THOUGHT LEADERSHIP: THE NEW ENERGY ECONOMY – A HYDROGEN FUTURE?
In a world recovering from the COVID-19 crisis, green energy is poised to be a key driver in the revitalisation of the global economy. An opportunity to reinvent the current energy economy presents itself as a way forward through infrastructure stimulus spending while simultaneously addressing the greatest existential threat to humanity – climate change.

As the world alters the current trajectory of unsustainable carbon emissions, profound changes to the current energy economy will take place. Fossil fuels will largely be replaced in the coming decades by green alternatives. In order to limit warming to a 1.5 degree maximum, countries across the planet will need to work together to reach net zero carbon emissions by 2050. Viewers of David Attenborough’s A Life on Our Planet will have witnessed the far-reaching impacts of humanity’s presence on the planet, and share in the hopeful possibility that our future can be altered for the better.

But how as a species can we achieve this monumental task of decarbonisation? Our focus in this article is on the potential role of hydrogen in a new energy economy. We evaluate different sectors and the viability of hydrogen-based solutions that could be applied. Through this examination, we also discuss what other alternatives might play a role in decarbonisation, including battery electrics.

It is likely that green hydrogen will have some involvement in the new future energy economy: ‘green’ hydrogen will replace fossil fuel produced hydrogen, and the use of green hydrogen can be expanded into new sectors as a natural gas or fuel substitute.

However, the question for investors is how big this will be, when this will be, and whether the potential opportunities outweigh the risk that hydrogen is superseded by other technologies and remains a niche fuel source. What is certain is that the world is at an inflection point where green energy will have a transformative effect on our world when it is needed the most.

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Early investors in the fledgling hydrogen economy at the turn of the millennium may recoil when the words ‘hydrogen fuel cell’ are uttered. Many remember the promise of fuel cell technology (mainly for vehicles and other small scale uses) and its subsequent demise shortly after. But what happened exactly? Investors piled into early fuel cell companies at the height of the dotcom boom – US equities Ballard Power Systems Inc (BLDP), Plug Power Inc (PLUG), and FuelCell Energy Inc (FCEL) were notable at the time, promising to revolutionise energy with their nascent fuel cell technology. Hydrogen was to be the new energy paradigm at the time when software IPOs were exploding with valuations based on metrics such as number of users and page clicks.

As the dotcom rally fizzled, so too did optimism for fuel cells. Fuel cell technology was hampered by a lack of commercial viability through high complexity, high costs, and a lack of requisite regulatory stimulus needed to propel zero emission technologies into primetime. The result for investors in these companies was poor. Since IPO, shareholders of these three (BLDP, PLUG, FCEL) fuel cell companies lost most of their investment.

This year, following the COVID-19 market nadir, these same three names have seen something of a renaissance (through for FCEL very recently).

**Chart 1: Performance of Fuel Cell Stocks**

Source: Bloomberg, Whitehelm Advisers

Note: Rebased to 100 at the start of each period using log returns for comparison.
What has caused this surge? It is possible that we have reached a turning point for green energy where investors are more willing to take on risk as governments ramp up their response to climate change. As part of COVID-19 economic recovery efforts, world governments are pledging to increase their spending on green energy. A hydrogen economy is one of the areas explored in these endeavours. Fuel cell technology companies may represent more speculative investments, but there is potential in other areas. The fallout of the dotcom experience, however, remains as a cautionary tale.

Before its false start in the early 2000s, the hydrogen economy had its genesis during the 1970s. The global oil crisis sparked a search for alternative energy and new research funding into the possibilities of hydrogen. The 1973 crisis also catalysed development of early stage solar and wind renewables, as well as improvements in gas turbine power plant efficiency. As the oil crisis subsided, so too did enthusiasm for early decarbonisation efforts. One of the problems with renewable energy has been its cost. Fossil fuels such as coal and natural gas have offered considerable cost advantages when the price of carbon is externalised. Over time as technology has improved, the cost of renewables has declined. Because green hydrogen is produced exclusively with renewables, the cost of this type of hydrogen is therefore inherently linked with their pricing.

Today, 76% of hydrogen produced globally comes from natural gas, and 23% from coal. Of the remainder, less than 0.1% of dedicated hydrogen production comes from water electrolysis. However, green hydrogen has seen accelerating growth. In 2019, a record 25 MW of electrolyser capacity was added, compared with less than 1 MW in 2010. The trend is clear, as decarbonisation is promulgated, electrolyser projects will increase in size and quantity. Similar to renewables cost curves, electrolysers should see continued cost reductions as scale increases and technology improves.

World governments have started developing plans for a future hydrogen economy to push this along. The EU has a multi-stage Hydrogen Strategy which is targeting 6 GW of electrolysers by 2024, and 40 GW by 2030. The Australian Government has also pledged A$500 million into hydrogen projects through its 2019 National Hydrogen Strategy with an aim to becoming a major global hydrogen supplier.

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3 Renewable Energy Integration, Helena Lindquist 2014
4 Generating Power At High Efficiency, Eric Jeffs 2008
5 The Future of Hydrogen, IEA 2019
6 https://www.iea.org/reports/hydrogen
Hydrogen: A Primer

Chemistry

- Hydrogen ($H_2$) was discovered in 1766 by Henry Cavendish
  - Named from Greek ‘hydro’ meaning water, ‘genes’ meaning forming
  - When burned with oxygen to generate power, no greenhouse gases are produced, only water vapour
- Hydrogen is the lightest chemical element, with just one proton in its nucleus
  - Very rarely occurs naturally; it has to be made
  - Must be separated from other molecules such as water or hydrocarbons
- Hydrogen has a boiling point of -253°C
  - Gaseous at room temperature
  - Energy intensive compression for storage and transport

Gravimetric energy density:
- Hydrogen: 120MJ/kg
- Gasoline & crude oil: 42-46MJ/kg
- Natural Gas: 55MJ/kg
- Batteries: 0.5 - 2.5 MJ/kg

Volumetric energy density:
- Hydrogen (liquid): 8 MJ/L
- Gasoline: 32-37 MJ/L
- Natural Gas (Liquid): 22 MJ/L
- Batteries: 1-5 MJ/L

Hydrogen has superior energy density to gas, coal, and oil, but it is less dense and takes up more space, making it more complex to compress and transport.

Hydrogen is a gas and can be piped, or it could be compressed into liquid form and carried by ship, like LNG. Hydrogen liquefaction requires -260°C, compared to natural gas at -160°C.

How is hydrogen produced?

- Grey: Sometimes called “brown” - hydrogen produced from fossil fuels, mostly from natural gas in a process called ‘steam reforming’, which breaks apart the methane ($CH_4$) molecules, or from coal gasification, all of which is carbon-intensive.

- Blue: Hydrogen produced from fossil fuels combined with carbon capture and storage.

- Green: Hydrogen produced by electrolysis from renewable power sources; using electrolyser to break apart water molecules ($H_2O$). The cost of green hydrogen is a function of the cost of the renewable power required, and the cost of the electrolyser.
How is it used today?

Hydrogen is mostly used as an industrial gas, and in many cases is produced on-site where it is used.

- **33%** Oil Refining
- **27%** Ammonia
- **11%** Methanol
- **3%** Steelmaking
- **26%** Other

Hydrogen is used in the oil refining industry to remove sulphur from crude oil, and is also added to produce higher value, lighter distillate products. It is used as a feed stock to create ammonia which is then made into fertiliser. A more niche use of hydrogen is in liquid form as rocket fuel alongside liquid oxygen.

Total demand for hydrogen is currently around 135 million tonnes per year.⁹

Potential Uses?

Hydrogen is versatile. In addition to its current use mostly as an industrial chemical, it can be used for:

- **Transport**: Using fuel cells, hydrogen can power cars and trucks, replacing petrol; and for trains and ships, replacing diesel.
- **Heating**: Blending with or fully substituting natural gas in gas distribution grids, which is used for heating and cooking in residential and commercial buildings.
- **Electricity and energy storage**: once produced, hydrogen can be stored for long periods and then be used to provide back-up electricity to renewable energy fed into electricity grids, for example, in winter when solar generation is lower.
- **As a substitute fuel for industrial and manufacturing that requires intense heat**, such as steelmaking, and glass and ceramic manufacturing.

⁹ [https://www.iea.org/reports/hydrogen](https://www.iea.org/reports/hydrogen)
While it is not clear yet which technologies will eventually replace fossil fuels in the hard-to-abate sectors, given its flexibility hydrogen certainly has the potential to make a large impact on global greenhouse gas emissions. Chart 2 illustrates the world volume of greenhouse gases coming from each sector. Energy used in buildings (through electricity and heat), transport, and industry makes up almost 60% of emissions. The remaining comes mainly from agriculture and forestry, waste, manufacturing (non-energy), other fuel combustion, and escape/fugitive emissions from energy production (i.e. natural gas leaks). The energy sector is the area where the hydrogen economy could potentially make an impact.

![Chart 2: World Greenhouse Gas Emissions by Sector (CO₂ tonnes equivalent)](chart)

*Source: Climate Watch, Whitehelm Advisers*
Chart 3 shows world energy consumption over time in terawatt-hours. In 2019, fossil fuels made up 84% of the total energy consumed. Phasing out the use of fossil fuels in favour of renewables is a key goal to reach climate targets. The production of electricity is only one facet of the energy equation – energy consumption also comes from heating, transport, and industrial usage. Hydrogen has the potential to work in tandem with renewables by acting as an energy storage medium and could also help curtail carbon consumption by replacing fossil fuels in areas that are difficult to abate.

With cost being one of the major hurdles to widespread adoption of green hydrogen, the theory is that a hydrogen economy can be built progressively by reaching scale in the easier areas first (e.g., converting from grey to green hydrogen for existing industrial uses such as oil refining), and as costs come down, governments can provide incentives to expand into newer areas (e.g., transport and energy storage), and so the greater scale continues to drive down the cost and innovation removes some of the current technological limitations.

Source: BP Statistical Review of World Energy, Whitehelm Advisers
The viability of the green hydrogen economy varies depending on the specific application. In part because of the rapid rise of battery technology for cars and electricity storage, there is greater potential for green hydrogen in areas where there is no straightforward carbon neutral alternative. These areas include feedstocks for industry and heavy transport such as rail, air travel and shipping.

INDUSTRIAL USE

The case for green hydrogen in industrial feedstocks is good, starting with switching from grey to green hydrogen where it is currently used. The cost of production via electrolysis versus steam reformation natural gas is the major hurdle.

Hydrogen is a key component of the petroleum refining process. In order to distil or crack petroleum products into more valuable refined outputs such as kerosene, gasoline, propane, and diesel, hydrogen is used to remove contaminants such as sulphur in a process called ‘hydrotreatment’. In addition, hydrocarbon chains are broken into lighter products through ‘hydrocracking’ where hydrogen is used to break carbon-carbon bonds. A majority of the hydrogen used in refineries is produced through on-site steam natural gas reforming and direct external supply. The remaining hydrogen input comes about as a by-product of the refining process and is therefore reused.

There is scope to switch all feed-in hydrogen to green sources, however, given that most refineries employ natural gas reforming already, carbon capture and storage (blue hydrogen) may be a more cost-effective option for this source of hydrogen, at least to start with. Regulatory carbon pricing and penalties would play a significant role in refinery uptake of green hydrogen as electrolysis is currently the most expensive hydrogen source to use. Reduced demand for refinery end products due to decarbonisation of transport will also help to lower the hydrogen inputs required in the first place.

The next largest industrial use of hydrogen is in ammonia production. Ammonia (NH₃) is largely used (80%) for fertiliser production, a key part of today’s agriculture. Ammonia is produced using the Haber-Bosch process which dates back to the early 20th century. Hydrogen from steam-reformed natural gas is combined with atmospheric nitrogen under pressure (100-200 atm) with an iron catalyst. Green hydrogen has the opportunity to replace grey hydrogen as feedstock, thereby eliminating CO₂ emissions completely, though at higher cost.
Methanol production represents a smaller, yet still significant proportion of hydrogen usage. Methanol is used for the manufacture of solvents, fuels, and a variety of industrial chemicals. Methanol is also produced using natural gas through steam reforming. Green hydrogen from electrolysis could also be used in this production area.

**TRANSPORT**

One of the most touted areas in focus for the hydrogen economy is that of the transport sector, which is responsible for about 16% of all greenhouse gas emissions - a significant proportion. This includes road transport (cars, buses and trucks), aviation, rail, and marine.

When considering the potential for fuel cells or synthetic fuels for aviation, rail, or marine purposes, hydrogen appears to be a viable option. However, the same cannot be said for road transport where electric batteries have a head start and superior overall efficiency.

While hydrogen fuel cells may seem like an ideal solution for road transport at first, it is a fight against fundamental physics. It is true that fuel cells do have better efficiency when compared to internal combustion engines, however, battery electrics are a clear winner overall. Chart 4 outlines the efficiency losses facing fuel cell vehicles as electricity is converted into hydrogen, and then back to electricity again. Battery electric vehicles also have lower upfront costs, a lower total cost of ownership, the same or better range, and can be charged at home. Hydrogen fuel cell vehicles, however, do have a faster fill rate - but again, electric recharging infrastructure is comparatively much further advanced than hydrogen refuelling.

For trucks and buses, refuelling can take place at depots and therefore may be less of an issue. Fuel cell technology is also likely to improve but cannot overcome its thermodynamic limitations. In the long-term, truck and bus operators will not opt to use vehicles that cost more to run unless specifically subsidised by governments or for niche applications. Battery electrics will also become more advanced leading to longer ranges, faster recharge times, and even cheaper costs. As a result of these limitations, hydrogen will likely be non-viable for the majority of road transport purposes going forward.

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**Chart 4: Efficiency Losses by Technology**

<table>
<thead>
<tr>
<th>Technology</th>
<th>Battery Electric</th>
<th>Fuel Cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewable Electricity</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Electrolysis</td>
<td>-5%</td>
<td>-30%</td>
</tr>
<tr>
<td>Transport, storage, distribution</td>
<td>-5%</td>
<td>-26%</td>
</tr>
<tr>
<td>Inversion AC/DC</td>
<td>-5%</td>
<td>-50%</td>
</tr>
<tr>
<td>Battery Charge Efficiency</td>
<td>-5%</td>
<td>-5%</td>
</tr>
<tr>
<td>Hydrogen to Electricity Conversion</td>
<td>-5%</td>
<td>-5%</td>
</tr>
<tr>
<td>Inversion DC/AC</td>
<td>-5%</td>
<td>-10%</td>
</tr>
<tr>
<td>Engine Efficiency</td>
<td>-10%</td>
<td>-10%</td>
</tr>
<tr>
<td>Overall Efficiency</td>
<td>73%</td>
<td>22%</td>
</tr>
</tbody>
</table>

*Source: European Transport & Environment, Whitehelm Advisers*
Unlike road transport, marine, rail, and aviation may offer a more suitable application for hydrogen fuel cells. The limited energy density of batteries means that for applications larger than trucks or buses, other technologies may be required. Hydrogen has high gravimetric energy density, that is, energy per unit weight. It is almost three times that of gasoline. Unfortunately, hydrogen is limited by its poor volumetric energy density, energy per unit volume. Hydrogen has only one fourth the volumetric density of gasoline. This makes storage problematic. For larger size transport, the spatial requirements for hydrogen storage and fuel cells may make it feasible in some cases, but it will face the same issue as batteries in terms of physics-based limitations.

In rail transport, greenhouse gas emissions are relatively small – the sector represents just 0.4% of total emissions. This is in part due to the electrification of railways. In France and Germany for example, 50% of rail lines are electrified, however, they carry over 80% of rail traffic. For instances where the marginal cost of electrification of lines is too costly, fuel cell trains could prove useful. Pilot projects for fuel cell trains are currently underway.

For aviation, fuel cells do not have the necessary energy density. Airbus has recently unveiled aircraft concepts which include a hydrogen gas turbine engine aeroplane with a target range of 2,000 nautical miles (3,700km). The average flight distance in Europe and North America is about 2,300km. These future aircraft could cover short-haul routes but transcontinental routes would be out of reach. A potential solution is to use hydrogen in the production of synthetic fuels. A caveat is that these fuels will be quite costly to produce. Synthetic jet fuel (kerosene) is estimated to cost between 4-6 times as much as kerosene produced from refined oil inputs. These costs will decrease over time, however, significant carbon pricing will be necessary to achieve cost competitiveness.

Maritime transport faces similar constraints. Ammonia has been floated as one option but requires three times the volume of conventional fuels. Synthetic fuels could be an alternative but would again depend on carbon pricing. Similar to the jet fuels, it is estimated that green hydrogen fuel costs around 4-8 times the price of very low sulphur fuel oil used in shipping. Although due to the high cost efficiency of bulk shipping, cost increases from fuel would not have a large impact on end costs, contrasting with those for aviation.

HEAT AND ELECTRICITY

Outside of transport and industry, energy use in buildings accounts for a large share of greenhouse gas emissions at 17.5% of the total. This is split roughly 60:40 for residential and commercial. This presents an enormous opportunity for reduction. A high proportion of heating is through the combustion of natural gas which is supported through extensive gas transmission and distribution networks. Proponents of a hydrogen economy posit that these existing natural gas networks could be retrofitted to carry a blend of bio-methane (‘green gas’) and green hydrogen instead.

This limited blending would allow use of most of the existing gas infrastructure, and the penetration of green hydrogen could rise as the costs of hydrogen production came down. This would be a relatively low-cost way to start to reduce emissions as it would allow the continued use of most of existing gas distribution networks.
networks to supply homes and business. However the cost is still likely to be higher than the other alternative, electrification of heating and cooking.

In their current configuration, natural gas transmission pipelines can accommodate up to a 10% blend of hydrogen along with gas, and distribution pipeline systems up to 20%. To carry a higher proportion or even 100% hydrogen, metal pipes must be replaced with plastic ones that are not susceptible to leakages, embrittlement, cracking, and corrosion (hydrogen molecules are smaller than methane molecules and so are more likely to leak). Retrofitting an entire natural gas network to use hydrogen is ambitious and very expensive, although there are one or two pilot projects under development. This is why most 2050 forecasts for gas distribution (assuming it is still operating) assume that hydrogen is still blended with green gas.

Right now the economics of substituting piped gas for piped hydrogen look very challenging. However even those who claim that complete electrification is the best way to acknowledge that starting to integrate hydrogen into the gas system will have flow-on benefits. The demand that this would create, even at very low percentages, would likely be sufficient to drive down electrolyser costs and improve technologies, making hydrogen more viable for other purposes. These networks could also help facilitate plans for ‘power to gas’, where surplus renewable electricity that cannot be used or stored by battery is used in electrolysis to produce hydrogen. The advantage is that the cost of production is low as the electricity used in the electrolysis process is essentially free. This hydrogen can then be distributed or stored long-term in underground salt caverns, much like are currently used for natural gas storage. The ability to store hydrogen for long periods of time is an advantage not matched by battery electrics which are limited to relatively short timeframes.

High efficiency heat pumps can deliver a high amount of heat per unit of electricity making them more cost competitive versus green hydrogen which faces efficiency losses due to electrolysis. When factoring in excess renewables needed to make up for electrolysis efficiency losses, gas network refits, and new furnaces/boilers, it may be more cost beneficial to invest in high efficiency heat pumps instead.

Although the picture is less clear in very cold regions, where the significant additional electric load that would be required in winter creates a large seasonal imbalance, and building a grid and storage to accommodate this would increase costs. Hydrogen could play an important storage role in this scenario. Hydrogen can also work hand in hand with renewables a smaller scale, supporting district heating or district micro- or city-grid networks. In this way hydrogen could provide the power currently supplied by peaking gas fired power plants.

But this is still many years away. Hydrogen is more likely to have success for high-temperature heat applications in industry where heat pumps are not suitable.

Fossil fuel operators are no doubt heavily incentivised to lobby governments in favour of pipeline retrofits over alternatives. Existing gas network asset values will be zero by 2050 if decarbonisation occurs via electrification so it is in their best interest to promote hydrogen heating over high efficiency electric-based heat pumps backed by renewable energy.

There are the same incentives for incumbent oil and gas interests to also favour blue hydrogen over green, and position this as the way to transitioning to green hydrogen down the track. However most players recognise the need to bypass this step and push straight to green hydrogen, in order to reach scale within the next 10 years.
The usage case for hydrogen over fossil fuels is based on emissions and cost. In a world where carbon emissions are not priced or penalised, there is no incentive for private enterprise to use hydrogen in place of fossil fuels, nor for the production of hydrogen from renewable sources. The reason is due to cost.

For some applications, such as switching from grey to green hydrogen in some industrial processes could be done relatively easily. Starting with this then incentivising broader usage could kick off a cost reduction curve similar to what we have seen in solar, wind and battery costs.

The earliest estimates we have seen for hydrogen to become cost competitive with other fuels is 2030. Until at least then, investors will be reliant on government incentives.

For green hydrogen, the major costs are the production of the hydrogen (the cost of the electrolysers, and the cost of the renewable energy to power the electrolysis), and the cost of the supply infrastructure, whether that be hydrogen refuelling stations for vehicle or marine fuel cell use, hydrogen-ready pipeline and compression networks, or end use hydrogen-ready boilers and furnaces.

The costs of green hydrogen are substantially higher than for grey hydrogen. Investors will be reliant on government regulation and carbon pricing to even this playing field. Fossil fuels such as natural gas have very low costs in some regions such as the United States which has driven out other methods of hydrogen production.

Chart 5 illustrates global hydrogen production costs in US$/kg in 2018.

Chart 5: Global Hydrogen Production Costs by Production Source (2018)

Source: IEA Future of Hydrogen, Whitehelm Advisers
Hydrogen made from natural gas was as cheap as US$0.9/kg whereas the best-case renewables-sourced hydrogen was over three times as costly at US$3.0/kg. The considerable variation in pricing for green hydrogen is as a result of the combination of several factors. Different electrolyser technologies and project scales translate to varying cost and efficiency levels. Load factors depending on renewable type and location also factor in.

While power-to-gas may be advantageous in generating hydrogen during periods of surplus electricity, the benefit can also be neutralised by idle or reduced electrolyser capacity during peak electricity cost periods.

If the adoption of green hydrogen is to accelerate, electrolyser costs will need to come down, while efficiency increases. This has been occurring, and there are encouraging signs that the scale of the ‘green deal’ plans for hydrogen are sufficiently large to drive further reductions. Certainly the targets set by electrolyser makers and governments are ambitious but achievable if the massive scale up in capacity occurs.

In the near term, carbon pricing must also be employed in order for green hydrogen to reach price parity with fossil fuel sources. Regulatory intervention will be needed in order to encourage investor participation with considerable investment into electrolyser build-out required.

It is easy to look at the cost reduction curves of solar and batteries over recent years, such as Chart 6, below, apply this to electrolyzers and get very excited about the potential for green hydrogen. Undoubtedly the world does need green steel, green shipping fuel and long-term energy storage, and hydrogen can meet all these needs. It is a very exciting development and fantastic to see that governments are exploring and pushing this. But this doesn’t mean that investors will make money.

![Chart 6: Levelised Cost of Energy of Solar PV](source: Lazard, Levelised Cost of Energy Analysis Version 14.0)
Government incentives so far are largely in the form of low-cost loans and guarantees. These still have to be paid back.

If significant electrolyser capacity is deployed as planned in coming years, investors may find returns through investment in established hydrogen production. This will be on a project by project basis, underpinned either by industrial users prepared to pay a premium for the ‘green’ inputs, or by direct government subsidy. For most investors, accessing this will be difficult, most likely in the private equity space, or through exposure to existing providers. In other areas such as road transport, investors should tread carefully as hydrogen is not competitive without considerable subsidies which may not continue.

Energy storage development projects could also prove uncertain – incentive structures that would allow returns to equity holders at reasonable risk levels aren’t in place yet. Even if they were, investors were notably stung following the GFC when Spain enacted retroactive cuts to feed-in tariffs that were overly generous.\(^{18}\)

The veritable gold rush of upcoming electrolyser investment could afford great opportunity for those investors with appropriate risk appetites, but careful consideration should be given in this unchartered green hydrogen environment.

Investments in component producers such as the electrolyser or fuel cell manufacturers may benefit from a broader approach, diversifying across a broader range of new energy technologies, but would still be a high-beta, high risk strategy. A PE or small cap strategy focused the smaller companies likely to be acquired by larger players may also generate returns, but again, with significant risk. In listed markets, a more stable way to access the hydrogen boom could be through the regulated gas networks and larger established energy supply companies.

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\(^{18}\) https://www.ft.com/content/19088742-1117-11e1-ad22-00144f6abdc0
CONCLUSION

As carbon emissions must be reduced, world governments will invariably provide funding across a spectrum of green energy technologies and ideas. Innovations in industry, transport, heating, and manufacturing, among others, will be necessary in order to achieve the climate change targets set out in the Paris Accord. Even so, 2050 targets may begin to appear too conservative in several years, putting ever increased focus on green energy.

A future in which hydrogen plays a key component of the new energy economy certainly seems possible. However, for investors a pathway to superior risk adjusted returns may not be so evident. The hydrogen economy will provide many opportunities, but allocating between themes such as distribution networks, electrolyser production, containment and storage media, and fuel cells to find the ‘winning trade’ is a challenging endeavour. There is a continuum of risk and return across opportunities. Established utility scale projects with certainty of cash flows may hold allure for investors seeking more stable returns with fewer surprises. Still, we have witnessed instances in the past through previous green energy projects where regulatory and governmental risks have the potential to emerge. Development projects may offer better prospects at higher risk. Other investors might look to even more speculative, high growth areas such as fuel cell technology companies with the potential for captivating returns – wary however of past outcomes which have fallen short of expectations.

Other competing areas of technology may serve to dampen the prospects of a hydrogen economy in the future. Current battery technology has largely been written off as uneconomical or technologically uncompetitive in terms of energy density. However, continuing incremental improvements in battery technology and investment cost efficiencies should see improved energy densities and exponential growth in cell production, with several terawatt hours of global production likely by the end of the decade.19

Despite this competition, there is likely to be room for hydrogen in a variety of investable spaces. There are areas in which different technologies may each excel, rather than all or nothing. While we cannot be certain which technologies or eventualities will prevail, it is abundantly clear that fossil fuels will play a diminished role in the future global energy landscape. We find that resulting fossil fuel assets are at high risk of diminished useful lives, with the potential to materially affect investment outcomes as humanity depends on their demise in the decades ahead. Policy makers and investors alike would be wise to turn their attention to potential long-term winners in the new energy economy such as hydrogen and battery electrics – powerful forces of change that will see our world transform sooner rather than later.

19 https://tesla-share.thron.com/content/?id=96ea71cf-8fda-4648-a62c-753a436c3b68&pkey=S1dbei4
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