps to explore the feasibility of hydrogen-based fuel cells. That technology is a better alternative to batteries because of the combination of weight, range and refuelling downtime. Buses could see a first rollout, given public support and pollution considerations. High upfront costs of fuel cell electric vehicles (FCEVs) and limited refuelling infrastructure in the UK hinder the more rapid adoption of FCEVs. The transport sector is likely to use green hydrogen, transported in trailers compressed or liquefied to a refuelling station, cost reduction in any of these value chain components is key.

Source: UK Hydrogen Strategy, BEIS, Shore Capital Markets

Figure 14: Hydrogen landscape in the UK (non-exhaustive illustration)

	Production Technologies					Storage						Distribution and Transport						Applications							
Company	Electrolysis and related processes	Reforming and CCUS	Methane Cracking	Gasification and Pyrolysis	Advanced Nuclear	Chemical Storage	Geological	Pressurisation, Materils	Intermediate Storage Vectors	Gas Grid	Cyrogenics	Pipe	Road	Infrastructure Refurbishment	Blending with Natural Gas	Synthetic Fuels	Switching / Hydrogen Network	Generation (Central and Distributed)	Combined Heat and Power	Energy Supply	Mobility	Domestic Heating	Cooking	Industry Use	Industry Feedstock
BOC	●	●										●	●					●			●				
Pure Energy Centre	●							●													●	●	●	●	
Johnson Matthey	●	●																			●				
Air Products		●										●													
Auriga Energy																		●			●				
Calvera								●					●												
Clean Power Hydrogen	●										●														
EDF	●				●																				
Intelligent Energy																		●			●				
Kew Technology				●					●																
KGD								●				●													
NanoSun													●								●				
Steamology																					●			●	
TCP																		●						●	
Adelan																		●							
AFC Energy																					●				
Alstom																					●				
Arcola Energy																					●				
Baxi Heating																						●			
BP		●																							
Bramble Energy																		●							
Cadent												●													
Cheesecake Energy								●																	
Chesterfield Special Cylinders								●																	
CPE								●																	
EMEC	●																								
Engas UK	●																								
Enocell																		●							
ever resource			●																						
Floggs Britain												●													
Fuel Cell Systems																					●				
Geostock							●																		
GIOCOMINI UK																						●			
HIIROC	●																								
Ideal Heating																						●			
Inovyn	●																								
Invicta Hydrogen Systems		●																							
iPower																			●						
ITM Power	●																								
Logan Energy																			●						
Microcab																					●				
National Grid										●															
National Nuclear Laboratory					●																				
PowerHouse Energy				●																					
Riversimple																					●				
SABIC							●																		
SGN																	●								
Shell	●																								
SSE Thermal							●																		
Storengy							●																		
Supercritical Solutions	●																								
U-Battery					●																				
ULEMCo																					●				
Vivarail																					●				
Worcester Bosch																						●			
Wrightbus																					●				

Source: Catapult Energy Systems, Shore Capital Markets

Opportunities for equity capital markets

Strong and coordinated government policies and incentives, and significant government and private sector funding would be necessary to mobilise the capital required to build scale and advance hydrogen technologies. An increasing pool of financial providers can be expected to come into the capital structure on the equity or debt side as the industry begins to demonstrate a credible track record of returns.

For equity investors seeking exposure to the hydrogen economy, opportunities should not be limited to companies focused specifically on pure-play hydrogen technologies. Further opportunities exist in companies actively engaged in the advancement of the hydrogen economy, which may include value-creating activities within the hydrogen economy such as energy input (natural gas, renewables), production, storage and end-use technologies.

The finalisation of the UK's hydrogen business model is expected this year, and further clarity would lead to more confidence for investors in companies pursuing innovative growth solutions in the industry. These include oil and gas producers, energy equipment and services, utilities, capital goods, as well as adopters of end-use solutions in transport, heat and industry.

Investors could also look at adjacent opportunities that may might be deemed to be competitive technologies: by far the largest investments are not expected to be in the hydrogen production and use system itself, but in the renewable energy electricity system required to support the massive increase in green hydrogen production.

Investment in hydrogen is expected to accelerate as we see a rise of impact investing and LGIM launched the first pure hydrogen economy ETF in Europe last February. Whilst hydrogen may seem a natural area of investment for impact investment, such investors would need to be mindful of the type of hydrogen (blue vs. green) and the application of the hydrogen technology invested in (e.g. the advantages of heat pumps vs. hydrogen heating).

Infrastructure funds have taken a systems approach to hydrogen. A recent example was the collaboration between TotalEnergies, Air Liquide, and VINCI with other large international companies to sponsor the creation of the world's largest fund exclusively dedicated to clean hydrogen infrastructure solutions, with the objective of accelerating the growth of the clean hydrogen ecosystem.

Institutional investors including pension funds, sovereign wealth funds and insurance companies are not excluded from this investing trend. These investors realise that the industry will be growing at an exhilarating pace and want to participate in this growth.

It should be stressed that investors should keep in mind where the most material and beneficial use of hydrogen lies holistically alongside other investments in clean and renewable energy sources. The current risk reward profile of the industry suggests a focus on opportunities that are less reliant on long-dated government funding or policy decision with lower off-take, technology and financing risks.

Conclusion

Hydrogen presents a huge opportunity for the UK to develop innovative technologies along the value chain and an opportunity for UK companies to play a leading role, not only on a national but also on an international stage.

Over the short to medium term, the hydrogen economy is faced with high costs of production relative to other sources of low carbon energy. The industry faces risks of nascent industries that include technology failures and cost overruns as there is limited experience of developing large scale hydrogen projects for many technologies.

In an encouraging step away from the historical modus operandum of upstream energy suppliers, sectoral collaboration has emerged in the UK, via clusters to spread the risks associated with developing a new energy market. Partnerships and joint ventures have been formed across the landscape, each with its own specific makeup of partners, areas of expertise, and strategic goals.

Companies with technology expertise clearly should consider ways of capturing the greatest possible share of the value available in the hydrogen market, through superior technology differentiation or solutions improving the efficiency of individual components and systems needed for various H2 applications, especially given the potential size of the opportunity.

The UK government has an important role to play, working with industry to move the hydrogen economy from strategy to delivery. Policy support is required as current market signals are not strong enough to drive investment into the sector at the pace required, potentially creating a technology and skills gap. One can also see the scale of the potential market would be influenced very significantly by the adoption in heat in the UK as well as transport.

Considering the size of the challenge and the urgency to make decisions, investors and corporates will need to be confident that there will be sufficient demand for hydrogen and avoid the risk of overcommitting capital and being aware of the risk of stranded assets.

In our view hydrogen will have a leading role to play in the energy system of the UK, across multiple channels, and rather than over-promise, under-deliver, and lose out to other global players, the UK should be able to rekindle the type of prominence that it used to have in the nuclear industry. Such a leadership was built on solid foundations over time and allowed industries to develop. The building blocks are starting to fuse, and we will be covering the progress in future notes, bringing out the opportunities for UK PLC's.

Lastly, we look forward to further policy support to provide more confidence in the sector. Of note are the finalisation of the business model in 2022 and a decision on hydrogen heating by 2026.

[1] ***H2FC Supergen, May 2020**, Opportunities for hydrogen and fuel cell technologies to contribute to clean growth in the UK*
[2] ***BEIS, August 2021,** "UK hydrogen strategy"*
[3] ***Regen,** "Hydrogen insight paper, Building the hydrogen value chain"*
[4] ***IRENA, Jan 2022,** "Geopolitics of the energy transition: The hydrogen factor"*
[5] ***IRENA, 2020,** "Green hydrogen policies and technology costs"*
[6] ***BEIS, August 2021,** "Hydrogen production costs"*
[7] ***BEIS, August 2021,** "Hydrogen analytical annex"*
[8] ***Hydrogen Council, Jan 2020**, "Path to hydrogen competitiveness, A cost perspective"*
[9] ***Catapult energy systems**, https://energylaunchpad.energy*
[10] ***IEA, June 2019,** "The future of hydrogen, Seizing today's opportunities"*
[11] ***National Grid, July 2020,** "Future energy scenarios"*

Abbreviations

APE	*Alkaline polymer electrolyte: Lye is used as an electrolyte to produce hydrogen from water.*
AEM	*Anion exchange membranes: Anion-exchange membranes are used to decompose water into hydrogen and oxygen gas.*
ATR	*Autothermal reforming: Process for producing syngas, composed of hydrogen and carbon monoxide, by partially oxidizing a hydrocarbon feed with oxygen and steam and subsequent catalytic reforming.*
CCUS	*Carbon capture, utilisation and storage: Process to remove and store CO_2 from the flue gas and from the atmosphere.*
FCEV	*Fuel cell electric vehicle*
GHG	*Greenhouse gas emissions*
HGV	*Heavy goods vehicles*
LCOE	*Levelised cost of electricity: Net present cost of electricity generation for a generating plant over its lifetime.*
LCOH	*Levelised cost of hydrogen: Methodology used to account for all capital and operating costs of producing hydrogen, enabling different production routes to be compared on a similar basis*
LOHC	*Liquid organic hydrogen carriers: Organic compounds that can absorb and release hydrogen through chemical reactions. Used as a storage media for hydrogen.*
PEM	*Polymer electrolyte membrane: Proton-exchange membranes are used to decompose water into hydrogen and oxygen gas.*
SMR	*Steam methane reforming: Process of using a desulphurised hydrocarbon feedstock such as natural gas to produce hydrogen.*
SOEC	*Solid oxide electrolyser cells: Electrolysis of water by using a solid oxide, or ceramic, electrolyte to produce hydrogen gas and oxygen.*
SUV	*Sport utility vehicle*

CONFLICTS OF INTEREST

Shore Capital maintains a Conflicts Policy which explains how conflicts are managed. A summary of the Conflicts Policy is available at www.shorecap.co.uk. For details of potentially relevant conflicts of interest (if any) on a specific stock whether disclosed in this research report or not, please refer to the following table or contact Shore Capital's compliance department on 020 7408 4050:

Company	Disclosures	Date	Recommendation
BOC, Pure Energy Centre, Johnson Matthey, Air Products, Auriga Energy, Calvera, Clean Power Hydrogen, EDF, Intelligent Energy, Kew Technology, KGD, NanoSun, Steamology, TCP, Adelan, AFC Energy, Alstom, Arcola Energy, Baxi Heating, BP, Bramble Energy, Cadent, Cheesecake Energy, Chesterfield Special Cylinders, CPE, EMEC, Engas UK, Enocell, ever resource, Floggs Britain, Fuel Cell Systems, Geostock, GIOCOMINI UK, HIIROC, Ideal Heating, Inovyn, Invicta Hydrogen Systems, iPower, ITM Power, Logan Energy, Microcab, National Grid, National Nuclear Laboratory, PowerHouse Energy, Riversimple, SABIC, SGN, Shell, SSE Thermal, Storengy, Supercritical Solutions, U-Battery, ULEMCo, Vivarail, Worcester Bosch, Wrightbus	The companies mentioned in the report are for reference and none of material contains recommendations	24/02/2022	No recommendations made.

Disclosures

^ Independent Research:
This is independent research. The analyst who has prepared this research is not aware of Shore Capital Stockbrokers Limited and/or another member of the Shore Capital group ("Shore Capital") having a relationship with the company covered in this research report and/or a conflict of interest which is likely to impair the objectivity of the research and this report should accordingly be viewed as independent.
+ Non-Independent Marketing Communication:
This is a non-independent marketing communication. The analyst who has prepared this report is aware that Shore Capital Stockbrokers Limited and/or another member of Shore Capital has a relationship with the company covered in this report and/or a conflict of interest which may impair the objectivity of the research. Accordingly the report has not been prepared in accordance with legal requirements designed to promote the independence of investment research and is not subject to any prohibition on the dealing ahead of the dissemination of investment research.

REGULATORY DISCLOSURES

It is the policy of Shore Capital Stockbrokers Limited not to make recommendations on companies for which it acts in an advisory capacity. Where this is the case, research reports refer to "House Stock". The reference to "Price" on the front cover of formal research reports is to the current price as at the date of the research report. The date and time when the production of the report is completed is the date and time stated on the relevant report.
Recommendation History:
For a list of all research recommendations of Shore Capital analysts and sales persons disseminated in the previous 12 months, please contact compliance@shorecap.co.uk or your usual Shore Capital contact.
Stock Recommendation Definitions:
Buy 10%+ absolute performance within 3-months or otherwise as specified.
Hold +/- 10% absolute performance on a 3-month basis or otherwise as specified.
Sell -10% absolute performance on a 3-month basis or otherwise as specified.
Valuation, Methodology and Assumptions:
For a summary of the basis of valuation, methodology and/or underlying assumptions used to evaluate the company covered in this research report, please click on the following link http://shorecap-disclosures.co.uk/methodology/methodology.pdf or contact your usual analyst or sales person at Shore Capital. For information on changes in valuation, methodology or underlying assumptions related to this research report (if any) please contact your usual analyst or sales person at Shore Capital.
Proprietary Models:
Shore Capital analysts typically utilise proprietary models to produce research reports. Information on the specific proprietary models used for the company or companies covered in this research report is available by contacting your usual analyst or sales person at Shore Capital.
Research Distribution
RecommendationDistribution
Lead Analyst:
The lead analyst with respect to each research item is the first and most prominent name. Please note that more than one analyst may work on a specific research item.
Planned Frequency of Updates:
Recommendations in Shore Capital research reports are kept under constant review. As such, there is no formal timetable for the review of such recommendations.

DISCLAIMER

The issue of this report is not necessarily indicative of long term coverage of the stock. Hence, updates may or may not be issued in the future. This report is published solely for informational purposes and is not to be construed as a solicitation or an offer to buy or sell any securities, or related financial instruments. It does not constitute a personal recommendation as defined by the Financial Conduct Authority ("FCA") or take into account the particular investment objectives, financial situations or needs of individual investors. The recipient of this information must make their own independent decisions regarding any securities, or financial instruments mentioned in this report.

The information above is obtained from sources considered reliable. However, the accuracy thereof cannot be guaranteed by us. Shore Capital or any of its associated companies (or its or their employees) may from time to time hold positions in the above equities as principal, and may also perform corporate advisory services for these companies. Share prices can go down as well as up and past performance is not necessarily a guide to the future. Some investments may require you to pay more money than the cost of the investment. The value of, or income from, any investments referred to in this report may fluctuate and/or be affected by changes in exchange rates. Levels and bases of taxation may change.

This document may not be reproduced or further distributed to any person (including the media) or published in whole or in part, for any purpose. The material in this document is not intended for distribution or use outside the European Economic Area or Switzerland (with the exception of the United States) and may not be published, distributed or transmitted to persons in Japan, Canada or Australia. This material is not directed at you if Shore Capital is prohibited or restricted by any legislation or regulation in any jurisdiction from making it available to you.

In the United Kingdom this document is being distributed only to, and is directed only at, persons who are (i) investment professionals falling within article 19(5) of the Financial Services and Markets Act 2000 (Financial Promotion) Order 2005 (as amended) (the "Order") or (ii) high net worth entities falling within articles 49(2)(a) to (d) of the Order or (iii) any other persons to whom it may be lawfully communicated (all such persons being referred to as "relevant persons"). This document is addressed only to, and directed only at, relevant persons and qualified investors within the meaning of the Prospectus Directive (2003/71/EC, as amended) and must not be acted on or relied on (i) in the United Kingdom, by persons who are not both relevant persons and qualified investors or (ii) in any Member State of the EEA other than the United Kingdom, by persons who are not qualified investors. Any investment or investment activity to which this communication relates is available only to, and any invitation, offer or agreement to subscribe, purchase or otherwise acquire any securities referred to in this document will be engaged in only with, in the United Kingdom, relevant persons who are also qualified investors, and in any Member State of the EEA other than the United Kingdom, qualified investors.

The views expressed in this document accurately reflect the research analyst's personal views about any and all of the subject securities and the company on the date of this document. Any opinion or estimate expressed in this document is subject to change without notice. Shore Capital may act upon or use the information or a conclusion contained in this document before it is distributed to other persons. None of Shore Capital Stockbrokers Limited or any member of Shore Capital, or any of its or their directors, officers, employees or agents accept any responsibility or liability whatsoever for any loss however arising from any use of this document or its contents or otherwise arising in connection therewith. By accepting this document, you agree to be bound by the foregoing limitations.

The following applies if the company is quoted on "AIM" – defined as the AIM Market of the London Stock Exchange. AIM is a market designed primarily for emerging or smaller companies and the rules of this market are less demanding than those of the Official List of the UK Listing Authority, consequently AIM investments may not be suitable for some investors. Liquidity may be lower and hence some investments may be harder to realise.

DISTRIBUTION IN THE UNITED STATES

This report is intended only for Major U S Institutional Investors, as defined by Rule 15a-6 under the U.S. Securities Exchange Act of 1934. It is not available for any other person or entity in the United States. Orders from Major U S Institutional Investors for securities covered in this this report may not be placed with Shore Capital Stockbrokers Limited (Shore Capital) and may only be placed with our correspondent, Auerbach Grayson & Company at 212-557-4444.

Shore Capital Stockbrokers Limited (Shore Capital) is not registered as a broker-dealer with the U S Securities and Exchange Commission, and it and its analysts are not subject to SEC rules on securities analysts' certification as to the currency of their views reflected in the research report. Shore Capital Stockbrokers Limited (Shore Capital) is not a member of the Financial Industry Regulatory Authority. It and its securities analysts are not subject to FINRA's rules on Communications with the Public and Research Analysts and Research Reports and the attendant requirements for fairness, balance and disclosure of potential conflicts of interest.

This research report is only being offered to Major U S Institutional Investors and is not available to, and should not be used by, any U S person or entity that is not a Major U S Institutional Investor. Shore Capital Stockbrokers Limited (Shore Capital) can not and will not accept orders for the securities covered in this research report placed by any person or entity in the United States. Orders should be placed with our correspondent, Auerbach Grayson & Company at 212-557-4444. Auerbach Grayson and Company LLC is a broker-dealer registered with the SEC and a member of FINRA and the Securities Investor Protection Corporation.

DISTRIBUTION IN CANADA

Shore Capital avails itself of the international dealer exemption from registration as a dealer in Canada in the provinces of Ontario and Quebec. Under Canadian securities regulations, Shore Capital is limited to providing research and brokerage services to permitted clients in those provinces. By accepting to receive research reports or brokerage services from Shore Capital, you represent that you qualify as a permitted client under Canadian securities regulations.

If you would like to amend your communication preferences please contact your Shore Capital representative, or alternatively, should you wish to unsubscribe from all email communications you can do so by emailing unsubscribe@shorecap.co.uk

Shore Capital Stockbrokers Ltd. is authorised and regulated by the Financial Conduct Authority. Member of the London Stock Exchange.
Registered in England and Wales at Cassini House, 57 St James's St, London, SW1A 1LD. Registered No. 01850105.
Member of the Shore Capital group

Contacts

Simon Fine
Chief Executive Officer
+44 (0)20 7468 7950
simon.fine@shorecap.co.uk

Dr Clive Black
Head of Research
+44 (0)151 600 3701
clive.black@shorecap.co.uk

Dru Danford
Head of Corporate Advisory
+44 (0)20 7468 7905
dru.danford@shorecap.co.uk

Malachy McEntyre
Head of Corporate Broking
+44 (0)151 600 3710
malachy.mcentyre@shorecap.co.uk

Nick Conyerd
Head of Market Making
+44 (0)20 7647 8135
nick.conyerd@shorecap.co.uk

John Ritchie
Head of Sales
+44 (0)151 600 3705
john.ritchie@shorecap.co.uk

David Simmons
Head of Sales Trading
+44 (0)20 7647 8126
david.simmons@shorecap.co.uk

Jane Horder
Head of Investor Relations
+44 (0)151 600 3715
jane.horder@shorecap.co.uk

London Office
Cassini House
57 St James's St
London SW1A 1LD
T: +44 (0)20 7408 4080

Liverpool Office
The Corn Exchange
Fenwick Street
Liverpool L2 7RB
T: +44 (0)151 600 3700

Edinburgh Office
76 George Street
2nd Floor
Edinburgh EH2 3BU
T: +44 (0)20 7079 1670