The role of hydrogen in the energy transition:

A complementary option, but not a silver bullet

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In brief

- The potential for hydrogen to play an important role in the transition to a low-carbon economy is increasingly of interest to investors.
- Some think hydrogen could be key to transforming our energy system and the industries that rely on it; others see it as an inefficient use of scarce resources and a distraction from other low-carbon technologies.
- In our view, hydrogen can be a sustainable solution for the energy transition, but it is not a silver bullet.
- Investors should develop a clear understanding of hydrogen's possibilities and limitations, and how it fits into different scenarios for reaching net zero, alongside the investment opportunities it can realistically offer.

Hydrogen: What you need to know

Hydrogen is the simplest and most abundant element. However, while hydrogen is abundant, on Earth it is usually found as part of a compound – most commonly in water molecules. Producing pure hydrogen therefore requires an input of energy, which can then be released when burned. As a result, hydrogen itself is not a source of energy, but can be thought of more as a form of energy storage, much like conventional batteries.

The energy used to produce pure hydrogen can come from different sources, ranging from coal to renewables, with each type of hydrogen production having a different impact in terms of carbon dioxide (CO_2) emissions. Today, 2% of primary energy is converted into hydrogen, and current global hydrogen production is responsible for around 2% of CO_2 emissions annually.[1] There is a need both to prioritise less fossil fuel-intensive means of hydrogen production – especially if hydrogen production increases as it plays a larger role in the economy - and to explore how an increased supply of clean hydrogen could help further support global decarbonisation efforts.

[1] International Energy Agency, "Hydrogen", IEA (Paris, 2022). https://www.iea.org/reports/hydrogen

Hydrogen production

As CO_2 emissions vary depending on how hydrogen is produced, a "rainbow" of different hydrogen types has emerged, categorised according to the method of production and the associated CO_2 emissions profile. Less than 1% of all hydrogen produced today is low-carbon ("green", "blue" or "pink")[2].

This proportion of low-carbon production must be significantly scaled up if hydrogen is to play a meaningful role in the global transition to net zero.

Exhibit 1: The Hydrogen rainbow

Colour	Brown	Grey	Blue	Turquoise	Yellow	Pink	Green
Energy source	Black/brown coal	Natural gas	Natural gas, coal	Natural gas	Mixed-origin grid energy	Nuclear	Wind, solar, hydro, geothermal
Technology	Gasification	Natural gas reforming	Natural gas reforming + carbon capture, usage and storage	Pyrolysis	Electrolysis	Electrolysis	Electrolysis
GHG emissions	High	Medium	Low	Varies according to fuel source	Medium	Minimal	Minimal

Source: J.P. Morgan Asset Management.

The most common method of producing hydrogen is currently natural gas reforming, whereby steam and natural gas react in the presence of a catalyst. This process, which accounted for 47% of total hydrogen production in 2021[3] results in 'grey' hydrogen, as well as by-products of carbon dioxide and carbon monoxide - both of which are contributors to global warming.

Electrolysis as a method currently accounts for a very small proportion of hydrogen production - just 4% in 2021[4]. As the table above shows, the GHG emissions from electrolysis vary according to how the electricity itself is produced. Electrolysis using electricity made from renewable energy is the process that must be scaled up to increase supply of 'green' hydrogen.

[2] International Energy Agency, "Hydrogen"
[3] https://www.irena.org/Energy-Transition/Technology/Hydrogen
[4] https://www.irena.org/Energy-Transition/Technology/Hydrogen

Hydrogen deployment: Fuel cells vs. combustion

Once pure hydrogen has been produced, there are two main ways of using it: either in fuel cells or for combustion. Hydrogen fuel cells, which produce clean electricity at the point of use, are considered the most efficient way of recovering energy from hydrogen. However, fuel cells are not as efficient as electric battery technology, because of the extra step required to convert electricity to hydrogen before it can be turned back again to electricity. Therefore, while the electricity created from fuel cells can be used with some existing technologies, such as electric vehicles and heat pumps, batteries are still a far more efficient way to store electrical energy. As a result, there are significant disincentives to deploying hydrogen fuel cells at scale.

Combustion, on the other hand, is a cheaper and easier method of using hydrogen, as well as being more compatible with existing infrastructure. It is, however, on balance a less efficient way to recover stored energy than fuel cells, and therefore requires more hydrogen production, which could have the unintended consequence of producing more CO_2 emissions – depending on how this hydrogen is produced.

Deployment

Use cases for hydrogen range from the unavoidable, to the uncompetitive.[5] In some industrial processes, namely chemicals production, refineries, and iron and steel making, there is no real alternative to hydrogen when it comes to decarbonising. Hydrogen is also crucial for decarbonising fertiliser production, which has significant implications for the emissions profile of the agricultural industry – currently responsible for around a quarter of global greenhouse gas emissions. However, in the majority of other potential use cases there are alternatives to hydrogen that are sometimes – but not always – more efficient and sustainable.

Many suggested use cases, such as for passenger cars, domestic heating and short-haul aviation, are inefficient uses of hydrogen. In these areas, decarbonisation efforts could be better served by using electric batteries, or heat pumps for homes. An additional consideration is that using hydrogen for one purpose can have knock-on effects for its availability in other, potentially more useful purposes. For example, efforts should be made to ensure demand for renewable energy to produce green hydrogen does not displace demand for renewable energy used in power generation.

[5] "The Clean Hydrogen Ladder (Now Updated to V4.1)", Liebreich Associates (15 August 2021).

Exhibit 2: The pros and cons of hydrogen in different use cases

Unavoidable — Uncompetitive

Category	Use case	Advantages and limitations
Chemicals and processes	Existing chemical and industrial processes	✓ No real alternative – low-carbon hydrogen is needed to replace grey hydrogen, which is essential for making fertiliser, hydrocracking, desulphurisation, methanol production and more.
	Steel making	✓ Hydrogen's high energy density and reactivity with iron ore means it can significantly reduce CO_2 emissions by replacing coal. Some estimates show decarbonisation potential of 70%. ✗ Long timeline for widespread adoption, as most steel plants are not nearing the end of their useful lives and are unlikely to be converted for hydrogen use soon.
Aviation and shipping	Shipping	✓ Batteries are too heavy and take up too much cargo storage space, whereas hydrogen can be stored in large amounts and for long periods. ✓ Fuel cell technology exists and can be retrofitted into most ships, and is easily scalable for large ships. ✓ Low-carbon hydrogen can be used to produce low-carbon ammonia, which could be promising as a zero-emission fuel for shipping. ✗ There is no hydrogen storage solution that combines high energy density and low energy input, which is also easily available, and easy to handle and store. ✗ Hydrogen's flammability means safety measures are needed during storage. ✗ Fuel cells take up more volume on cargo ships, raising some opportunity cost from lost cargo. ✗ If liquid hydrogen was used, refrigeration costs could be prohibitively high as it must be stored at cryogenic conditions of -253°C.
	Long-haul aviation	✗ It is challenging to electrify long-haul aviation due to limitations in battery design. Hydrogen is also limited due to low volumetric density, but it could be used to some extent as a basis for synthetic fuels or in the form of hydrogen fuel cells. ✗ Low energy density of hydrogen means heavy tanks are required, which makes it challenging to use in planes. ✓ While the technology for using hydrogen as a power source in commercial aircrafts is not yet established, leading companies in the sector are working on this and expect some use of hydrogen in commercial aircrafts in the next decade (see p.11).
	Coastal and river vessels	✓ Energy density is not as important as it is for aviation, so hydrogen could be used either in a fuel cell or internal combustion engine.

Category	Use case		Advantages and limitations
	Short-haul aviation	✗	Significant space required for hydrogen storage tanks and other equipment makes battery-powered aircraft a more viable alternative.
Power system	**Long-term storage**	✓	Hydrogen can be stored in salt caverns, depleted gas fields, or as compressed gas and liquefied at strategic points.
		✓	Hydrogen can be converted back to electricity centrally at 60% or more electrical efficiency via fuel cells.
	Blending hydrogen and hydrogen-based fuels into power plants	✓	Using hydrogen in gas-fired power plants could be a way of using and storing excess renewable energy and accelerating renewables build out.
		✗	Co-firing in coal power plants using low-carbon ammonia has been suggested as a way to reduce emissions from coal plants. However, it is much more expensive to use ammonia coal co-firing than to replace coal with renewables, especially with a high co-firing ratio.[6]
		✗	The emissions reductions achieved by running coal plants using ammonia co-firing do not bring plant emissions in line with what is needed to reach net zero by 2050. Keeping coal plants online also opens operators up to stranded asset risk as regulations evolve, regardless of whether they are using ammonia co-firing.[7]
		✗	Round-trip efficiency of using green hydrogen in gas plants to produce electricity is less than 40%; using blue hydrogen makes little sense when carbon capture and storage could simply be added to existing gas-fired power plants.
		✗	Natural gas is cheaper than green, blue and even unabated grey hydrogen, so this use case makes little sense economically.
	Island grids (small grids not connected to larger power networks)	✓	Hydrogen could be a solution where grids need more days of resilient supply than can be provided by batteries.
	Clean power imports	✓	Hydrogen pipelines are a cheap way of importing energy between two countries that are both using hydrogen.
		✗	Only viable if both countries are using hydrogen, as round-trip losses from converting power into hydrogen and back again are significant.
		✗	High voltage direct current (HVDC) cables are a more likely alternative.

6 "Japan's Ammonia-Coal Co-Firing Strategy a Costly Approach to Decarbonization, Renewables Present More Economic Alternative", BloombergNEF (28 September 2022).

7 https://www.e3g.org/news/explained-why-ammonia-co-firing-in-coal-power-generation-is-a-flawed-approach/

Category	Use case	Advantages and limitations
Heat	**High-temperature industrial heat**	✓ The majority of high temperature applications (>500°C) are beyond the capacity of current electrification technology; hydrogen burns up to 2100°C and so can supply heat across this range.[8] ✗ Hurdles to adoption of hydrogen for this use case include constrained supply and the amount of capital expenditure required for switching costs.
	Commercial heating	✓ Hydrogen could be used to bolster supplies from electricity when demand is high. ✗ Other solutions are more practical and efficient.
	Blending hydrogen into gas grids	✓ The International Energy Agency's Net Zero Emissions scenario suggests the global average blend in 2030 will include 15% of hydrogen in volumetric terms. ✓ However, this use case would make sense only if low-carbon hydrogen were used, as grey hydrogen would result in an increase in CO_2 emissions – so this is another use case competing for limited green hydrogen supplies with large question marks around its utility. ✗ This use case would also achieve minimal CO_2 reduction at a very high cost – up to \$500/tCO_2 (total CO_2) according to the International Renewable Energy Agency (IRENA).[9] ✗ 20% hydrogen blend by volume delivers only 6% reduction in CO2 because of hydrogen's lack of density and the extra energy required to move it through pipes.[10] ✗ There is also the question of whether gas pipelines can safely and efficiently contain a gas mixture with a high hydrogen content. Equipment would need to be retested for the presence of hydrogen and potentially replaced. There are technical changes that would need to be explored to make this use case reasonably efficient.
	Domestic heating	✗ Hydrogen is less efficient and more expensive than alternatives such as heat pumps, district heating and electrification.

[8] "Assessment of Green Hydrogen for Industrial Heat", Deloitte Renewable Thermal Collaborative (Deloitte, April 2023).
[9] Cembalest, M., "Whydrogen? Expanded Use Cases for Hydrogen May Be Narrower Than Advertised, and the Timeline is Long", Eye on the Market, J.P. Morgan (4 May 2022).
[10] "The Clean Hydrogen Ladder", Liebreich Associates.

Category	Use case	Advantages and limitations
Land transportation	Off-road vehicles	✓ Hydrogen can be used in areas without good grid connections, but to which compressed hydrogen can be supplied via a trailer – useful for construction, mining and forestry vehicles, for example.
	Rail transport	✓ Hydrogen can be a useful fuel to replace diesel trains for long-distance journeys and freight rail, since the cost of extending overhead electricity infrastructure on long corridors can be very high. ✗ No point extending hydrogen to power trains that are already electrified; and on passenger rail, 70% of global kilometres travelled were already electrified by 2016.[11] The potential market for hydrogen-powered freight trains is also small.
	Long distance trucks and coaches	✓ Compressed hydrogen could allow for longer range and faster refuelling, without the space constraints provided by passenger vehicles. This use case is more likely to be viable if green hydrogen costs decline. ✗ Trucks and coaches are more likely to be electrified as infrastructure is more advanced and connectable. ✗ Hydrogen charging stations involve more complications than electric vehicle counterparts given the need for chillers to prevent overheating.
	Passenger cars	✗ Hydrogen fuel cell vehicles are not implementable at scale; fuel tank space constraints make range similar to electric vehicles but with higher energy conversion losses and less power. ✗ Cannot be conveniently refuelled, less seating and cargo space, worse acceleration and higher maintenance. ✗ Electric batteries are an existing scalable solution at a more advanced stage of development, which offer a more efficient low-carbon alternative.

Source: J.P. Morgan Asset Management.

The pros and cons of hydrogen as an energy carrier

A main advantage of hydrogen in decarbonisation strategies is that it has no CO_2 emissions at the point of use, whether this is by fuel cell or combustion. Hydrogen is therefore a clean energy carrier in terms of deployment alone, although it can be responsible for emissions depending on how it is produced. Hydrogen is also storable at scale, which makes it a valuable potential solution for use cases that have typically been hard to solve for – such as backup power for balancing out generation in intermittent grids. The use of hydrogen in this way could improve electricity reliability and help to support decarbonisation.

Finally, hydrogen is in principle a technologically proven solution, with the full value chain of electrolysis, fuel cells and gas transportation all having been tried and tested – albeit at smaller scales than would be needed for hydrogen to make any significant contribution to decarbonisation.

On the other hand, hydrogen is currently costly to produce, and would need further investment in research, development and the scaling of production to become a more affordable method of energy storage. Producing hydrogen currently costs more than either of its constituent inputs of electricity and natural gas, which are themselves competitors for most of hydrogen's use cases. However, renewable energy prices continue to fall faster than forecasts expect them to, and if this trend continues then green hydrogen produced via renewable energy will become cost-competitive. Even if prices do not continue to fall, the significant increase in available renewable energy should help to ensure a stable supply at a low price, enabling the production of lower-cost green hydrogen.

[11] "Whydrogen?" Eye on the Market, J.P. Morgan.

Using hydrogen as a solution for climate change could also inadvertently lead to other problems. Leaks during the production and delivery processes, for example, are a potential disadvantage of hydrogen, and increased demand could make leakage an even greater risk. Hydrogen leakages can cause ozone layer reduction and slow the breakdown of methane in the atmosphere, contributing to climate change.[12] Applications that entail delivery and transport of compressed hydrogen have to be highly controlled to prevent leakages.

Ultimately, however, whilst hydrogen is unlikely to be a silver bullet for any use case, it is set to play an important role in decarbonisation.

Hydrogen's role in reaching net zero

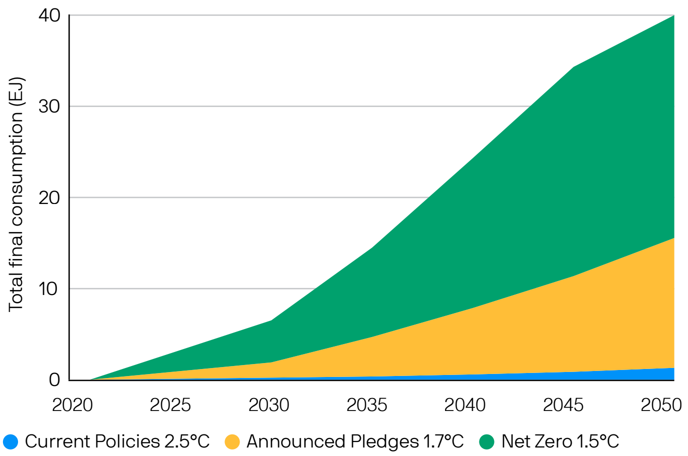
Decarbonising the global economy and reaching net zero emissions by mid-century will require all possible solutions to be employed. Hydrogen as a carrier of low-carbon energy has a role to play alongside other solutions, but this role should not be overstated. In its Stated Policies Scenario, where only current climate policies continue to be implemented, the International Energy Agency (IEA) projects hydrogen consumption for energy to remain broadly flat at the present low levels.

In more ambitious decarbonisation scenarios, hydrogen consumption does see an increase; however, its share in total energy consumption remains limited. In the IEA's Announced Pledges Scenario, where besides current policies also all additional policy commitments are implemented, consumption of hydrogen for energy is projected to increase by a factor of nearly 350 by 2030, from the very low levels in 2021. The Net Zero Emissions scenario, which is a more ambitious rapid decarbonisation pathway, projects an even steeper increase in hydrogen consumption, by a factor of roughly 920, by the end of this decade (**Exhibit 3**).[13]

In the IEA's Net Zero Emissions scenario, hydrogen could reduce carbon emissions by 60 gigatonnes of CO_2 by 2050, equivalent to 6% of total cumulative emissions reductions.[10] That said, the second chart in Exhibit 3 shows how the share of hydrogen relative to other sources of energy remains at just over 1% in 2030, and under 9% in 2050.[14]

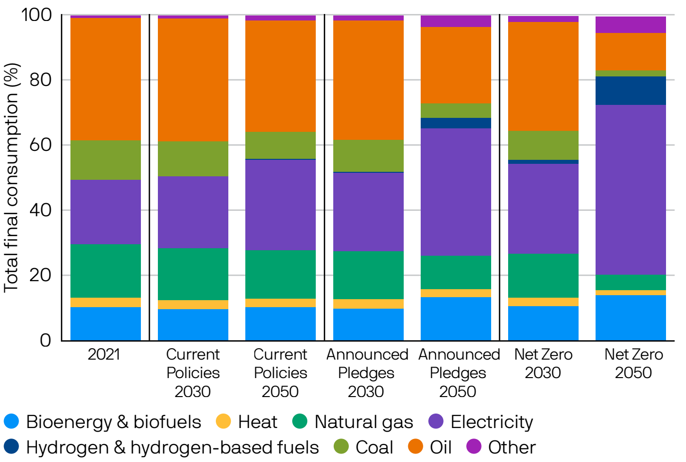
Blending hydrogen in the gas grid accounts for 26% of total hydrogen use in 2030, although this contribution is projected to fall to 11% in 2050 as other hydrogen uses increase.[15] Given certain reservations about blending hydrogen into the gas grid, how realistic this projection is remains to be seen."

Exhibit 3A: Hydrogen consumption as projected by climate scenarios



Source: J.P. Morgan Asset Management, IEA data.

Exhibit 3B: Breakdown by energy source of Total Final Consumption across climate scenarios



Source: J.P. Morgan Asset Management, IEA data.

[12] Hydrogen particles mop up free radicals, which help to break down methane in the atmosphere. Releasing more hydrogen therefore results in methane breaking down more slowly. Source: Thunder Said Energy, "Hydrogen: What GWP and Climate Impacts?" https://thundersaidenergy.com/downloads/tag/methane/

[13] From 0.05 exajoules (EJ) in 2021 to 1.736 EJ and 4.61 EJ in 2030 in the Announced Pledges Scenario and Net Zero Emissions scenario respectively. Source: International Energy Agency, "World Energy Outlook 2022", IEA (Paris, 2022).

[14] IEA World Energy Outlook 2022.

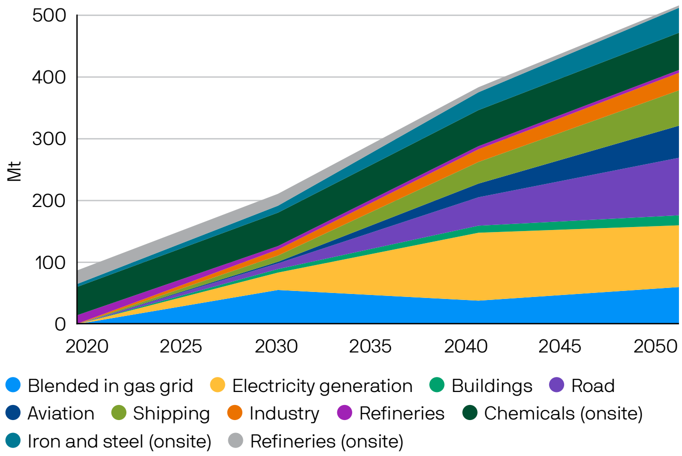
[15] IEA Net Zero by 2050: A Roadmap for the Global Energy Sector, May 2021.

Transport and power generation are the key drivers of hydrogen demand in the IEA's Net Zero Emissions scenario. Aviation accounts for nearly 10% of the need for hydrogen across all sectors by 2050, up from 0% in 2020 and just over 1% in 2030 (**Exhibit 4**).[16] This modest medium-term projection is most likely due to the uncertainty around the technical feasibility of using hydrogen as an aviation fuel, as discussed in Exhibit 2. Road and shipping transportation account for 4.4% and 4.8% of hydrogen use in 2030, respectively, which seems optimistic given the near-zero percent share in 2020.[17]

At the same time, hydrogen and ammonia are projected to contribute at best 2% to power generation by 2050.[18] 'This projection does, however, translate into large volumes of hydrogen needed, with power generation accounting for 13% of total hydrogen use by 2030.[19] While in the past years, low-emission hydrogen accounted for less than 1% of total hydrogen production there are roughly 700 projects currently in the pipeline, predominantly green and some blue hydrogen (**Exhibit 5**).[20,21] These projects are at various stages of development, from feasibility studies to under construction. Assuming that all of these projects come online successfully, the total installed electrolyser capacity could reach 240 gigawatts by 2030.[22]

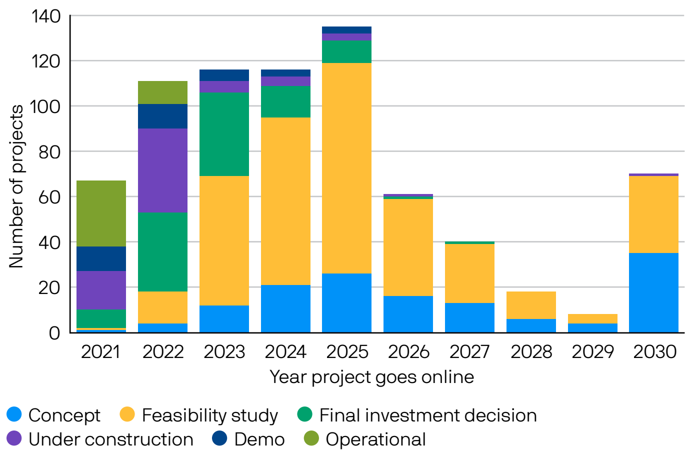
That said, this capacity would still fall nearly three times short of the levels envisaged by the Net Zero Emissions scenario, which reflects the uncertainties around the various use cases discussed in Exhibit 2.[23] It is also highly unlikely that all planned projects will be successfully implemented on time, given the nascent nature of these technologies and the fact that some projects that were supposed to have already come online are still either under construction or in earlier phases of planning.

Exhibit 4: Hydrogen and Hydrogen-based fuel use in the IEA's "net zero emissions" scenario



Source: J.P. Morgan Asset Management, IEA data.

Exhibit 5: Hydrogen project pipeline by status type



Source: J.P. Morgan Asset Management, IEA data.

16 IEA Net Zero by 2050: A Roadmap for the Global Energy Sector, May 2021.
17 IEA Net Zero by 2050: A Roadmap for the Global Energy Sector, May 2021.
18 IEA World Energy Outlook 2022.
19 IEA Net Zero by 2050: A Roadmap for the Global Energy Sector, May 2021.
20 "Hydrogen", IEA.
21 Based on the IEA Hydrogen Database as updated in October 2022. The analysis in this paper is subject to data quality considerations – the database may not be complete, for example it may not include recent projects since its last update.
22 "Hydrogen", IEA.
23 700 gigawatts. Source: "Hydrogen", IEA.

Policy and regulatory support for hydrogen in the energy transition

The political attention that hydrogen has received to date has so far not translated into notable gains for investors. However, things could be set to change following a wave of recent policy announcements and national energy strategy updates. Supportive policy and regulation is an important foundation for investment decisions, so the focus by policymakers on clean hydrogen production and deployment could lead to a rapid scaling of opportunities.

Policies have appeared in the form of national goals and targets, with 26 countries now committed to using hydrogen as part of their future energy systems.[24] Subsidies and tax breaks are another policy development; of particular note is the US Inflation Reduction Act (IRA), which incentivises hydrogen production with subsidies in the form of a production tax credit up to USD 3 per kilogramme, if all eligibility criteria are met. This subsidy could make low-carbon hydrogen cost-competitive with hydrogen produced by steam methane reformation, and drive the deployment of electrolysers.[25] Even before such incentives were announced, the IEA had projected that the cost of green hydrogen could fall 30% by 2030 as a result of declining costs of renewables and scaling up of hydrogen production.[26]

Other regions are promoting direct investment in hydrogen. The European Union, for example, has established a Hydrogen Bank, and recently awarded EUR 3.6 billion of funding to 41 clean energy projects, with the majority going to hydrogen projects.[27] Meanwhile, the UK's Powering Up Britain plan allocates GBP 240 million to a Net Zero Hydrogen Fund, which will support the scaling up of small and innovative projects.

Lastly, there is a push for more clarity and standardisation around hydrogen in order to increase market interoperability and remove bottlenecks to increased production. A recent IEA report called for an internationally agreed framework based on emissions intensity rather than the colour-based scheme used to classify hydrogen today, which has proved impractical as a basis for the contracts that underpin investment.[28]

The extent of hydrogen's role in the energy transition, and the viability of scaling up production and usage, are still not entirely clear. Nevertheless, we see a range of potential investable opportunities emerging across the commodities, utilities and capital goods sectors in particular.

24 International Energy Agency, "Hydrogen Supply – Analysis", IEA (Paris, September 2022).
25 King, B., Hiltbrand, G., Tamba, M., Herndon, W., Larsen, J., "Scaling Green Hydrogen in a Post-IRA World", Rhodium Group (16 March 2023). https://rhg.com/research/scaling-clean-hydrogen-ira/
26 International Energy Agency, "The Future of Hydrogen: Seizing Today's Opportunities", IEA (Paris, June 2019).
27 https://climate.ec.europa.eu/eu-action/funding-climate-action/innovation-fund/large-scale-calls/projects-selected-grant-preparation_en
28 International Energy Agency, "Towards Hydrogen Definitions Based on Their Emissions Intensity", IEA (Paris, April 2023).

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Industrial gas companies such as Air Liquide, Linde and Air Products have large existing traditional hydrogen businesses where they sell grey (and in the future increasingly low-carbon "blue") hydrogen for use in refineries, ammonia, steel and electronics end-markets. Industrial gas companies can benefit from leveraging their existing hydrogen pipeline networks in key industrial basins. We see Air Liquide, Linde and Air Products as clear beneficiaries from the future hydrogen economy, with higher potential risk/reward profiles at Air Products as a result of its integrated value chain strategy, which includes a willingness to manage and absorb the hydrogen/ammonia price from its investments.

European oil majors (BP and Shell) and US integrated oil companies (Exxon Mobil and Chevron) have also been developing their hydrogen strategies by leveraging their existing asset footprints. For example, during its Low Carbon Solutions spotlight Exxon Mobil laid out its Gulf Coast strategy to build the world's largest blue hydrogen facility (capable of producing 1 billion cubic feet per day, or ~900 kilotonnes per annum) and several carbon capture and storage hubs serving heavy industry.

On the equipment side, Baker Hughes appears well positioned to provide compression and gas turbines for future hydrogen projects. The company believes the opportunity could be worth USD 6 billion to USD 7 billion in annual new energy orders by 2030 (in both hydrogen, and carbon capture and storage).

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European utilities presently have two main areas of investment opportunity relating to hydrogen: transporting hydrogen (potentially utilising existing gas transport networks) and using hydrogen for power generation.

Hydrogen transportation is an area of focus for operators of existing gas network infrastructure, such as Enagas and Snam (gas network operators in Spain and Italy, respectively). These companies are proponents of national or pan-European networks of pipes carrying hydrogen, to operate alongside or eventually replace existing gas networks. Enagas argues that the cost of transporting hydrogen through pipelines over long distances is two- to four-times less than the cost of transmitting electricity (in order to produce hydrogen) over the same distance. There is still a lot of regulatory uncertainty over the proposed investments in hydrogen networks, and investment in this area is likely to be small until (at least) the late 2020s.

Several European utilities (including RWE and Engie) are looking at a variety of pilot projects using hydrogen as a fuel for power generation, either in repurposed existing gas-fired power stations or new builds. These projects offer one route to providing decarbonised flexible generation, which is essential in order to fully decarbonise the electricity generation system (and will be needed to balance intermittent renewable generation). The cost of using hydrogen for power generation is significantly higher than the cost of gas, so these projects are reliant on subsidies at present. Engie and RWE plan to invest around 5%-10% of total capital expenditure to 2030 in hydrogen-related projects (including electrolysers). The earnings contribution from these activities is not expected to be meaningful before the end of the decade.

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Capital goods – Lucie Carrier, Equity Research Analyst, European General Industrials

The capital goods sector is exposed at various levels to the hydrogen economy, including green hydrogen. The sector is exposed in three main areas:

1. Hydrogen generation, via the manufacturing, supply and installation of electrolysers, and the balance of stacks and plants, or via the equipment needed to construct electrolyser systems and hydrogen plants;
2. Hydrogen management, including storage and transportation (for example, via the supply of compressors - currently being manufactured by Atlas Copco - and electrical motors);
3. Hydrogen use in green transportation, such as rail transportation, which is already a commercial solution in use by Alstom, for example.
   Air transportation also has potential; Airbus, for example, has announced a plan to develop the world's first hydrogen-powered commercial aircraft by 2035.[29]

On the electrolyser side, various technologies coexist with alkaline electrolysers, which are seen as the most established given they are arguably cheaper and easier to use. Polymer electrolyte membrane (PEM) electrolysers, on the other hand, might be more suited for the production of green hydrogen.

While several large industrial companies, such as Siemens Energy and Thyssenkrupp, have established a presence in the area of hydrogen production, many pure play/smaller companies are now emerging. China is also supporting the development of the industry, with a few domestic champions. That said, value and supply chains still need to be scaled and industrialised. Many uncertainties remain with regards to the long-term competitive dynamics of the industry, and over which technologies will eventually win out.

At this stage, we believe exposure to companies providing hydrogen management services may perhaps be more attractive to explore, as the technologies and investment opportunities aligned to this nascent theme have been much more firmly established.

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[29] https://www.airbus.com/en/innovation/low-carbon-aviation/hydrogen/zeroe

The authors are grateful to **Galina Alova**, Sustainable Investing Research Analyst, for her contributions to this paper.

LV-JPM54375 | 10/23 | 09ns230507123952