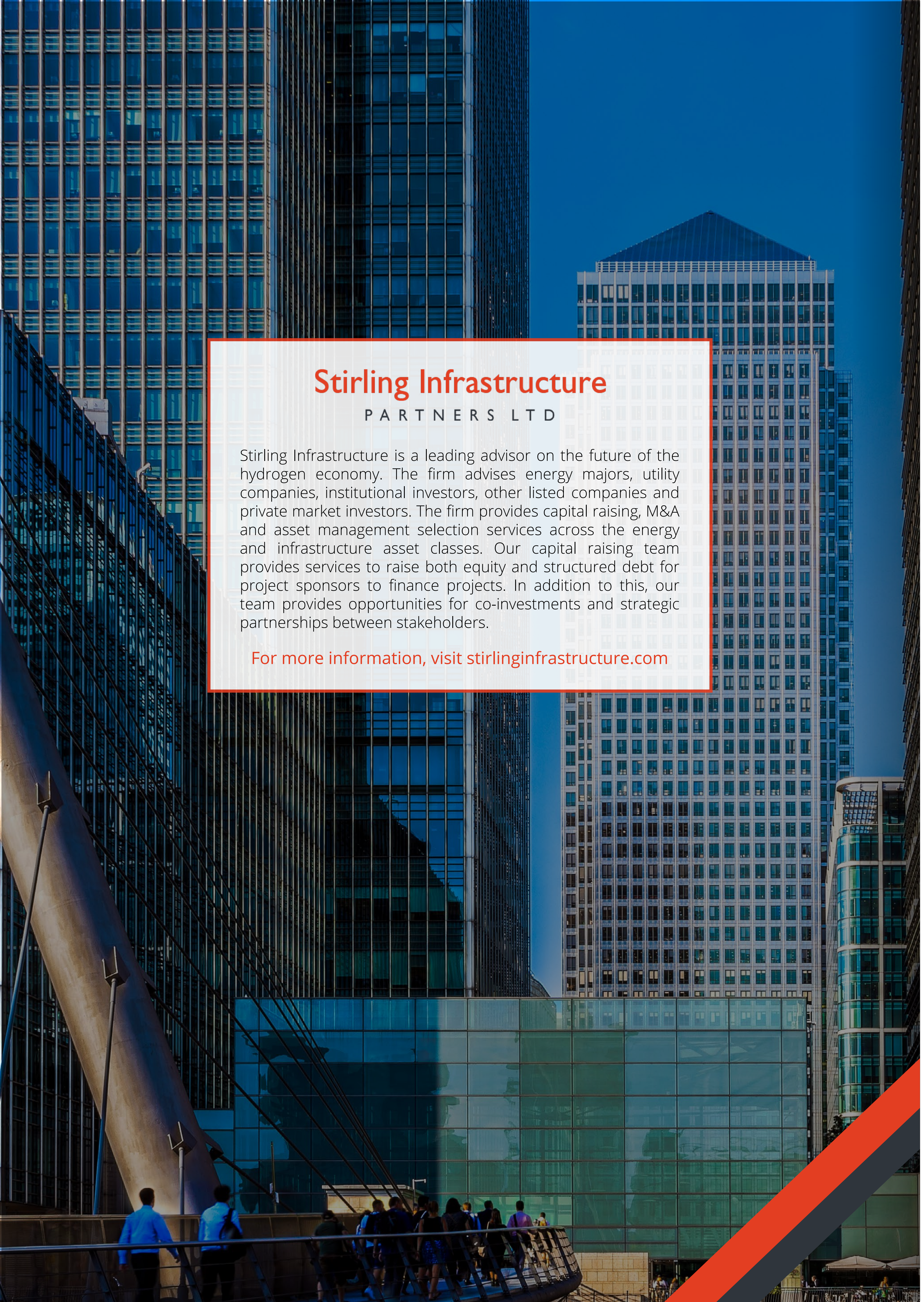
Hydrogen Production and Supply

Global Markets Outlook

Stirling Infrastructure
PARTNERS LTD

INSIGHTS

Hydrogen Reports Series



Stirling Infrastructure

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Stirling Infrastructure is a leading advisor on the future of the hydrogen economy. The firm advises energy majors, utility companies, institutional investors, other listed companies and private market investors. The firm provides capital raising, M&A and asset management selection services across the energy and infrastructure asset classes. Our capital raising team provides services to raise both equity and structured debt for project sponsors to finance projects. In addition to this, our team provides opportunities for co-investments and strategic partnerships between stakeholders.

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EXECUTIVE SUMMARY

The world is transitioning to renewable energy from a need to combat climate change and diversify the global energy mix. Supply of hydrogen globally has been dominated for decades by Brown or Grey hydrogen, both of which are created using fossil fuels. However, as the global energy transition takes place and we see an increase in the use of renewable power, hydrogen can be produced in a cleaner way. It is Stirling Infrastructure's view that an informed assessment of the supply side of regional markets is required by our clients to best inform investment decisions and the following insights and conclusions which are reached in this paper are taken from our own bespoke forecast modelling as well as extensive research.

The Hydrogen Value Chain

The hydrogen value chain is split into upstream, midstream, and downstream processes. Whilst this paper focuses on the upstream and midstream processes, downstream use cases are discussed in detail in our companion Demand Paper and Briefing Sheets. It is Stirling Infrastructure's view that hydrogen supply should be viewed as both chemical feedstock production and renewable energy storage.

The upstream process

Currently global supply of hydrogen is dominated by Grey and Brown methods which utilise fossil fuels. However, as hydrogen consumption grows with increased use in the energy sector and the world transitions to greener technologies, Green and Blue hydrogen will both have a part to play. It is Stirling Infrastructure's view that hydrogen generated from renewable power utilising an electrolyser to produce Green hydrogen is the best solution moving forward.

Midstream – Storage and transport

The utilisation of hydrogen globally depends on effective storage and transportation. This can be achieved in many ways but it is Stirling Infrastructure's view that use of liquid organic hydrogen carriers present the best opportunities. This is due to their efficient loading and unloading processes compared with other forms of storage e.g. compression and LOHCs' diesel-like properties which allow simple integration with current infrastructure.

South America

South America presents a wealth of renewable energy potential which is, as yet, largely undeveloped. Significant investment will be required to develop capacity alongside policy, partnerships and international collaboration in order to make projects profitable. From a supply perspective, South America is ideally suited to provide very low-cost renewable electricity which can be used to produce green hydrogen at a competitive cost.

North America (comprising US, Canada, Mexico and the Caribbean)

Whilst Canada and the USA are advanced economies that are exploring the hydrogen economy as a means to decarbonise their energy mix, Mexico lags behind. Both blue and green hydrogen solutions are being investigated: generally, blue is being put forward as a solution in highly industrial areas whereas green hydrogen is seen as the ultimate goal if hydrogen plays a role in the full decarbonisation of industry.

Middle East

Because of its abundant renewable resources and fossil fuels, Saudi Arabia is positioning itself as a future hydrogen exporter with a main focus in producing blue hydrogen.

Africa

Africa positions itself as hydrogen producer and exporter to Europe considering its huge potential renewable capacity. However, the continent's renewable capacity has so far been largely untapped due to a lack of infrastructure and investment. Despite this potential, it is Stirling Infrastructure's experience that investors are cautious in allocating capital to this region. However, on a selective basis, there are commercial opportunities.

Europe

Europe has positioned itself to be a leader in hydrogen innovation, production, distribution, and consumption. Most European countries have produced a hydrogen roadmap and strategy, which is based on differences in current energy mix, renewable energy capacity, gas distribution infrastructure, investor attitudes towards hydrogen, and current investment in hydrogen projects. Europe has the potential to become a hydrogen ecosystem, producing blue, green, and pink hydrogen.

Asia Pacific (APAC)

Asia is expected to be a world leading region in producing and exporting hydrogen and hydrogen technology where it can be produced at low cost thanks to abundant renewables and fossil fuel reserves in the region. For hydrogen technology, Asia is a leading region with many countries announcing national strategies in support of fuel cell technology.

ACTION POINTS FOR INVESTORS – HYDROGEN SUPPLY

1. The energy transition is in full swing with policy makers' and investors' scrutiny of carbon emissions now greater than ever. As a result, green hydrogen projects (hydrogen created from electrolysers powered by renewables) are likely to become more attractive for investors through increased subsidy support and cost reductions through learning. Investors are encouraged to monitor regional policy developments and commitments and rates of decline in levelised costs of green hydrogen production.
2. Blue hydrogen (where hydrogen is generated from natural gas using steam methane reformation and most of the resulting CO_2 is captured and sequestered) could provide a welcome new avenue for the natural gas production businesses of multinational and national oil and gas companies – an opportunity these companies are keen to talk up. This is certainly possible but investors are encouraged to pay close attention to the full life cycle of carbon emissions all the way from gas extraction to delivery of the hydrogen. Blue hydrogen may find highly localised markets in industrial areas close to its production, reducing transportation and storage costs.
3. Regionally, South America is an attractive location for investments into low-cost green hydrogen projects due to its large and currently untapped sources of renewable energy, especially wind and hydro. The Middle East also offers potential for solar-powered green hydrogen projects. For both South America and the Middle East, linking green hydrogen production with emerging demand centres will require the development of viable midstream and transportation processes (see below) and potential investors are encouraged to scrutinise trends in this subsector.
4. Asia has the potential to become a leading region for both green and blue hydrogen production due to its abundant renewables potential and substantial natural gas reserves, especially in Australia, Malaysia and Indonesia. It also offers a relatively local market for hydrogen as countries like China, Japan and South Korea build out fuel cell technologies.
5. In terms of transport and storage of hydrogen, liquid organic hydrogen carriers (LOHCs) are an attractive solution due to the relative ease of their loading and unloading processes, their diesel-like properties allowing for integration into existing infrastructure and their relatively open-ended storage time limits. Companies demonstrating competency as LOHCs could provide attractive investment opportunities as increasing sources of hydrogen supply require ever greater linking to demand centres.

USING THIS PAPER AND KEY CONCLUSIONS

This paper is our investor's primer on how the economies across the world will accelerate the use of hydrogen as part of their energy mix. This is in the context of decarbonising the global energy sector as the world pushes for net zero. This document provides insight into the opportunities and factors that our investment banking team considers necessary for our clients to make effective capital allocations within the supply side of the global hydrogen economy.

It has been found that, with regards to production, blue and green hydrogen production technologies are the most viable for the future. Blue hydrogen will allow natural gas to be made a much cleaner fuel by removing and storing carbon dioxide emissions and green hydrogen can be used to make hydrogen with no emissions. Currently blue hydrogen is the more economical production method and a process that suits oil and gas companies with assets in the natural gas industry. Green hydrogen's cost will come down in the future as more companies invest in new technologies and renewable energy capacity increases. Therefore, it was found to be the best option for hydrogen production in the long term.

The midstream component of hydrogen production involves storing and transporting hydrogen to downstream applications. It has been found that ammonia and liquid organic hydrogen carrier (LOHC) technologies provide the best opportunities for hydrogen storage. Both would allow hydrogen to be transported long distances on ships, trucks or trains. Ammonia is already an established tradeable commodity and LOHCs would allow hydrogen to be stored in a liquid with diesel-like qualities – making it easily transported. Short-distance transport could be done with pipelines.

Downstream applications involve heating, chemical feedstock, industry and transport. It was found that hydrogen has the most potential for use in the chemical, industrial and heavy transport industries. Chemical usage is already established and unlikely to increase its usage, however the type of hydrogen could be made green. Industrial and heavy transport uses represent the largest potential for increasing in the next thirty years because they are difficult to electrify.

The regional analysis found that currently China and North America represent the largest producers of hydrogen. In the future, South America and Africa haves the potential to produce green hydrogen in large quantities due to its abundant potential for renewable energy. Europe is expected to be a large producer and consumer of hydrogen and would be a key market for South American production.

INTRODUCTION

The complex challenges associated with addressing climate change came to the fore again in November 2021 when representatives from around the world gathered in Glasgow for COP26. A non-legally binding agreement was signed which will help shape the global agenda on climate change for the next decade. Glasgow builds on the Paris Agreement, a legally binding treaty signed in 2016 between 196 state parties and which aimed to limit global warming to below 2 degrees above pre-industrial levels. At COP26, countries agreed to meet again in 2022 to pledge further cuts to emissions of CO_2 in a bid to keep global temperature rises within 1.5 degrees, which scientists now say is required to prevent a "climate catastrophe".

Meeting this goal will require a rapid reduction in global CO_2 emissions until they reach net zero by the middle of the century. For the first time at a COP meeting, the Glasgow Agreement included an explicit plan to "phase down" coal use. To support this ambitious decarbonisation agenda, global energy use will need to transition to renewable sources, including clean hydrogen (defined as hydrogen produced with zero or very low emissions). Hydrogen's potential as a facilitator of the energy transition was explicitly recognised at COP26 where 28 companies including the global majors BP, Shell and TotalEnergies pledged to accelerate the use of clean hydrogen.

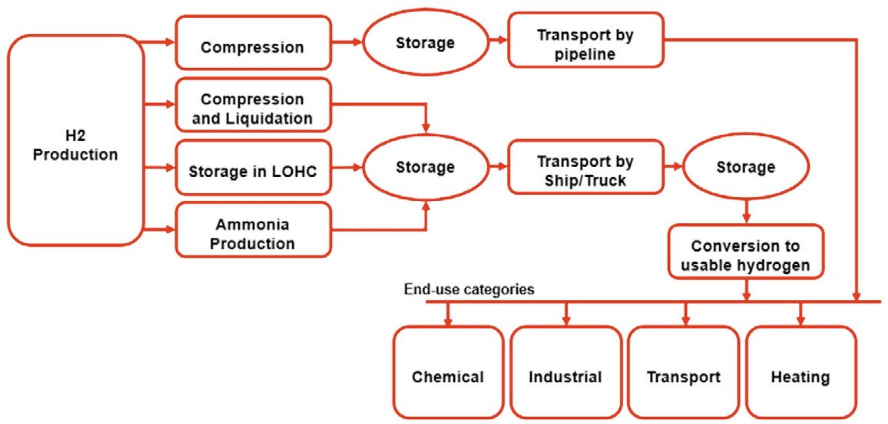
This paper will highlight how hydrogen can be produced and supplied to all parts of the economy. Focusing on supply and delivery, different regions have been investigated around the world and their capabilities now and in the future have been assessed. The sections in this report are split into:

1. What the hydrogen value chain entails and where value can be added within it. The processes that will make up the hydrogen economy and how they would fit together have been researched.
2. The upstream component of the value chain: production. This includes a description of each hydrogen production process. The future of production in the context of capital allocation for the future is presented.
3. The midstream component of the value chain: storage and transportation. Means of storing hydrogen and transporting it to where it can be used have been assessed. Stirling Infrastructure Partners presents its view on the technologies which could be used.
4. A brief overview of the downstream usage: use of hydrogen in transportation, industry and utilities. This is expanded upon in Briefing Sheets available on Stirling Infrastructure's website.
5. These upstream and midstream components of the hydrogen economy will be assessed globally. A macroeconomic view is taken and the world is assessed by region. Each region's readiness will be measured and representative hydrogen projects will be investigated.

THE HYDROGEN VALUE CHAIN

The hydrogen value chain is split into upstream, midstream, and downstream processes. Whilst this paper focuses on the upstream and midstream processes, downstream use cases are discussed in detail in the *Demand Paper and Briefing Sheets*. Figure 1 shows a representation of the hydrogen value chain. Each block represents a process in the delivery of the hydrogen to the customer and each represents an investment opportunity where value can be added.

Figure 1 - Representation of the hydrogen value chain



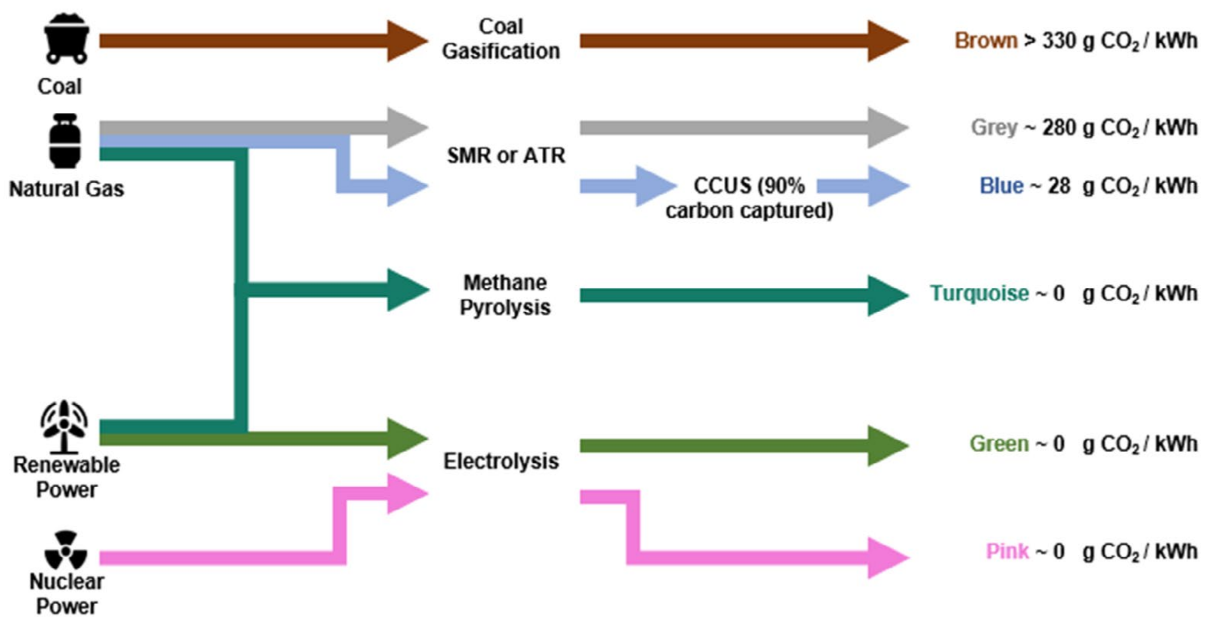
Hydrogen is produced using natural gas, coal or electricity. It is then either converted to a carrier, either by chemical processes, or by compression and cooling. If the hydrogen is compressed, it can be transported in pipelines, both in existing natural gas pipelines as a blend with natural gas, or on its own in specialised hydrogen pipelines. If hydrogen is stored as a liquid, in a liquid organic hydrogen carrier (LOHC) or as ammonia, then it can be transported using existing oil and gas infrastructure. It can be transported by ship or truck to where it needs to be used. If the hydrogen is stored within another chemical, then it must be removed from this (dehydrogenated) before it can be used.

UPSTREAM – HYDROGEN PRODUCTION

The upstream process involves producing hydrogen from natural resources. The production of hydrogen is not a new process, in fact it has been produced in mass for decades for ammonia production and petroleum refining. However, these processes have traditionally used natural gas/ methane as a feedstock which leads to high amounts of CO_2 production in the hydrogen forming process. As carbon capture utilisation and storage (CCUS) becomes more widely used, these emissions can be significantly reduced. However, electrolysis could be used to make hydrogen production net zero.

The process in which hydrogen is produced has traditionally been described using colours. Although less attention is being paid to the colour and more to the carbon emissions from each process, this paper will use the colour convention below to describe how the hydrogen has been produced along with emissions associated with each process. Figure 2 shows the processes associated with each colour and the associated CO_2 emissions per kWh of hydrogen produced.

Figure 2 - Hydrogen production processes



EMITTING PRODUCTION PROCESSES

Brown

Brown hydrogen uses coal to produce hydrogen. Coal and steam are combined at a temperature above 700 °C in a process called coal gasification. Coal is burnt in order to reach this high temperature – resulting in more emissions. This process is the most emitting of the hydrogen production processes.[1]

Grey

Grey hydrogen uses natural gas to produce hydrogen. Natural gas and steam are combined in a process called Steam Methane Reformation (SMR) or Autothermal Reformation (ATR) to produce hydrogen and CO_2. The hydrogen is then separated from the CO_2 and other combustion production. This process produces a stream of pure hydrogen.[2]

1 Office of Energy Efficiency and Renewable Energy
2 International Journal of Hydrogen Energy

Blue

Blue hydrogen uses the same process as grey hydrogen – using natural gas as a feedstock. However, once the hydrogen has been separated from the exiting gas, carbon dioxide is also separated. This can remove more than 90% of the carbon dioxide emissions from the flue gas.[3] This pure carbon dioxide stream can then be compressed, transported to a carbon sequestration facility and stored in saline aquifers or depleted oil and gas reserves.

NET ZERO HYDROGEN PRODUCTION PROCESSES

Turquoise

Turquoise hydrogen is the least ready for hydrogen production at-scale. It is the thermal decomposition of methane (the main component of natural gas) into its components – hydrogen and carbon. This process is called methane pyrolysis. The temperature for this to occur without a catalyst is above 1200 degrees Celsius, but with the incorporation of a catalyst into the process, of which there are many materials possible (Ni, Co, Fe etc.), this can be significantly reduced. The method for heating methane is through the use of renewable power which would make the process carbon neutral. The greatest advantage of this method over alternatives is that the by-product is solid carbon compared to the carbon dioxide gas produced by brown, grey, and blue hydrogen production processes. This resulting solid carbon could be marketed to improve the economics of the process, however, currently there is not a large demand for this.[4]

Green

Green hydrogen is created by electrolysis using electricity generated by renewable sources such as wind, solar, and hydroelectric power. The renewable energy is used to split water into its constituent components: hydrogen and oxygen. The oxygen could be marketed as another usable product.

Pink

Pink hydrogen functions in the same way as green hydrogen - by electrolysis of water. However, the power used comes from nuclear power. Although as carbon neutral as green hydrogen, there are other environmental impacts associated with nuclear power that reflect on this process.

GLOBAL HYDROGEN PRODUCTION

Global annual hydrogen production is currently approximately 70 million metric tonnes (MMT). Of this, 76% is produced by autothermal reformation or steam methane reforming, 22% is produced by coal gasification, and only 2% is produced by electrolysis.[5] In order to fulfill the potential energy requirement of the hydrogen economy, projections have estimated that over 300 MMT will be required.

MIDSTREAM - STORAGE AND TRANSPORT

HYDROGEN CARRIERS

Overview

A variety of candidates have been presented as liquid organic hydrogen carriers. There is yet to be a global consensus on which of these or if any are best suited to hydrogen storage and the variety of applications.

Working principle

The concept behind any hydrogen carrier is to increase the storage efficiency and ease of use of hydrogen. Currently the majority of hydrogen globally is stored in compressed tanks, either liquified or simply as a very high-pressure gas. The issue with this is the energy requirement for liquification as approximately 15% of the energy content is used in the compression process.

Should an appropriate carrier be developed whereby we can store a greater mass of hydrogen in a smaller space (increase the effective energy density) and at a higher efficiency this will improve the cost effectiveness of the whole hydrogen economy. Furthermore, high pressure equipment is both expensive

3 Princeton University
4 Chemie Ingenieur Technik
5 US Department of Energy

and unsafe compared with ambient storage mediums – possible using some carriers.

Usage of most carriers requires a reformation step following storage or transport in order to retrieve the stored hydrogen and 'raw' carrier. These reformation devices range in size, cost and efficiency. However, due to the increased energy density and ease of long-distance transport compared with elemental hydrogen, carriers possess a wealth of advantages.

Types

LOHC (Liquid Organic Hydrogen Carrier)

This group of compounds with promising storage capacity are all based on the principle of hydrogenation of aromatic molecules to store large volumes of hydrogen. Then under relatively mild conditions, the carrier can be rearomatised to release the hydrogen.

With long lifespans under storage in both the hydrogenated and de-hydrogenated state as well as excellent efficiency in both processes they present a good opportunity. Recycling these carriers thousands of times is also possible meaning in general once the carrier is produced it will be used over and over without depleting. This further supports the carbon zero transition as although many of the carriers originally may have come from 'dirty' chemical feedstocks they last for such a long period the effect is almost negligible. Furthermore, many of the carriers which are being researched and developed have been made to allow production to become a carbon zero process. The other advantage LOHCs have over other hydrogen carriers is its liquid state in ambient conditions and diesel-like property. These properties allow LOHCs to facilitate existing mature oil transmission and distribution networks from pipelines to trucks.

As development of the hydrogen economy continues, we should expect volumes of hydrogen requiring both storage and transport to massively increase. Therefore, development of green syntheses of carriers is key due to the quantity required globally. Short term however, utilisation of even dirty carriers will enable cheaper hydrogen transport globally and can be used as a proof of concept. In the longer-term carbon zero carriers will be required.[6]

Solid state carriers

These carriers store hydrogen in a stable solid state in ambient conditions, ideal for transport and storage. Research focus on solid state carriers has been on metal hydrides like aluminium hydride, though nonmetal hydrides like borohydride have been developed in laboratory conditions. Solid state carriers have a relatively high volumetric hydrogen storage capacity (Figure 3), but due to their strong interatomic bonding, their dehydrogenation process is extremely energy intensive. This physical constraint on solid state carriers in nature limits their commercial potential, and they are the least ready hydrogen carriers with low research interests.

We believe that solid state carriers are not expected to be mainstream hydrogen carriers in the future hydrogen economy. However, there might be a niche market where solid state carriers can play. Credit to its stable and non-degradation nature, solid state carriers are ideal for long-term storage as backup or emergence power storage.

AMMONIA

Ammonia is an attractive hydrogen storage medium because of its high storage density (123kg H2/m3) comparing to liquification (70kg H2/m3), and its well-established value chain.

Ammonia is synthesised from hydrogen and nitrogen through the century old Haber-Bosch process that is already highly energy efficient, storing hydrogen in its chemical bonding. By decomposing ammonia at high temperature, the dehydrogenation process, ammonia is converted back into nitrogen and hydrogen. Ammonia produced from green hydrogen is known as green ammonia. The hydrogenation and dehydrogenation process of green ammonia has zero carbon emission, in contrast with methanol, an alternative to ammonia as a hydrogen carrier, which emits carbon dioxide during dehydrogenation.

Because of its primary use as a fertiliser, the ammonia industry has established a comprehensive value chain with mature technology and facilities in its large-scale production, storage, and international transportation. Although ammonia is toxic and irritating, century-long industry experience in handling ammonia has accumulated know-how to handle ammonia safely. Furthermore, apart from being used as fertiliser, ammonia can be used as fuel by direct combustion.

The current challenge in using ammonia as a hydrogen carrier lies in its energy costly dehydrogenation process due to its high operating temperature. Catalysts can be used to lower the operating temperature, but the current most effective catalyst, Ru (ruthenium) is expansive. Research has been conducted to investigate new catalysts.

With the development of new catalysts in the dehydrogenation process, we believe production of ammonia will increase dramatically as the world transitions into a hydrogen economy. Because of its already strong use case in the fertiliser industry, adopting ammonia as hydrogen storage and transport significantly lowers the risk compared with other alternatives.

6 Hydrogen production from homocyclic liquid organic hydrogen carriers (LOHCs):

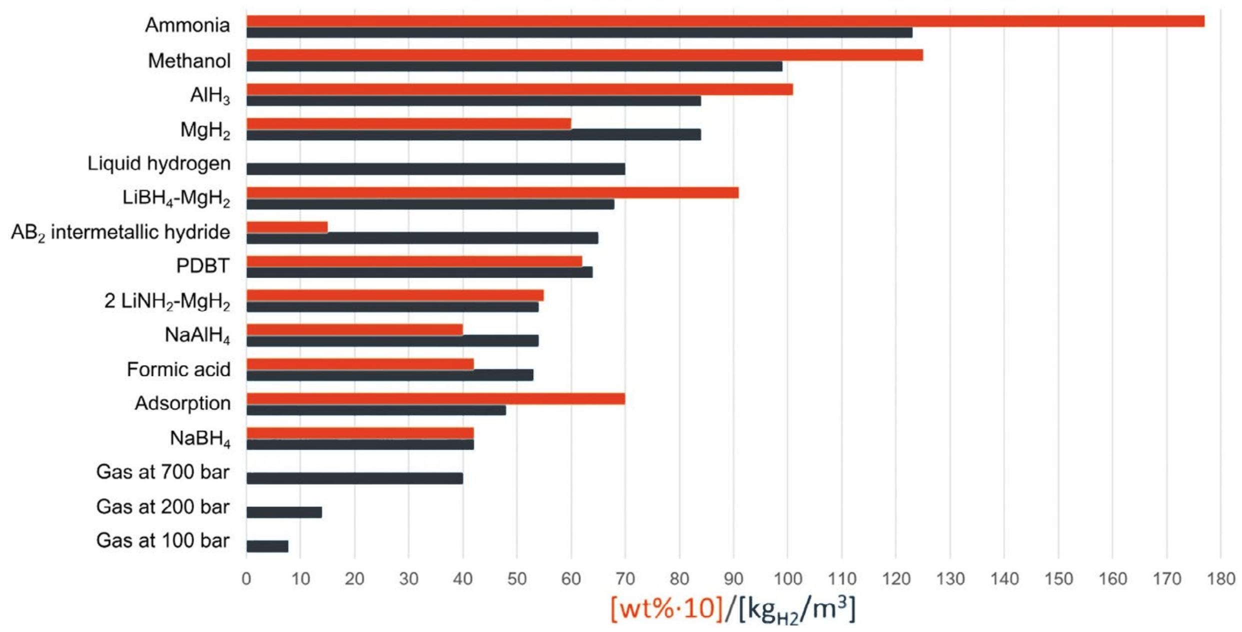
COMPRESSION AND LIQUIDATION

Because of the low density of hydrogen, currently hydrogen is stored and transported in a compressed gas state or liquid state to increase its storage and transport capacity. However, as the industrial standard of compressed hydrogen is at 700 bar and liquidation of hydrogen requires a temperature below -253 degrees, it is extremely energy costly to store hydrogen in either way: it is estimated that the energy needed to store hydrogen in liquid state costs a third of the inherent energy of hydrogen stored.

Furthermore, it is costly to transport compressed and liquid hydrogen over long distance. There are currently two common ways to transport hydrogen: through pipelines and in storage tanks. Hydrogen can be compressed into special hydrogen pipelines but they are costly to make. Although hydrogen can be blended in existing natural gas pipelines, a maximum of 20% hydrogen share is allowed due to safety concerns from hydrogen embrittlement of pipelines, a mechanical structure failure caused by gaseous hydrogen. For storage tanks, compressed or liquid hydrogen must be stored in double-walled storage tanks with carbon fibre as composites to withhold high pressure.

With an envisioned future hydrogen economy with long distance hydrogen transport internationally, we believe that compressed and liquid hydrogen are not expected to be the mainstream. Instead, ammonia and LOHCs are more likely to be adopted.

Figure 3 - Storage density of different hydrogen carriers



Orange represents gravimetric storage capacity while blue as volumetric storage capacity[7]

Table 1 - Comparison between key hydrogen storage methods

	Green Ammonia	LOHC (DBT-PDBT)	Compression (700bar) and Liquidation
Cost of production $/kg	0.38 - 0.54	-	-
kgH2/m3	123	54	40 - 70
Hydrogenation Conditions	200-350 bar, 300-550°, iron as catalyst	50bar, 150°	-
Storage energy cost kWh/kgH2	2 - 4	0.7	10
Dehydrogenation conditions	1bar, 650°, ruthenium as catalyst	1 bar, 300°	-
Dehydrogenation energy cost kWh/kgH2	6.3	9	-

7 Benchmarking studies and energy-economic analyses – Korea Institute of technology

REGIONAL SUPPLY

HYDROGEN SUPPLY
SOUTH AMERICA

STORAGE

Ammonia is a product that is commonly bought, sold and used around the world. This means that the storage mechanism is already well understood. Generally, ammonia is stored in steel tanks at –33 degrees Celsius so that it is a liquid.

LOHCs can be stored in containers. Because of their fossil fuel like properties, LOHCs can be stored in existing oil infrastructures with minor or no modifications.

Gaseous hydrogen, however, can be stored in several ways. Firstly, the hydrogen can be liquified by storing at –253 degrees Celsius and a pressure of 100-700 bar. This allows hydrogen to be stored more densely compared to when it is in a gaseous state. Compressed hydrogen can be stored in large storage containers or even in deep salt caverns and depleted oil and gas fields.

For large scale hydrogen storage, companies focus on underground hydrogen storage. For example, Centrica has announced its plan to repurpose its decommissioned natural gas field Rough into a hydrogen storage site by 2027 with a capacity to heat one million homes for a year.

DOWNSTREAM - USAGE

Downstream use cases include industrial, chemical, heat, and transport. Hydrogen can be used to decarbonise all these industries. More information on each use case can be found in our companion Hydrogen Demand Paper and Briefing Sheets on Stirling Infrastructure's website.

REGIONAL SUPPLY

As a reference statistic we present the IEA's forecast of 42% global renewables by 2050. We have selected several key economies for which we present our detailed domestic forecasts.

SOUTH AMERICA

Overview

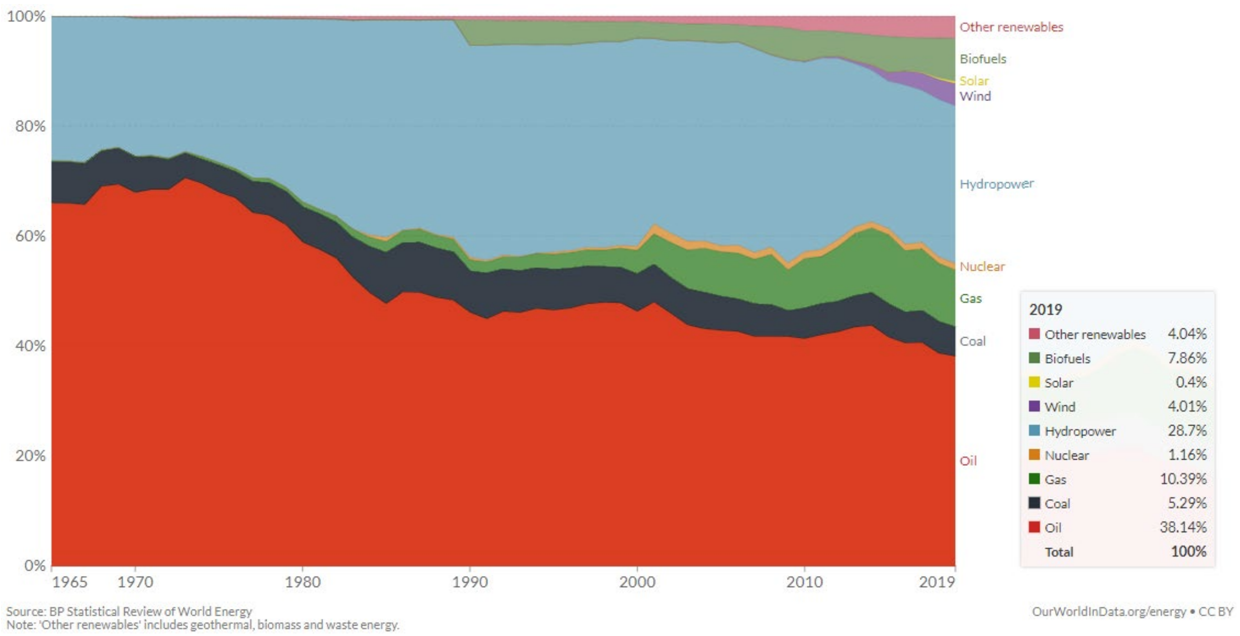
South America presents a wealth of renewable energy capacity which is as yet largely undeveloped. Significant investment will be required to develop this capacity alongside policy, partnership and international collaboration in order to make the projects profitable. From a supply perspective, South America is ideally suited to provide very low-cost renewable electricity which can be used to produce green hydrogen at a competitive cost.

Brazil

Brazil looks set to continue to bolster its already massive amount of renewable energy capacity as it deepens its interest in the hydrogen economy.

Energy Mix

Figure 4 - Energy consumption by source, Brazil



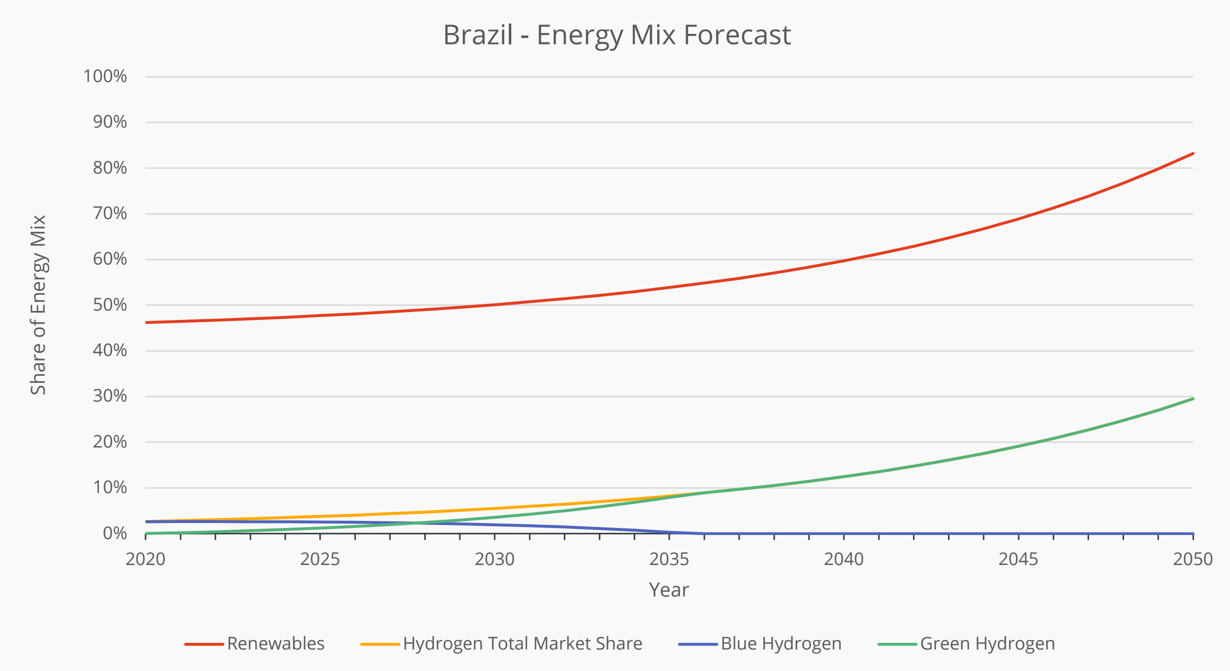
Brazil experiences fluctuation in its supply of renewable electricity due to hydropower based on the weather conditions. Due to its high exposure (29%), a storage medium for this renewable power would be beneficial as it would allow more hydropower capacity to be built as in a 'bad' season the loss of supply can be replaced by stored renewable power.

Batteries are one solution however high cost associated with the materials required to build such a storage facility combined with the issues of discharge over time leads hydrogen to be the preferred storage medium.

Current production

There are low levels of green or blue hydrogen production currently in circulation in Brazil however there are plans to produce more and utilise hydrogen as an export. The development of Brazil's hydropower compared with the rest of the world places them in an excellent position to become a future world leading exporter along with much of South America.

Forecast



Using our forecast model, we predict upwards of 80% of Brazil's power to be generated by renewable sources by 2050. We also predict hydrogen to take a 30% stake in this energy market due to the variety of use cases in Brazil which cannot be electrified. This figure could be predicted even higher had a full hydrogen strategy been published and a greater deal of capital had been allocated in the region for this development. We forecast a greater amount of hydrogen will be produced in Brazil through green electricity however this will be exported and is discounted from the forecast.

Case Study – Base One, Ceara Brazil

Australia's Enegix expects to complete a $5.4bn green hydrogen plant with a capacity of 600,000 Tonnes per year production. This plant plans to take on a base load of 3.4GW[8] and export the hydrogen from the Port of Pecém. The port will also allow access to the required water for the electrolyser. Continued expansion of the Ceara state renewable network with solar, onshore and offshore wind will allow 100GW of capacity to be realised at the site eventually. The site is set to be built on 500 hectares of commercial land and looks to be an expanding project going forward. The wealth of untapped renewable energy in the region was a deciding investment decision for Enegix alongside excellent shipping connections. Alongside its main interest in hydrogen Enegix also plans to utilise the byproduct oxygen produced in the electrolysis process.[9]

Chile

Chile will look to capitalise on its massively underdeveloped renewable capacity within a pro hydrogen setting with officials aiming to position Chile as a world leading exporter.

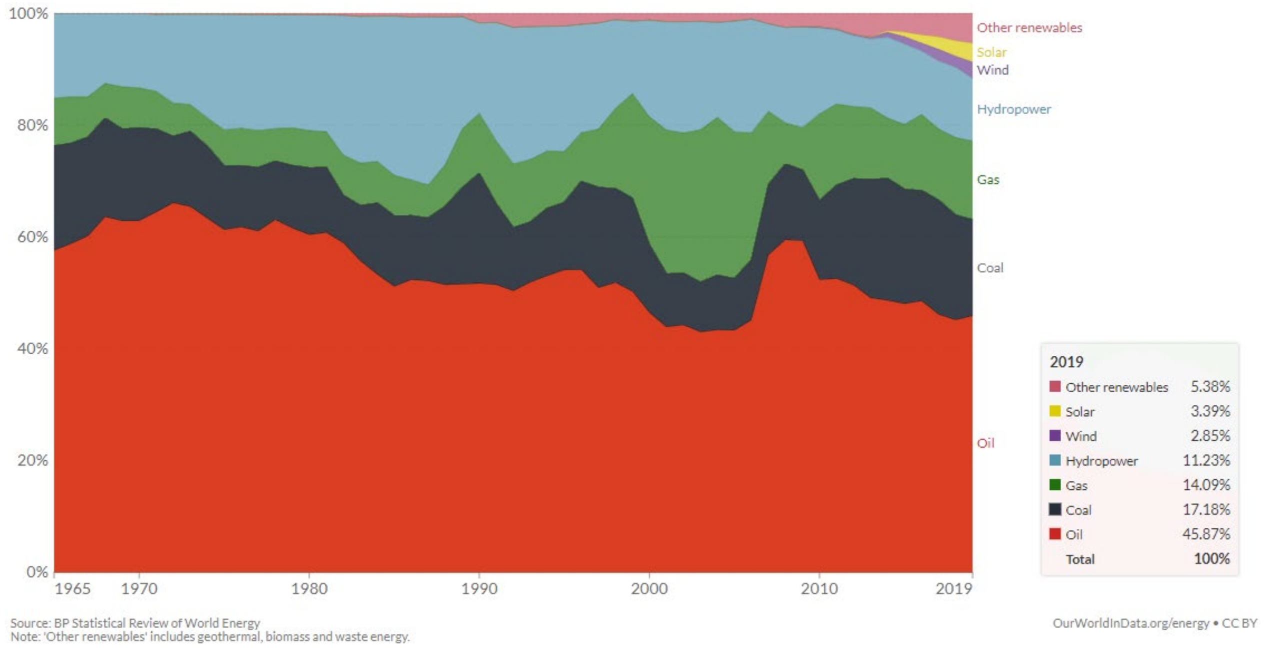
Current Production

Very low levels of production currently however with up to seventy times current renewable production capable extremely low-cost green hydrogen can be produced in the future.

8 Large-scale storage of hydrogen
9 renewableenergymagazine

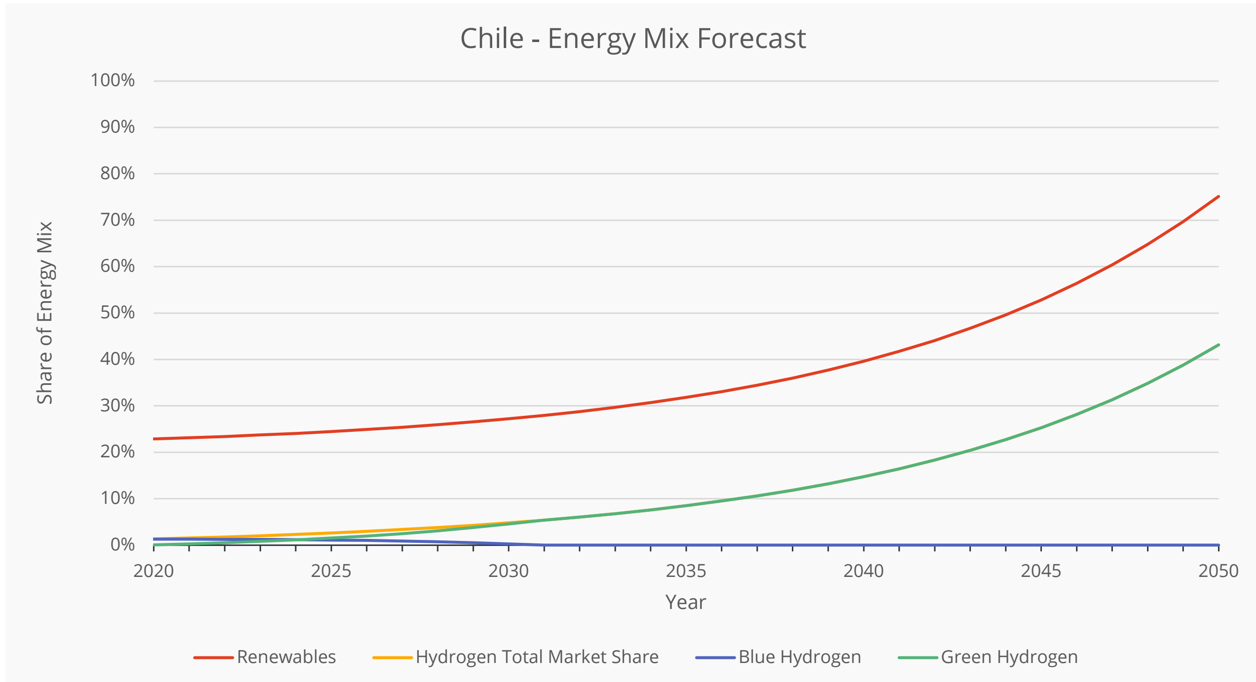
Energy Mix

Figure 5 - Energy consumption by source, Chile



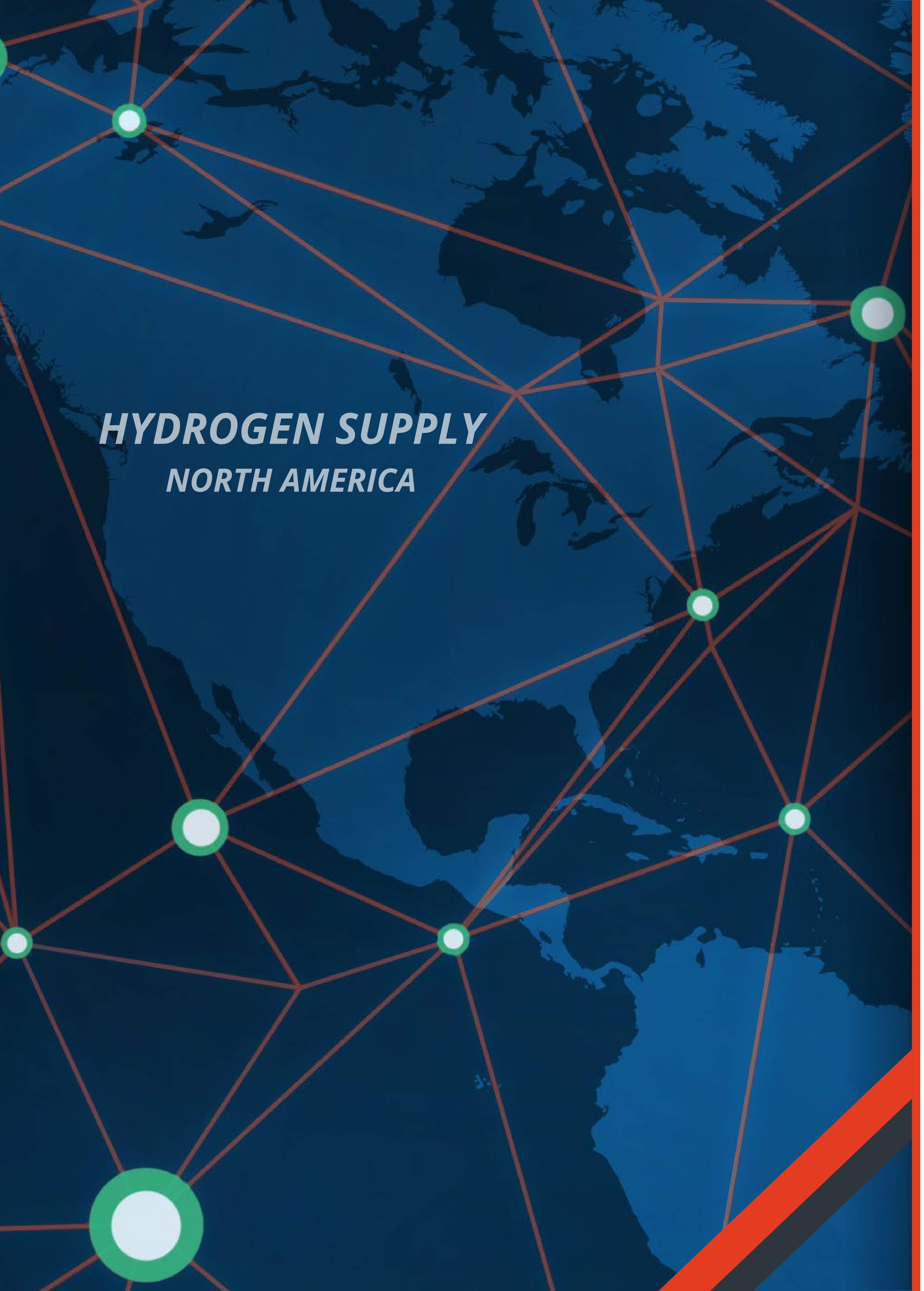
With large amounts of undeveloped renewable capacity in a country where already 20% of energy comes from renewable sources, electricity costs will plummet as demand allows the implementation of a far greater supply than the country could ever need. With a similar issue to Brazil when it comes to reliability of supply due to weather, hydrogen may be seen equally as an energy storage medium allowing the country to internally allocate a larger proportion of the energy mix to renewables.

Forecast



Our model predicts that upwards of 70% of Chile's energy mix will be renewable by 2050 due to its massive capacity alongside hydrogen taking a 40% market share due to the aggressive government and local sentiment as well as policy. The forecast does not account for exported energy.

Further to this the government projection is green hydrogen prices can fall below $1 per Kg which would be a 5-fold decrease from current prices due to the almost free renewable energy they can provide with suitable development. To realise this the government have issued short term tenders expiring 2025 for projects (up to $30m).



Case Study – Fundacion Chile, $300m Raise for 12-15 green hydrogen projects

This public- private partnership looks to support sustainable development in Chile. A primary objective of the partnership is to support the Chilean government's agenda moving towards a green hydrogen economy. They aim to fund a collection of projects in the region to position Chile as a global exporter.[10]

Case Study – Engie, Ammonia manufacture coupled with explosives plant

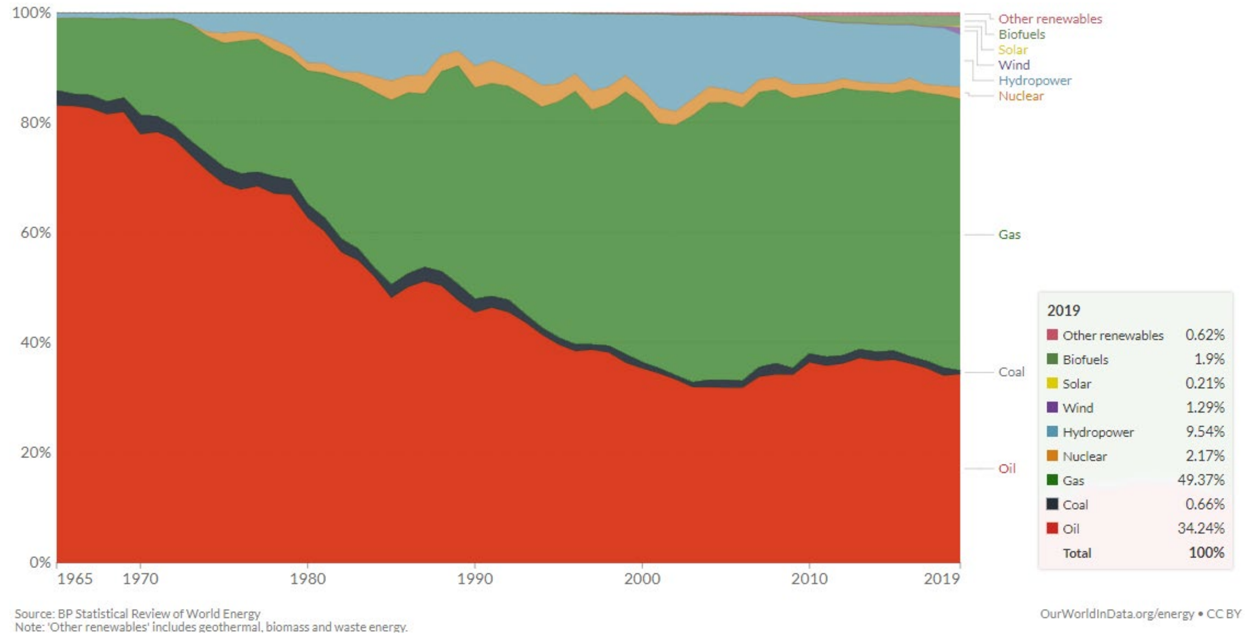
The region also has interest in supporting its other industries such as mining and explosive manufacture. Engie has invested into a partnership with several local companies, with the goal of establishing an economical supply of green ammonia to be used in the manufacturing of explosives.[11]

Argentina

Argentina is positioned to continue its development into a green hydrogen economy, as with the other South American countries discussed it possesses a wealth of renewable capacity and a government who are keen to push the green hydrogen economy. This push through policy is to be achieved by tax regulations instead of subsidy. It is key to note the implications of this and potential difficulties it brings.

Energy Mix

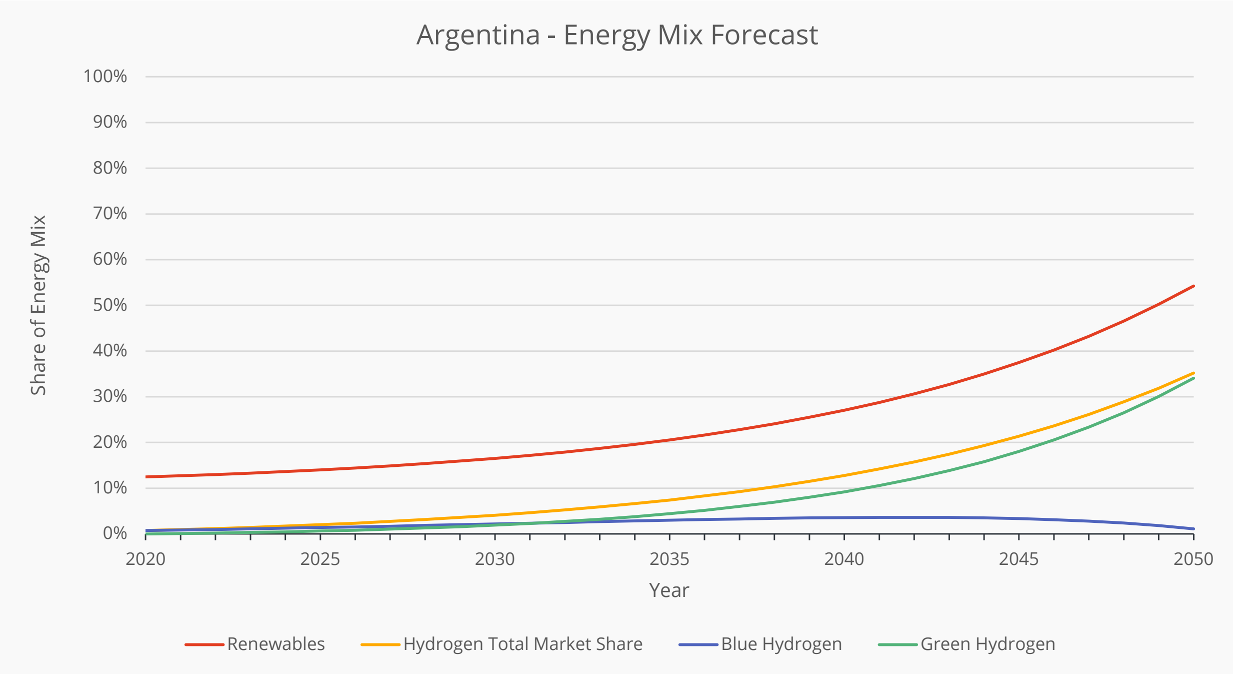
Figure 6 - Energy consumption by source, Argentina



With only 13% renewables it is comparatively behind some other South American nations however should the investment into renewable power continue as the government indicate this should steadily rise. Many of the hard to reach areas in Argentina could be well serviced by hydrogen where electrification remains a challenge.

10 bnamericas
11 https://fch.cl/

Forecast



Our forecast is less bullish with respect to Argentina's renewables outlook compared with other South American nations due to their less developed starting point combined with a lack of available capital in the region for renewables projects. The renewable capacity in Argentina is less plentiful than in the other South American nations discussed. These factors combined with the track record of the government failing to set a budget on a twenty-year plan expiring in 2019 for a green hydrogen strategy limits their capability within our forecast. This plan which was agreed in 2006 has had its deadline extended by 20 years before it was due to expire in 2021. Had a budget been allocated the plan would have been passed as law and undoubtedly Argentina would have accelerated its transition.

Case Study – Hychico

This is a small island type electrolyser running off a wind farm. Operating as a proof of concept since 2008. There have been few developments recently with the company behind the development simply marketing themselves for their expertise in operation and maintenance of such plants as they look to upscale in the future.

Other notable South American countries

Paraguay, Uruguay and Columbia all have interests in the green energy transition and, along with Mexico, they all plan to scale up their renewable capacity. Within these economies we also see strong international collaboration with each other, Europe and the USA in order to allocate sufficient capital for infrastructure development.

Summary

South America is well suited to developing a strong hydrogen economy only hampered by a lack of available capital in the region and sufficient policy to ensure the profitability of the infrastructure. Should government funding become available for such projects and, given the wealth of untapped renewable capacity, South America would be well positioned globally in this market.

NORTH AMERICA

Overview

North America consists of the USA, Canada, and Mexico. Whilst Canada and the USA are advanced economies that are exploring the hydrogen economy as a means to decarbonise their energy mix, Mexico lags behind. Both blue and green hydrogen solutions are being investigated: generally, blue is being put forward as a solution in highly industrial areas whereas green hydrogen is seen as the ultimate goal if hydrogen is going to decarbonise industry.

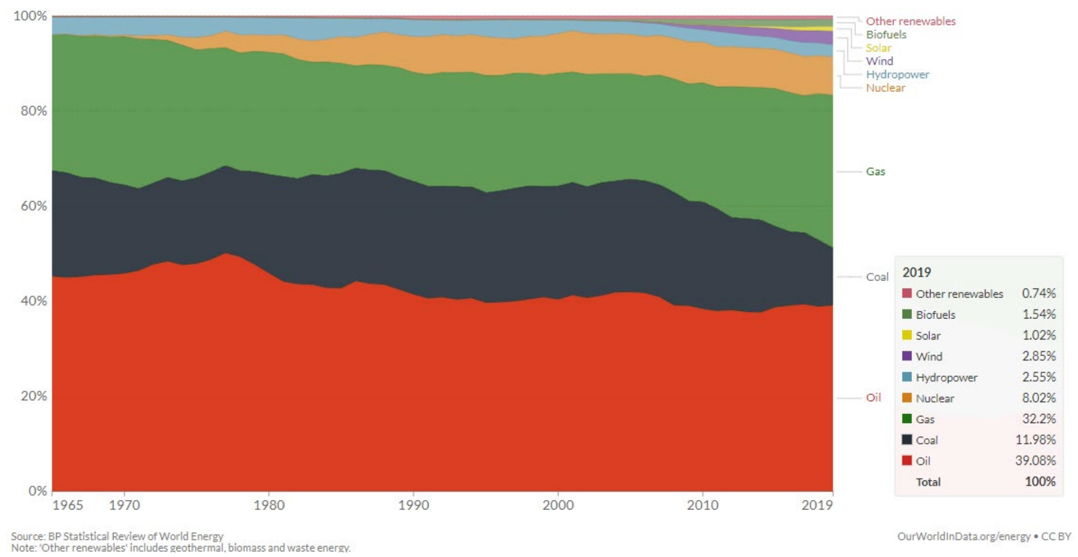
United States

The majority of current hydrogen production in the USA comes from three states: California, Texas, and Louisiana. Of the 10 MMT of annual hydrogen production in the USA, 95% of it is produced by SMR (grey), 4% by coal gasification (brown) and 1% is produced by electrolysis.[12] This makes up ~1/7th of world production.

Energy Mix

The USA has moved away from coal power in the last 15 years, reducing its share in total US energy consumption. This has mostly been taken up by an increase in natural gas' share. Although the USA's energy share has been approached as a whole, state by state, the energy mix will be very different.

Figure 7 - Energy consumption by source, USA



Forecast

The forecast indicates that the US will increase their hydrogen production, firstly with blue hydrogen in Texas and Louisiana, where there is existing hydrogen infrastructure (pipelines etc.). Green hydrogen will then be produced as the cost reduces in the coastal states where there is a larger potential for renewables. For example, California where the demand is being increased through the investment in FCEVs and other states where there is a large amount of investment in renewable energy.

Canada

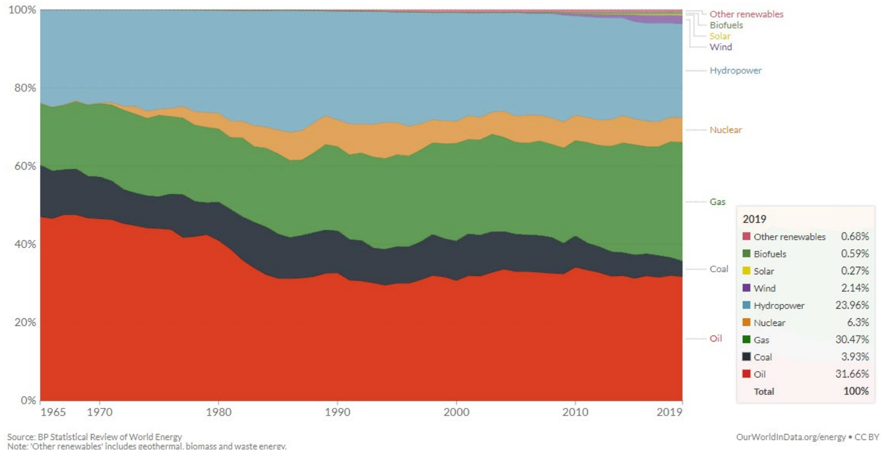
Canada already produces ~3 MMT of grey hydrogen per year and its rich natural gas reserves and industry in the west of the country make it suitable for an increase in blue hydrogen production. Whereas the east of the country has a very large capacity for hydroelectric power, which makes up a large proportion of electricity production, making it suitable for reliable green hydrogen production.

Energy Mix

Canada is a country rich in natural gas and hydroelectric power. In the east of the country, there is a significant amount of hydroelectric power which makes green hydrogen very appealing. In the west, there is a large amount of industry and oil and gas infrastructure. This makes blue hydrogen more appealing and also provides a case for demand in this region.

12 https://www.argusmedia.com/

Figure 8 - Energy consumption by source, Canada



Forecast

The forecast indicates that Canada will take up hydrogen at a rapid rate. There are already projects such as Edmonton's hydrogen energy complex that aims to increase the production of blue hydrogen in the west. This aims to produce 0.5 MMT per year which would, on its own, increase Canada's hydrogen production by ~1/6. Whilst the initial increase in production would be accounted for by large scale blue hydrogen projects such as this, green hydrogen projections suggest that, as the cost comes down and the scale increases, green hydrogen production will increase past blue hydrogen. This is likely to occur in the east where there are large amounts of renewables – mostly in the form of hydroelectric power.

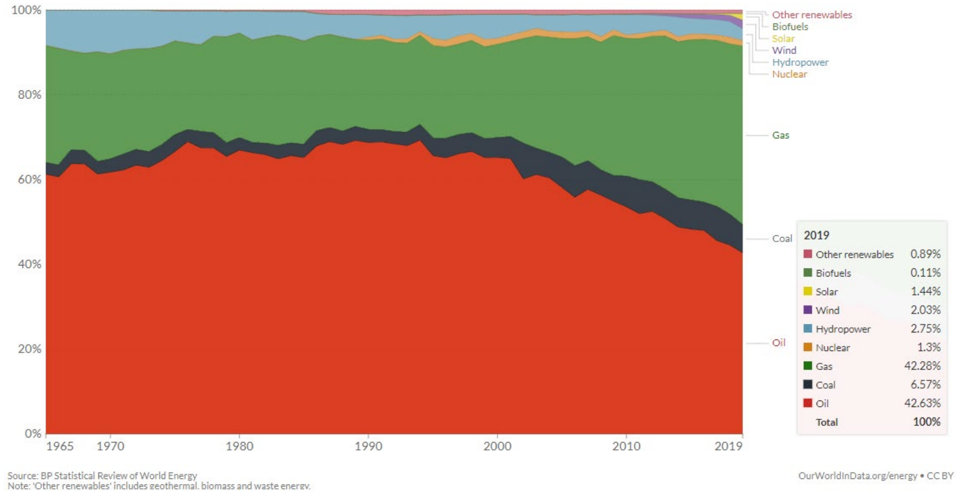
Mexico

Mexico is the least prepared for a transition to the hydrogen economy. There are very few hydrogen projects happening at the moment in Mexico. However, Mexico is well located to supply hydrogen to the USA and Canada if their demand increases.

Energy Mix

Over 90% of energy usage in Mexico comes from fossil fuels. Due to the limited amount of renewable energy, green hydrogen would have to be built with new renewable projects. Using existing natural gas to produce (blue) hydrogen through SMR, with CCS technology could be a better option if Mexico is to quickly increase their production.

Figure 9 - Energy consumption by source, Mexico



Forecast

As Mexico has a good basis for renewable energy, predominantly solar power, if Mexico reaches its renewable targets and makes use of this energy, it could increase its production of green hydrogen. The forecast predicts that Mexico is unlikely to become a massive producer of hydrogen. However, if it does, then it is likely to become a producer of green hydrogen more so than blue.

MIDDLE EAST

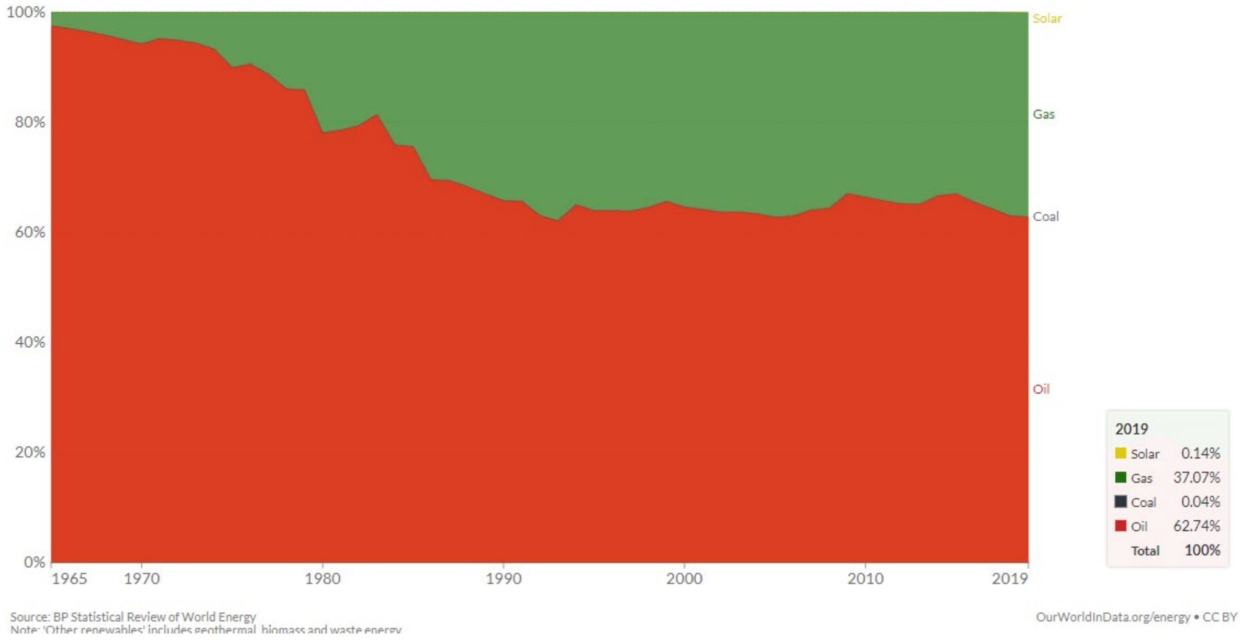
Saudi Arabia

Overview

Because of its abundant renewable resources and fossil fuels, Saudi Arabia positions itself as future hydrogen exporter with a main focus in producing blue hydrogen.

Energy Mix

Figure 10 - Energy consumption by source, Saudi Arabia



As the world's second largest oil reserve and the fifth largest gas reserve country[13], Saudi Arabia's backbone economy is to export fossil fuels. This significant economic reliance on fossil fuel weighs on its energy mix, with a mere 0.15% of its energy consumption coming from renewables.

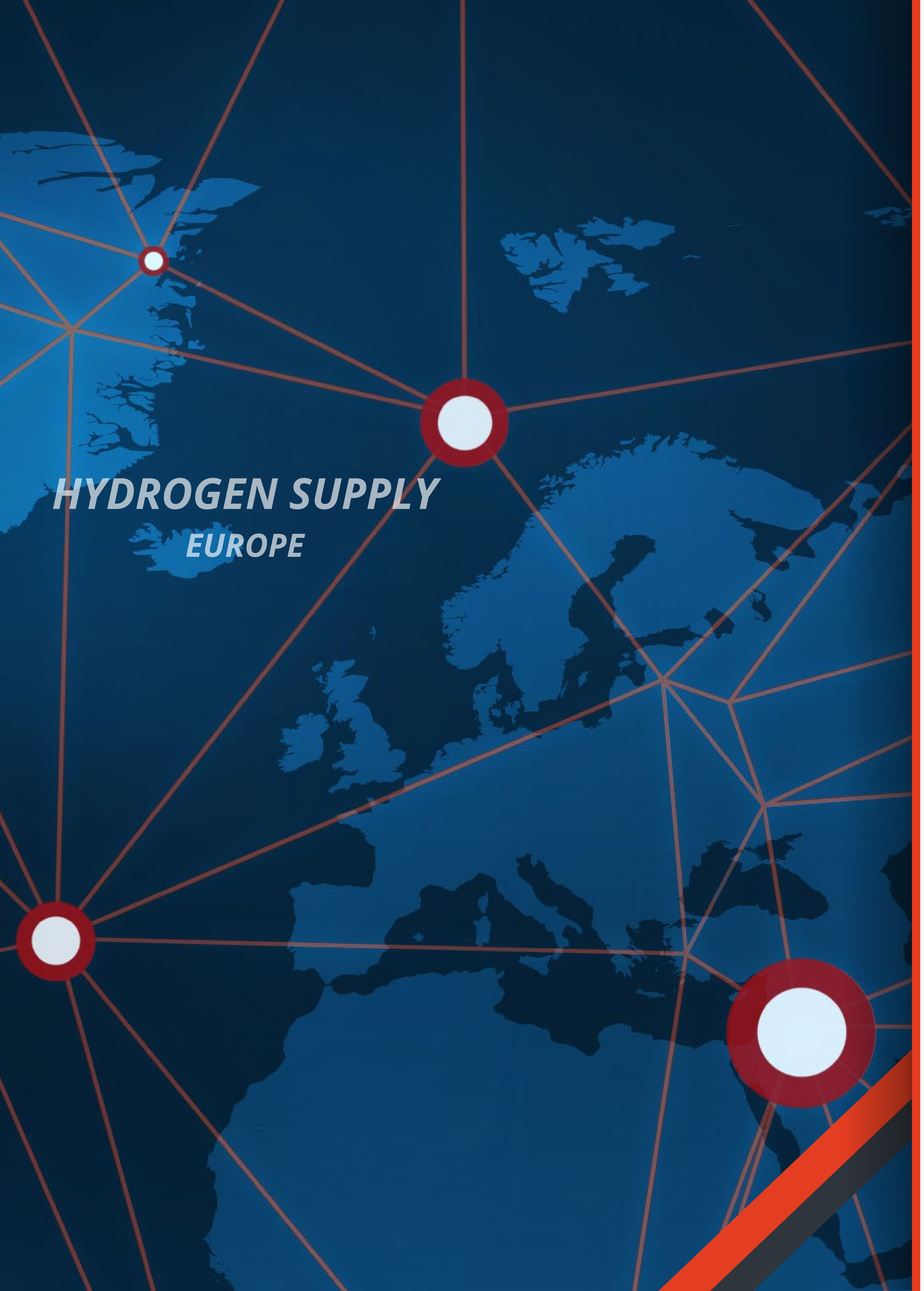
Current production

Due to a lack of internal hydrogen demand, the current scale of hydrogen production in Saudi Arabia is small. As Saudi Arabia's government has been aware of the importance of developing hydrogen to maintain its current position as energy exporter recently, a substantial amount of subsidy and investment is fed into its national hydrogen production projects. With the completion of ongoing hydrogen projects, hydrogen production is expected to increase substantially in the near future.

Forecast

Saudi Arabia is well-suited to produce blue hydrogen. Its abundant natural gas reserve secures a low cost of production for hydrogen, and depleted oil and gas fields can be utilised to store captured carbon emissions, turning grey hydrogen to blue. After realising its huge potential to produce blue hydrogen at a low cost, Saudi Arabia plans to exploit Jafurah gas field, which holds 200 trillion cubic feet of natural gas and was originally planned for liquified natural gas exports, for blue hydrogen production with an investment of $110bn. Natural gas will be primarily produced and used as substitutes to coal in power generation, with the remaining for blue hydrogen production. At the same time, Saudi Arabia is also investing heavily in green hydrogen production. Air Products (US), Acwa Power (Saudi Arabia) and Neom (Saudi's future city plan) plan to install 4GW of renewables to produce 650t green hydrogen per day, which will be used to produce green ammonia because of its ease of storage and transport compared to pure hydrogen. Because of its strong comparative advantage to produce blue hydrogen, we believe Saudi Arabia to be one of the earliest hydrogen exporters at scale, as industries already have knowhows to produce grey hydrogen at scale and the challenge to capture and store carbon dioxide is tackled by Saudi's depleted oil and gas field.

13 US Department of Energy



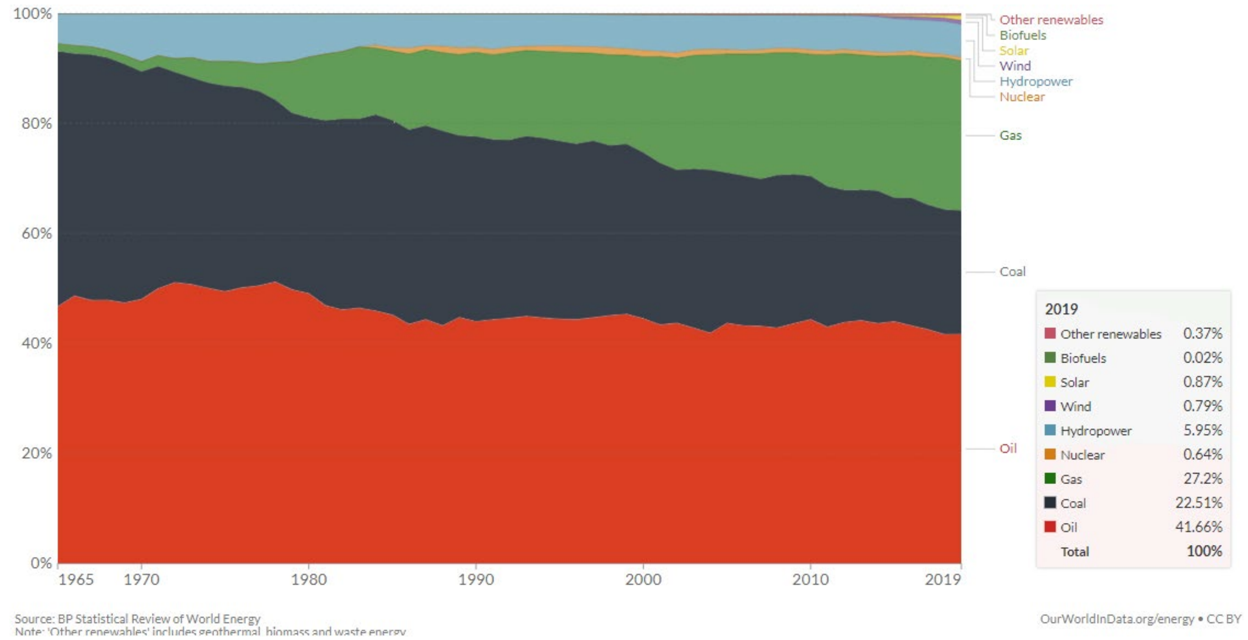
AFRICA

Overview

Africa positions itself as hydrogen producer and exporter to Europe considering its huge potential renewable capacity. However, the continent's renewable capacity has so far been largely unexploited.

Energy Mix

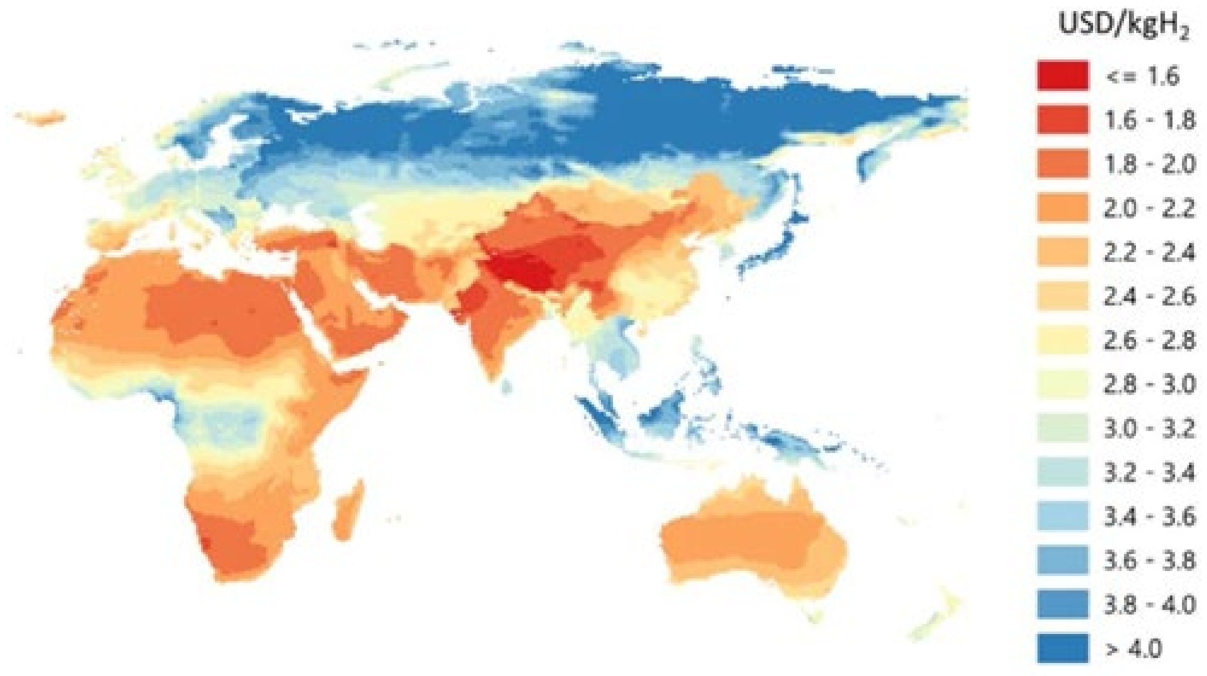
Figure 11 - Energy consumption by source, Africa



Africa, thanks to its large reserve of fossil fuels, relies heavily on fossil fuels as its energy source with a percentage of 90% in its energy mix. Renewables in contrast only account for 10% of total energy consumption. In fact, Africa has tremendous renewable resources. In North Africa, solar and wind power is abundant: the average solar intensity in Sahara Desert is 2,500-3,000kWh/m^2, which is much higher than that of Europe with 1,400kWh/m^2.[14] Also, while the average cost of production of wind-generated electricity is $58/MWh in Europe[15], Morocco has a cost of only $35/MWh. From the IEA's map of predicted long term hydrogen cost from solar and wind resources (excluding hydro), Africa has a clear cost advantage. Furthermore, in Central Africa, hydro power is rich. As an example, the planned Inga III dam in Democratic Republic of the Congo has potential capacity of 44GW, twice that of the world's current largest one in China. Although there is a great potential in African renewable capacity, most renewables have not been exploited due to a lack of funding and technology considering that most African countries are still undeveloped. The installed renewable capacity only accounts for 2% of global share in 2020.

14 Worlometers
15 Dii Desert Energy (2019), A North Africa – Europe Hydrogen Manifesto

Figure 12 - Hydrogen costs from hybrid solar PV and onshore wind systems in the long term



[16]

Current production

Current hydrogen production is very limited in Africa at present due to a lack of internal demand. Hydrogen is primarily used in fertiliser and refining industries, which are secondary sectors, whereas the economy of most African countries is based on primary sectors where hydrogen has little presence.

Forecast

Although current hydrogen production in Africa is small, we believe that there is a huge potential and possibility for Africa, especially North Africa due to its geographic proximity to Europe, to grow as a world leading region for hydrogen production and export. Europe has been interested in developing Africa as its hydrogen production factory given that the EU is aware that its renewable capacity is not sufficient to fulfil its hydrogen demand. The EU has launched a "2x40GW green hydrogen initiative", targeting to source 40GW of electrolyser capacity in the EU and another 40GW from neighbouring regions including North Africa by 2030. Investments from the EU are in place as well. There is a $35bn investment from NDICI[17] for period 2021-2027 to focus on climate objectives for sub-Saharan Africa, and another $3.5bn from EIB[18] for financing climate related investment and sustainable development.[19] With the cooperating partnership between Africa and the EU, we believe that production of green hydrogen in Africa is expected to soar after its renewable potential is exploited under the substantial investments.

16 WindEurope
17 IEA (2019), Future of Hydrogen
18 Neighbourhood, Development and International Cooperation Instrument
19 European Fund for Sustainable Development

EUROPE

Overview

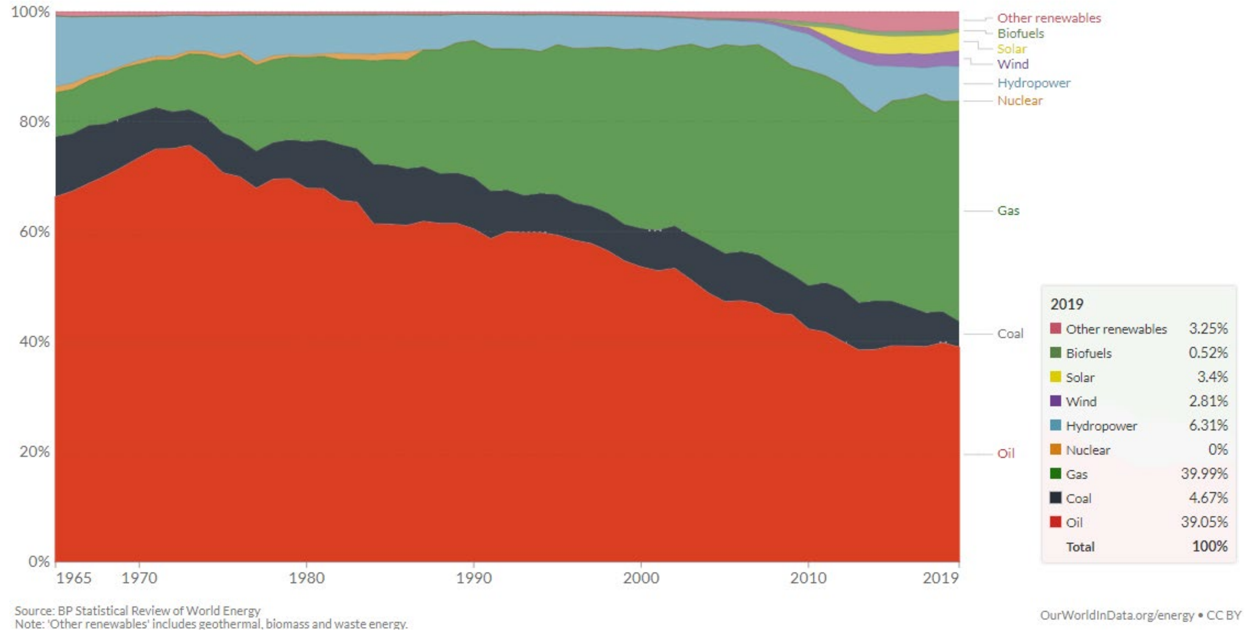
Europe has positioned itself to be a leader in hydrogen innovation, production, distribution, and consumption. Most European countries have produced a hydrogen roadmap and strategy, which is based on differences in current energy mix, renewable energy capacity, gas distribution infrastructure, investor attitudes towards hydrogen, and current investment in hydrogen projects. Europe has the potential to become a hydrogen ecosystem, producing blue, green, and pink hydrogen.

Italy

Italy has the potential to become a green hydrogen hub connecting North Africa, where green hydrogen can be produced at a low cost, and Europe, where there is strong demand for green hydrogen. Italy can leverage its geographical location, renewable energy capacity and gas infrastructure to play an important role in the international hydrogen market.

Energy Mix

Figure 13 - Energy consumption by source, Italy



In 2019, the structure of total energy consumption in Italy is: 39.05% oil, 39.99% gas, 4.67% Coal 4.67%, and 16.29% renewables. It is also important to note that 43.17% of electricity in the country is generated through renewable, and this creates a favourable condition for green hydrogen production. The government aims to have 30% of its energy consumption and 55% of electricity generation from renewables by 2030.

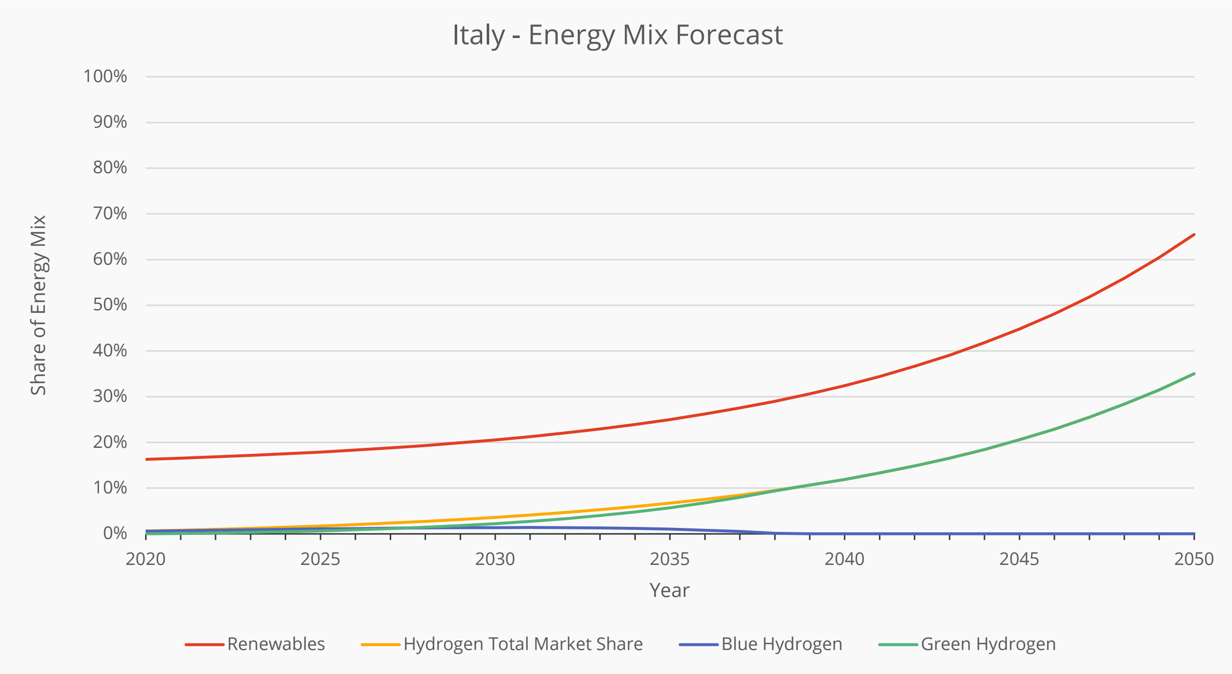
Current production

The current production of hydrogen in Italy is still in its infant stage. The country is expected to install 5 GW of electrolysers capacity by 2030, which is around 11% of total EU target.

Utility and Oil & Gas companies in Italy are investing in the development of hydrogen infrastructure and production. For example, the Italian energy infrastructure operator Snam has been running experimental projects blending 10% hydrogen into its natural gas transmission network in Contursi Terme in Southern Italy. The company has also invested USD 39.6 billion in the leading electrolyser manufacturer ITM power.[20]

20 Clifford Chance

Forecast



Italy's National Hydrogen Strategy announced that USD 12 billion will be spent by 2030 to promote the production and application of hydrogen in the economy. This process could bring over 200,000 jobs to the country and up to USD 32 billion to its gross domestic product.

The government aims at green hydrogen as the main driver for its decarbonisation goal, considering its great potential in renewable energy capacity development. According to our model, by the year 2050, the country will have up to 65% of energy being renewables, and 35% of energy consumption will be powered by hydrogen.

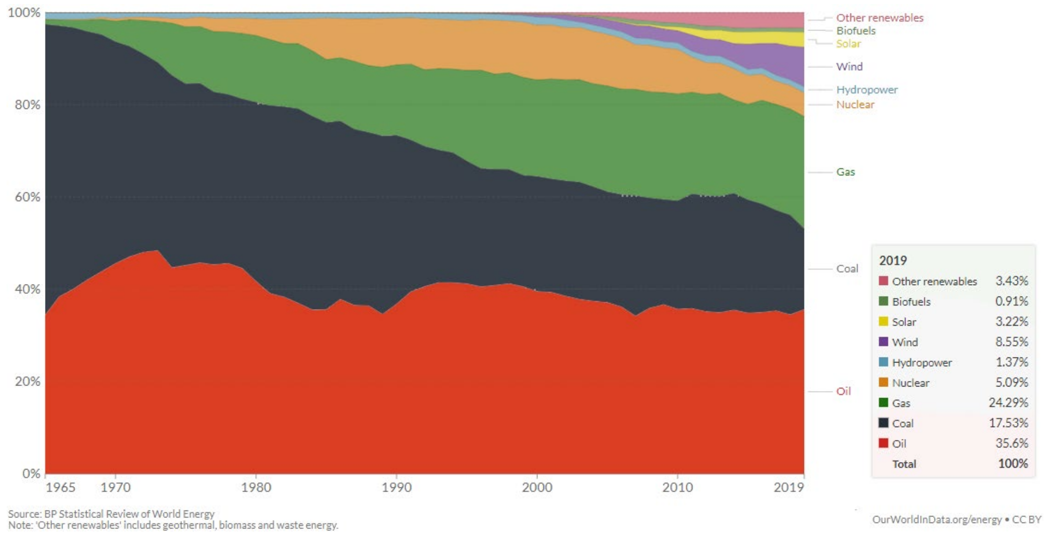
Due to Italy's geographical location, it can serve as a hydrogen hub connecting North African countries such as Tunisia, where renewables are produced at a low cost, and major European countries such as Germany, where a large amount of hydrogen would be consumed.[21]

Germany

Germany is at the forefront of hydrogen innovation and implementing hydrogen into every-day business use cases. By far, Germany has one of the largest quantities of hydrogen cleantech ventures, one of the largest hydrogen charging station networks, and will invest more than $9.74 billion in large-scale hydrogen projects.

Energy Mix

Figure 14 - Energy consumption by source, Germany



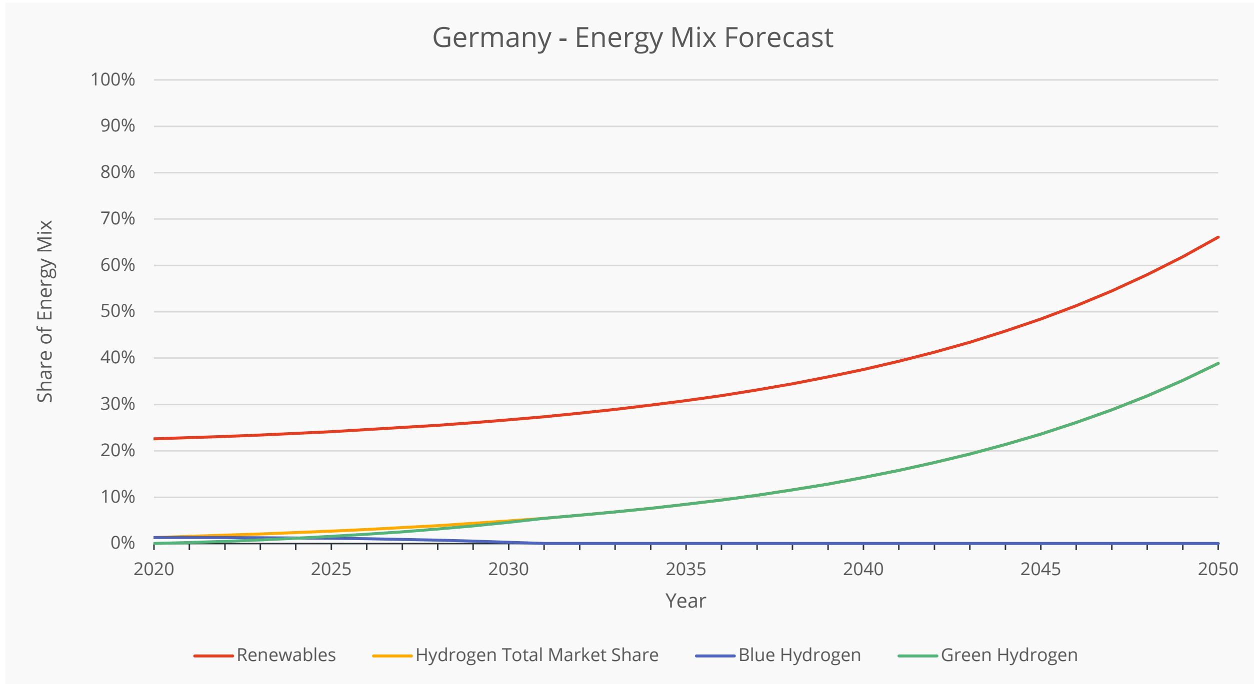
21 https://www.snam.it/en/Media/news_events/2020/Snam_hydrogen_blend_doubled_in_Contursi_trial.html

Hydrogen is being implemented as an effort to decarbonise Germany's industry and reduce carbon emissions. As of 2019, only 22.5% of Germany's energy mix was sourced from renewable energy, including nuclear, hydro, wind, and solar. As a result, non-renewable energy makes up 77.5% of Germany's energy mix, consisting of 35.6% oil, 24.29% gas, and 17.53% coal. Although there has been a gradual shift away from coal consumption over the last decade, natural gas has been substituted for coal. As Germany has positioned itself at the forefront of global decarbonisation, it aims to use hydrogen as the tool for replacing natural gas and reducing carbon emissions in energy-intensive processes.

Current Production

Germany is one of the top grey hydrogen producers and exporters, following the Netherlands, Canada, Belgium, and United States. Green hydrogen accounts for 5% of Germany's hydrogen production, which is a significantly higher proportion than in other countries. On average, global green hydrogen accounts for no more than 1% of total hydrogen production. Germany currently accounts for 20% of global electrolyser share and anticipates to produce 14 TWh of green hydrogen by 2030.

Forecast



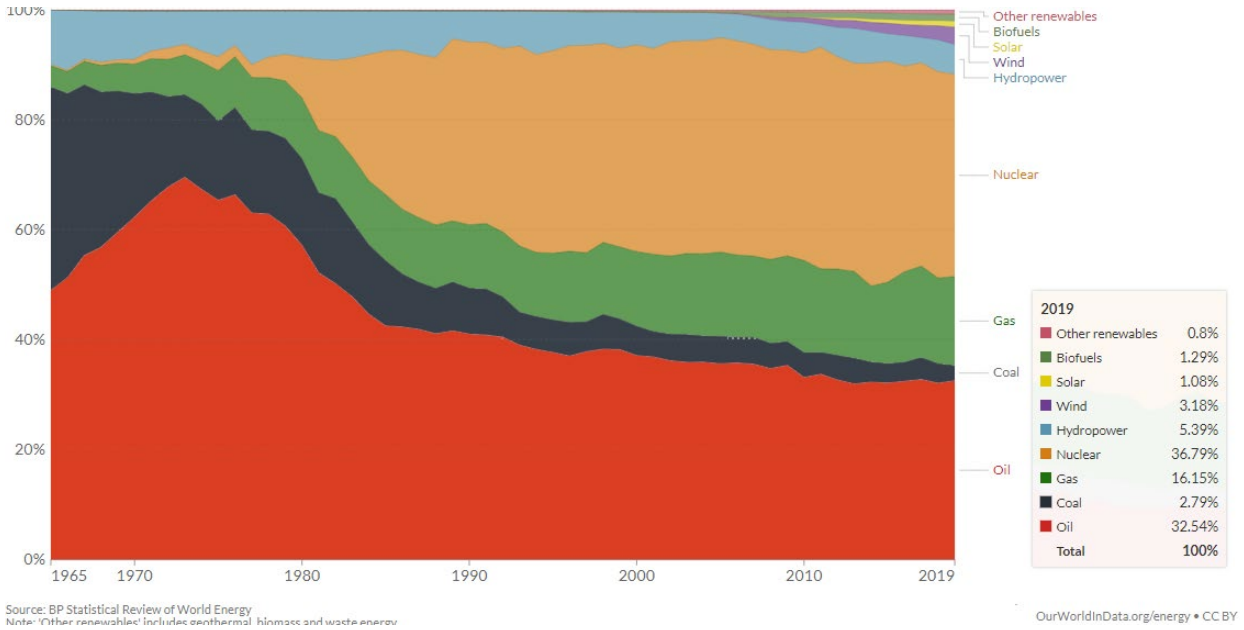
Hydrogen in Germany's energy mix is forecasted to grow exponentially after 2025, which is when pilot projects end, and full-scale projects are expected to start. High hydrogen demand across the transportation, chemical, and industrial sectors will require considerable hydrogen imports. For instance, decarbonising the steel industry in Germany would require a two-fold increase in renewables capacity, which is unfeasible for a country with limited access to offshore wind and solar fields. Thus, Germany is partnering with renewables-rich countries, such as Morocco and Chile to guarantee future hydrogen imports.

France

France has an advantage in adopting green hydrogen thanks to abundant nuclear power, a robust carbon taxation scheme, and an aggressive national hydrogen strategy with a substantial amount of subsidy in place.

Energy Mix

Figure 15 - Energy consumption by source, France



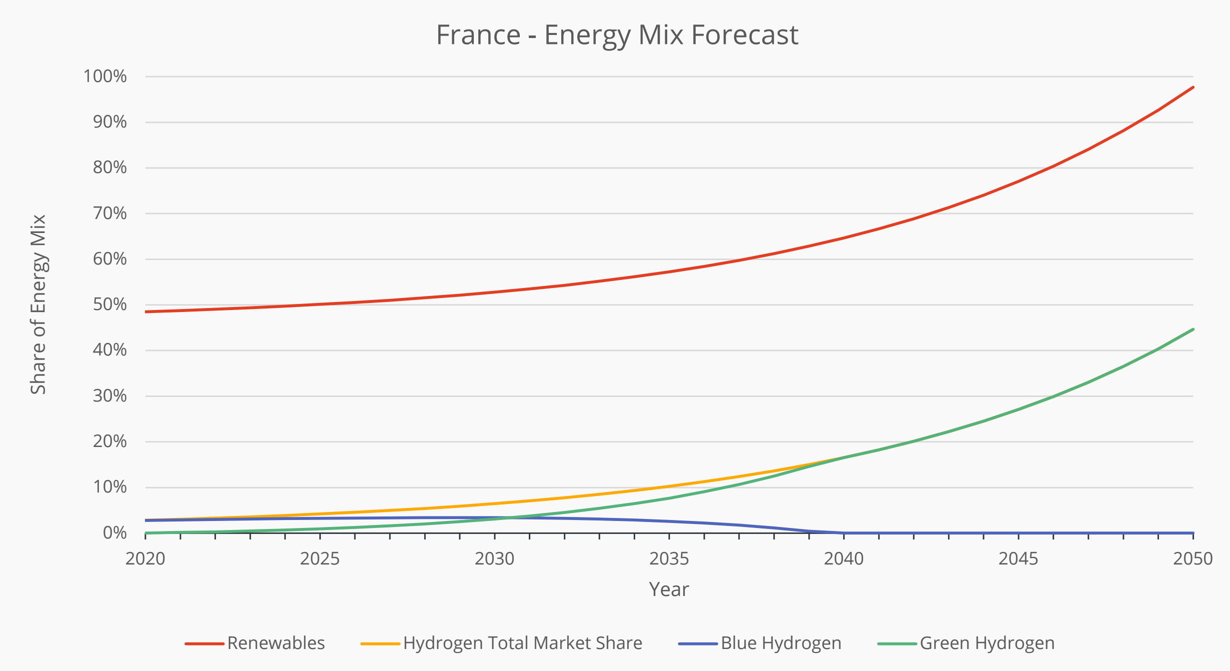
France is one of the world leading countries in decarbonisation. Nuclear power, which could be considered as zero carbon, dominates France's energy consumption with the highest percentage in 2019 and non-fossil fuels made up to around a half of French energy usage. Furthermore, nuclear power generates 70% of total electricity in France, which is indispensable in producing green hydrogen through electrolysis. As electricity generation from nuclear power has low variable cost and can be operated at full loads, this strong presence of nuclear power in the energy mix, particularly in electricity generation, gives France comparative advantages to produce green hydrogen at a low cost and at stable amounts compared to other countries relying on intermittent and currently expansive renewables (solar, wind, hydro).

Current production

Currently France is not a big hydrogen producer. On the other hand, it is the third largest hydrogen importer primarily for its refining steel industry. With its abundant nuclear power, however, green hydrogen production in France is expected to boom in the near future with the installation of electrolysers. The French government has launched a €7bn national hydrogen strategy with a target to install 6.5GW of electrolysers by 2030, of which €2bn over 2020-2022 and €3.4bn by 2024. Furthermore, in order to help the French economy recover from Covid-19, the government has announced a €100bn stimulus package through 2022, of which €30bn is dedicated to green hydrogen.[22]

22 https://www.trade.gov/market-intelligence/italy-invests-green-hydrogen

Forecast



According to our forecast, green hydrogen will dominate the hydrogen market by 2030 after the installation of electrolysers are in place by then. This also coincides with French national hydrogen strategy's objective to replace carbonated hydrogen from fossil fuels (brown/grey/blue hydrogen). Apart from a substantial amount of investment from French governments into hydrogen and stringent hydrogen strategy, the high uptake of hydrogen's share in France is also thanks to its aggressive carbon taxation scheme. This significantly high carbon tax will speed up the decarbonisation of French industries and their transition into hydrogen.

Table 2 - French carbon taxation scheme in 2014[23]

	2014	2015	2016	2017	2018	2019	2020	2021	2022
Carbon tax €/ton	7	14.5	22	30.5	44.6	55	65.4	75.8	86.2

23 RECHARGE (2020), France's €7bn hydrogen strategy could feature role for nuclear
Ministry of the Ecological Transition (2017), Carbon taxation

ASIA

Overview

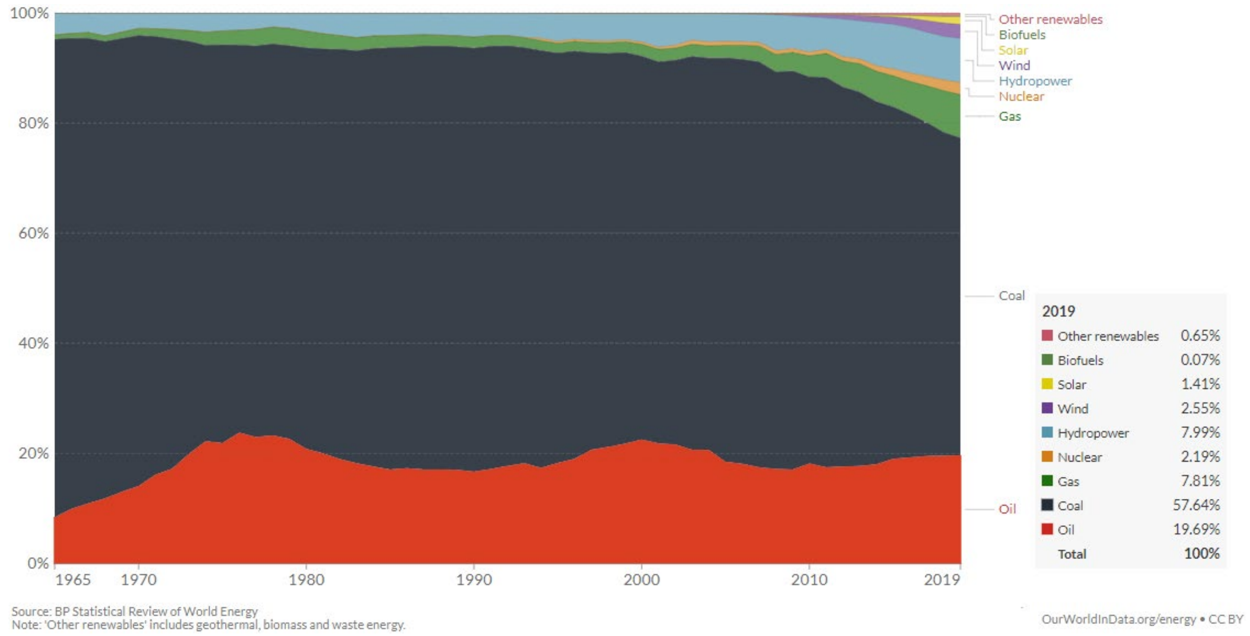
Asia is expected to be a worlding leading region in exporting hydrogen and hydrogen technology where hydrogen can be produced at low cost thanks to abundant renewables and fossil fuel reserves in Asia. For hydrogen technology, Asia is a leading region with many countries announcing national strategies in support of fuel cell technology.

China

Hydrogen has the potential to become an important driver for China to achieve its Net Zero goal by 2060, as announced by Chinese President Xi in September 2020. The government's determination to decarbonise its economy is an important driver for hydrogen-related technologies to develop in the country. The country is projected to be both a major supplier and consumer of hydrogen in the future.

Energy Mix

Figure 16 - Energy consumption by source, China



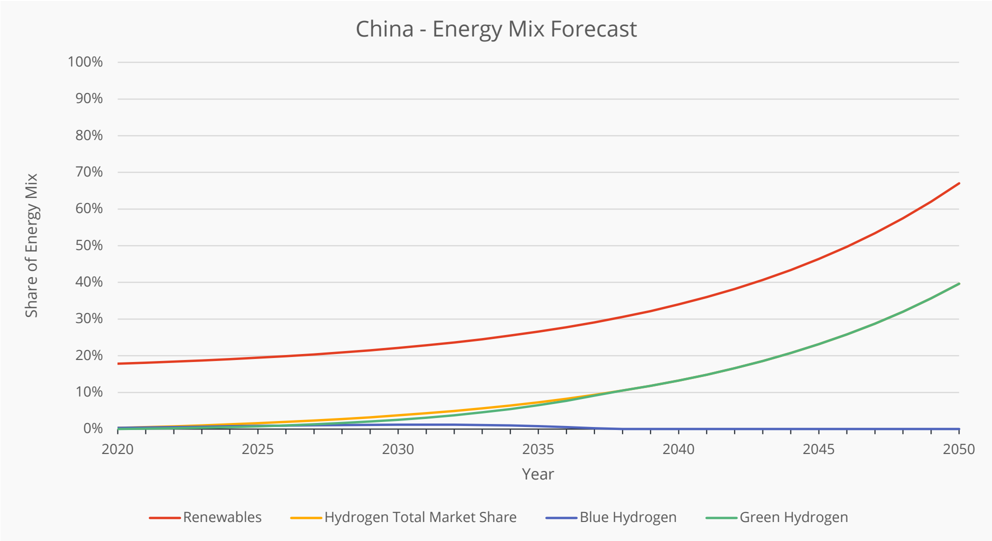
As the largest energy consumption country in the world, China has nearly 85% of its energy use being generated from fossil fuels. The country is rich in coal, which accounts for around 58% of energy consumption, and relatively lacks oil and gas reserves. It is estimated that China will have 75% of energy use being renewables by 2060.

Current production

China is currently the largest producer of hydrogen in the world. In 2020, China produced 33.42Mt of hydrogen, which is around 1/3 of world's total production. The majority of H2 is produced in the Northwest and North part of the country. We expect the country to further expand its hydrogen production in the next decade. According to Professor MingGao Ouyang in Tsinghua University, around 10Mt of hydrogen production as a by-product from industrial process in China is not yet fully utilised.

As the world's largest consumer of energy, China is determined to decarbonise its economy. The country has set up goals to reach peak carbon emission by 2030 and reach net zero carbon emission by 2060. This provides momentum for clean energy to grow. Hydrogen is mentioned frequently in recent Chinese policies for decarbonisation. It is estimated that the demand for hydrogen could reach 35Mt (5% of total energy use) in 2030 and 60Mt (10% of total energy use) in 2060. Major use cases of hydrogen in China would include fuel cell vehicles in transportation sector and steel production in industrial sector.

Forecast



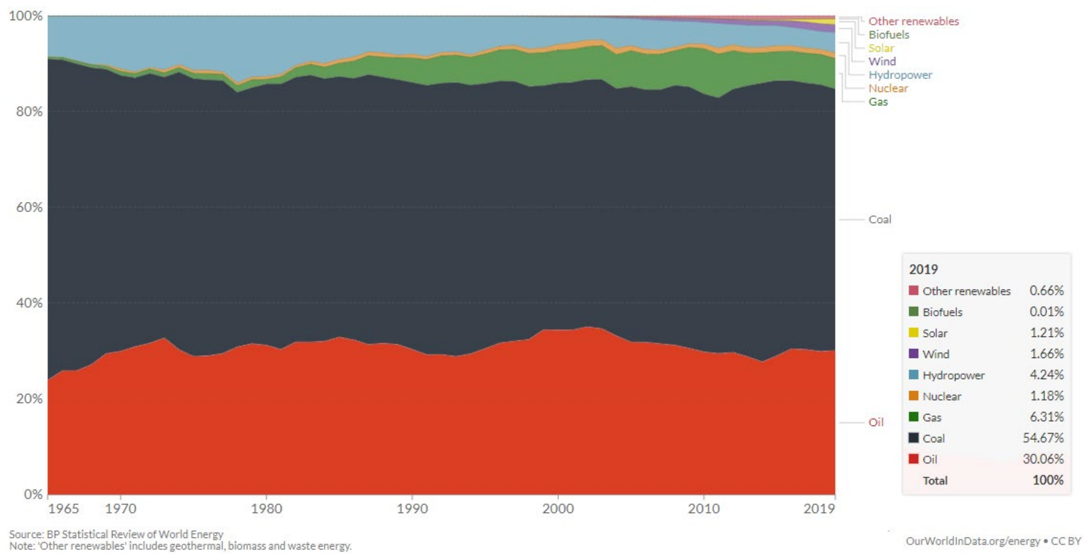
Our model suggests that renewable energy would make up nearly 70% of total energy use in China by 2050. Although China's policies have not indicated the country's preference towards green or blue hydrogen, we predict that green hydrogen production in China could surpass blue hydrogen around 2030, due to China's decarbonisation goals and development of wind and solar energy.

India

Due to the relatively low cost of renewable energy and policy support, India could be a major supplier of green hydrogen in the Asia-Pacific region in the future.

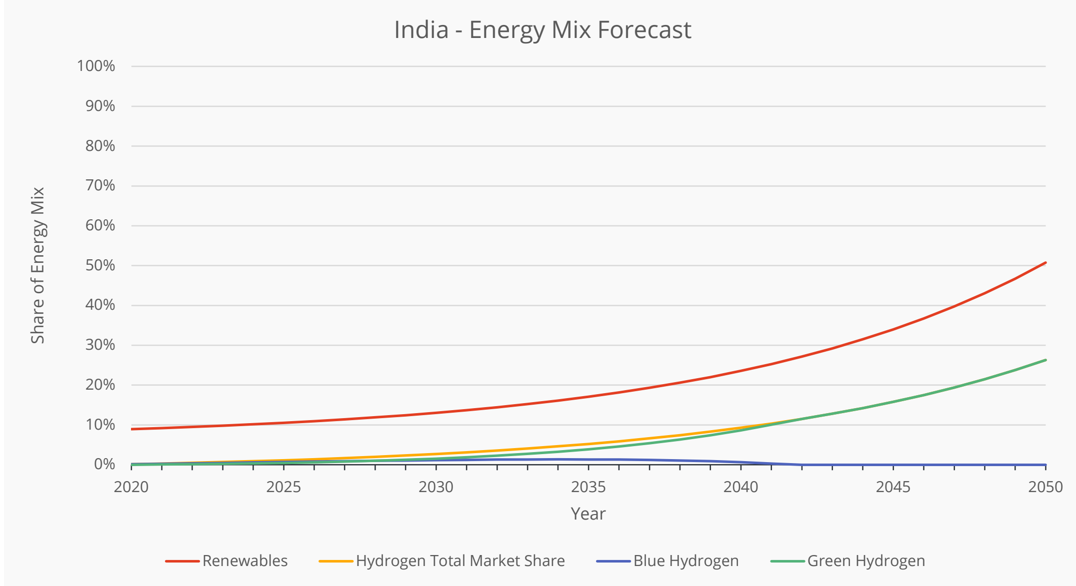
Energy Mix

Figure 17 - Energy consumption by source, India



India is the third largest energy consumption country in the world. Its energy use relies heavily on fossil fuel and 91% of India's energy was generated by fossil fuel in 2019. The country is ambitious in developing renewable energy, with a target of achieving 175 GW of renewable capacity by 2022.

Forecast



The demand for hydrogen in India is currently around 6Mt per year, and it is mainly used in refinery and fertiliser industries. As a major energy consumption country that has been considering setting a net zero goal, India is estimated to consume around 28Mt of hydrogen by 2050. On the infrastructure side, India also plans to leverage its existing CNG pipeline grid and infrastructure to lower the cost of hydrogen transportation.

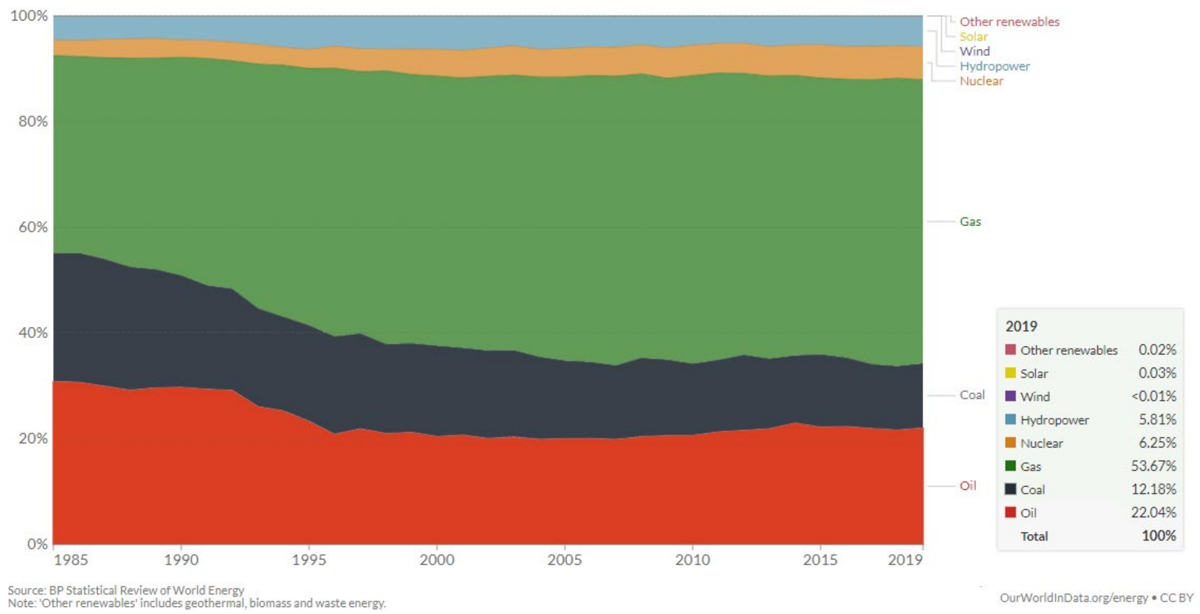
Our model predicts that by 2050, renewables will account for nearly half of India's energy demand. Due to relatively low cost of wind and solar energy in the Asia-Pacific region, the transition from blue hydrogen to green hydrogen could happen as soon as 2030 in India, and India could be a major player in the green hydrogen export market in the Asia-Pacific region.

Russia

Russia is one of the largest fossil fuel exporters globally and positions itself as a future hydrogen supplier and exporter. However, government's attitude towards hydrogen is not clear.

Energy Mix

Figure 18 - Energy consumption by source, Russia

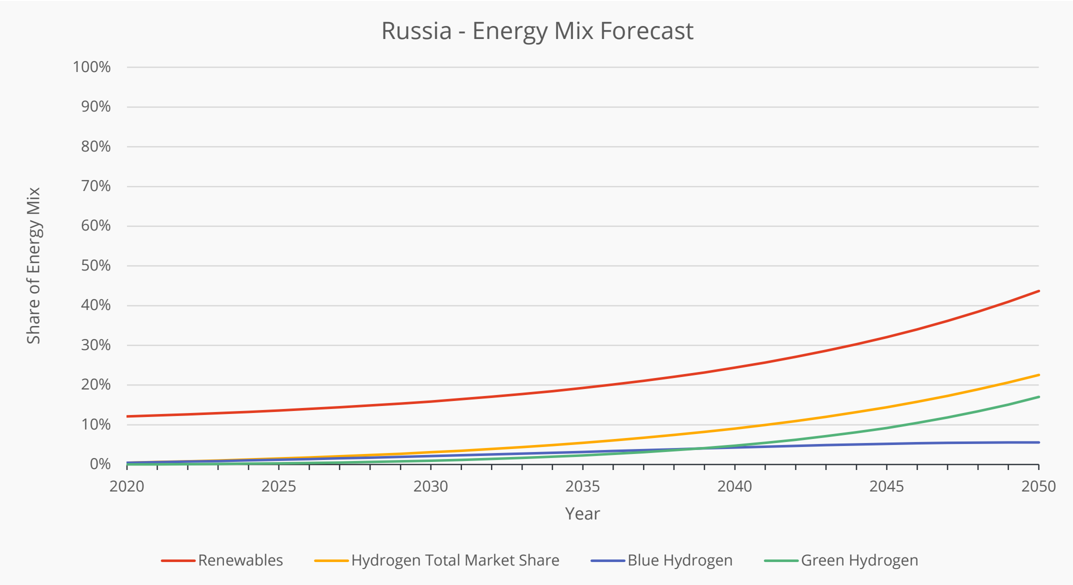


As the world's third largest fossil fuels exporter, Russia holds tremendous amounts of oil and natural gas reserves: 6.4% of global oil reserves and the second largest proven reserves of natural gas. Abundance in fossil fuels is reflected in Russia's energy mix, with nearly 90% of its energy consumption coming from fossil fuels. Furthermore, although in theory Russia has a variety of renewable resources from wind to geothermal, its rugged weather and soil conditions make exploiting these renewables difficult and costly.

Current production

Currently Russia already produces a large amount of hydrogen with an annual production of 2Mt, but almost all is grey hydrogen, produced from natural gas without carbon capture. As Russia plans to retain its international position as energy exporter in future, it is expected to decarbonise current hydrogen production and supply and export more low-carbon hydrogen (blue & green hydrogen) to Asia and Europe due to their requirement on clean energy from policies like Carbon Border Adjustment Mechanism (CBAM) from Europe.

Forecast



In order to reach the goal as future hydrogen exporter, Russia published two documents; one is Energy Strategy until 2035 and the other Hydrogen Roadmap until 2024. According to Energy Strategy, Russia plans to export 0.2Mt hydrogen in 2024 and 2Mt in 2035, and Hydrogen Roadmap gives two state-controlled energy companies, Gazprom and Rosatom, to develop and supply turquoise and green hydrogen respectively. However, due to the low Technology Readiness Level (TRL) for turquoise hydrogen and a lack of renewables and nuclear stations for green hydrogen, Russia is more likely to supply blue hydrogen by exploiting existing grey hydrogen production facilities from natural gas and depleted oil and gas field for carbon storage before 2050. As Russia's economy currently heavily relies on fossil fuel exports, its transition to a hydrogen economy is slow and government investment and projects are relatively limited compared with European and Middle East countries. This is reflected in our forecast that Russian renewable share only accounts for 45% of its energy usage and hydrogen market share 20% by 2050, which are outpaced by France for example with figures nearly 100% and 45% respectively.

FOR FURTHER INFORMATION

This paper provides insights into trend data with analysis for investors to make an informed investment decision into the hydrogen value chain.

The firm provides a comprehensive range of services which includes M&A transaction services, raising both debt and equity to finance hydrogen projects globally.

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