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Assessment of Clean Hydrogen in MENA

Whitepaper

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CONTENTS

GLOSSARY

BCM – Billion Cubic Meters
CCS – Carbon Capture and Storage
CCUS – Carbon Capture, Utilisation and Storage
CAGR – Compound Annual Growth Rate
CO_2 – Carbon Dioxide
CO_2e – Carbon Dioxide Equivalent
COP – Conference of Parties
FCEV – Fuel Cell Electric Vehicle
GCC – Gulf Corporation Council
GHG – Greenhouse Gas
GW – Gigawatts
MW – Megawatts
MENA – Middle East and North Africa
MoU – Memorandum of Understanding
PEM – Polymer Electrolyser Membrane
PGMs – Platinum Group Metals
PPA – Power Purchase Agreement
PV – Photovoltaics
SAF – Sustainable Aviation Fuel
TWH – Terawatt Hour
R&D – Research and Development
UAE – United Arab Emirates
UN – United Nations
UNFCCC – United Nations Framework Convention on Climate Change
US – United States

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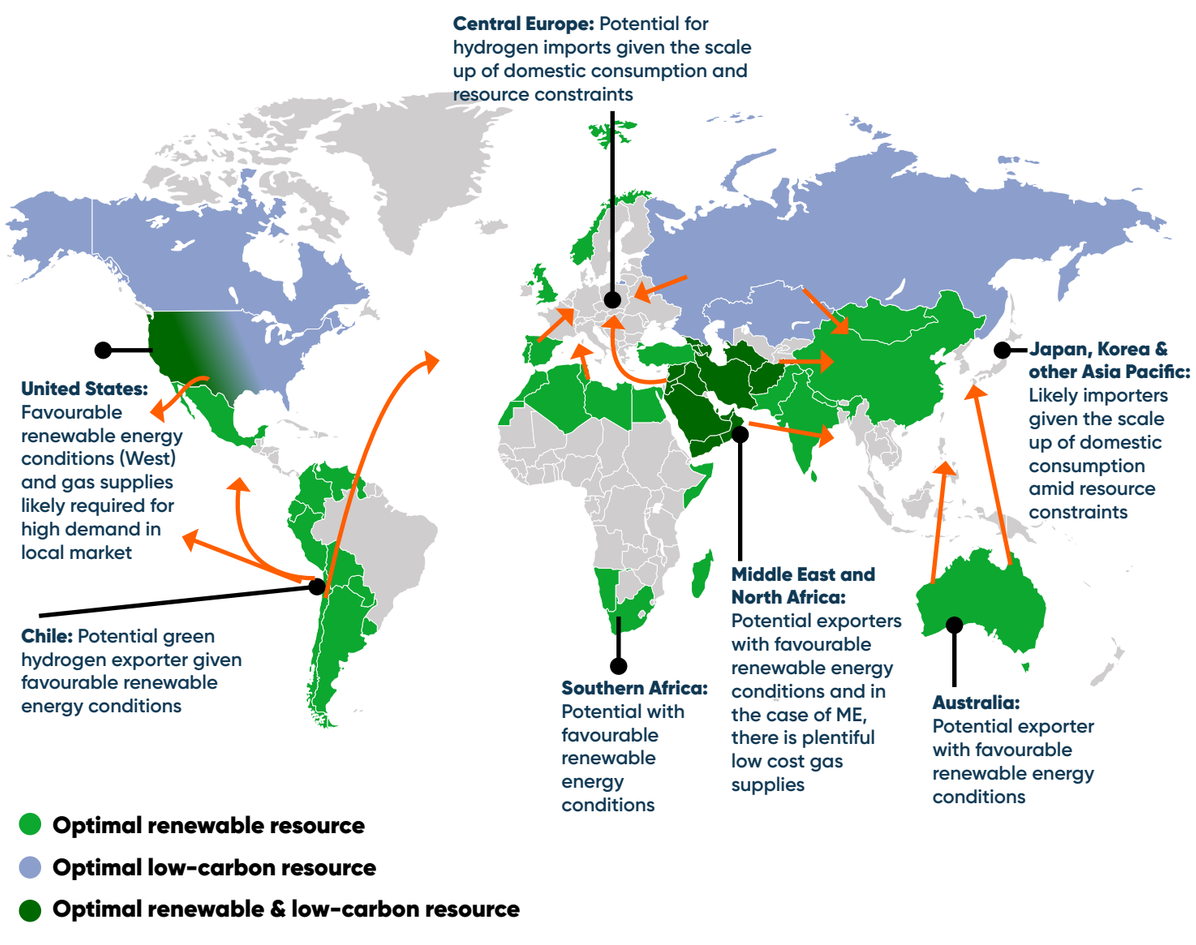
Section 1: Relevance of Hydrogen in MENA

1.1 Types of Hydrogen

Often described as the new oil of the 21st century, hydrogen is the most abundant element in the universe. Discovered by English scientist Henry Cavendish in 1766, it is an extremely versatile energy carrier with exceptional energy density. Crucially, when produced via renewables, it carries zero CO_2 emissions – very meaningful as humans aim to decarbonise their global footprint between 2050-2070. In its clean form, hydrogen can also be used as a fuel to supplement or displace others in transportation (notably aviation, shipping and rail) and heavy industry. It has potential to decarbonise hard-to-reach areas that current renewable markets have long had trouble accessing. In short, it could be a global gamechanger.

Hydrogen is far from a new market, with 70 million metric tonnes produced worldwide, primarily for the chemicals market.[1] But 99.6% of this volume comes from hydrocarbons,[2] which means it does not contribute to reducing CO_2 emissions. Therefore, hydrogen itself must quickly diversify in order to be a pivotal part of the energy basket in MENA and beyond.

Exhibit 1: Interconnectivity: Approximately 30% of global hydrogen can be involved in international trade



Source: Goldman Sachs

Kaleidoscope of colour

Increasingly ambitious climate goals are spurring new avenues for hydrogen production. Currently, grey hydrogen is the most common form of hydrogen. This is created from natural gas, or methane, using steam methane reformation, but without capturing the GHGs made in the process. This massively reduces its usefulness amid MENA's decarbonisation plans.

Green hydrogen
Looking ahead, green hydrogen is the most relevant type of hydrogen for long-term decarbonisation as it does not emit any CO_2 emissions. It is made by using clean electricity from surplus renewable energy sources, such as solar or wind power, to electrolyse water. Electrolysers use an electrochemical reaction to split water into its components of hydrogen and oxygen, emitting zero CO_2 in the process. While this is the ideal solution environmentally, there are some practical hurdles that governments, businesses and academia are trying to resolve. For one, green hydrogen is still a very young market – it constitutes 0.1% of global hydrogen production[3] – and as such, it is expensive to produce. As with all other hydrogen methods, solutions for safe, scalable and affordable storage and transport options also need addressing.

Blue hydrogen
Blue hydrogen is considered one of the "cleaner hydrogens", but it does emit CO_2 emissions due to its production from natural gas. It is sometimes described as low-carbon hydrogen, alongside green hydrogen, as the steam reforming process does not actually avoid the creation of GHG emissions..[4] CCUS is essential to producing blue hydrogen and helping make it "cleaner", but infrastructure is extremely limited and there are concerns over leakage in the production chain. Blue hydrogen is cheaper than green hydrogen, which means it will likely gain more momentum among investors and be the primary "clean" hydrogen in the 2020s. Green hydrogen will then likely be applied more in the late-2020s as R&D and investments make it more cost-competitive.

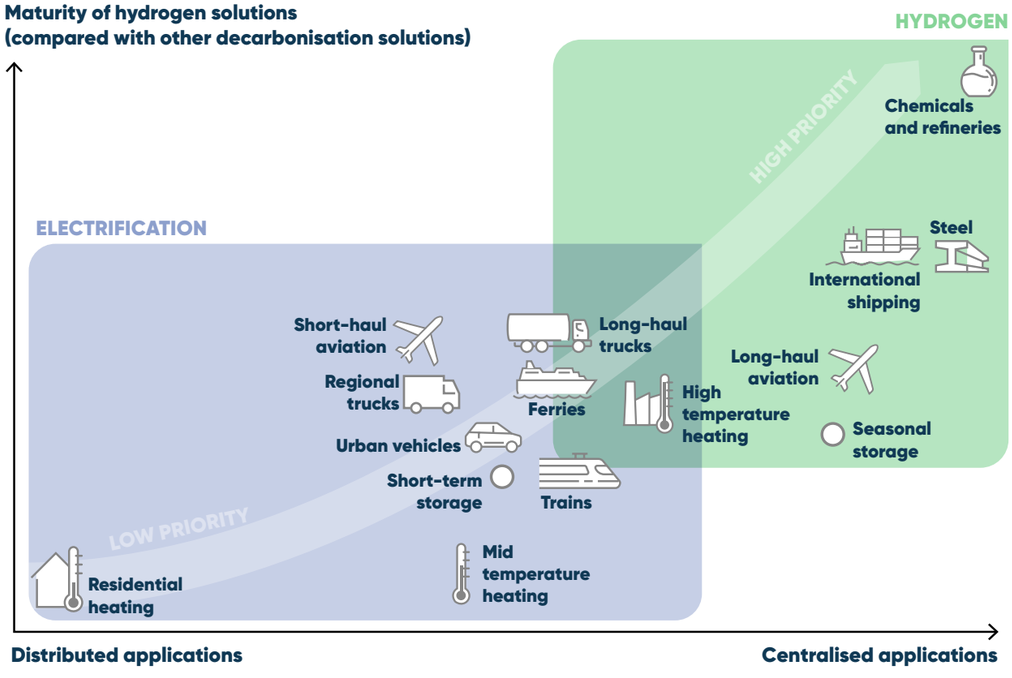
Pink hydrogen
Smaller markets of hydrogen include pink hydrogen (also known as purple or red hydrogen), which is generated via electrolysis powered by nuclear energy. The size of this market could quadruple between 2018-2028 in the Middle East alone (from a low base).[5]

Turquoise and yellow hydrogen
Turquoise hydrogen can also be made using a process called methane pyrolysis to produce hydrogen and solid carbon, while yellow hydrogen is a relatively new phrase for hydrogen made through electrolysis using solar power.

White hydrogen
White hydrogen is a naturally occurring geological hydrogen found in underground deposits and created through fracking, but there are currently no means to exploit this yet.[6]

1 Wood Mackenzie; 2 Wood Mackenzie; 3 Wood Mackenzie; 4 National Grid; 5 US Energy Information Administration (EIA); 6 National Grid.

Exhibit 2: Clean hydrogen policy priorities

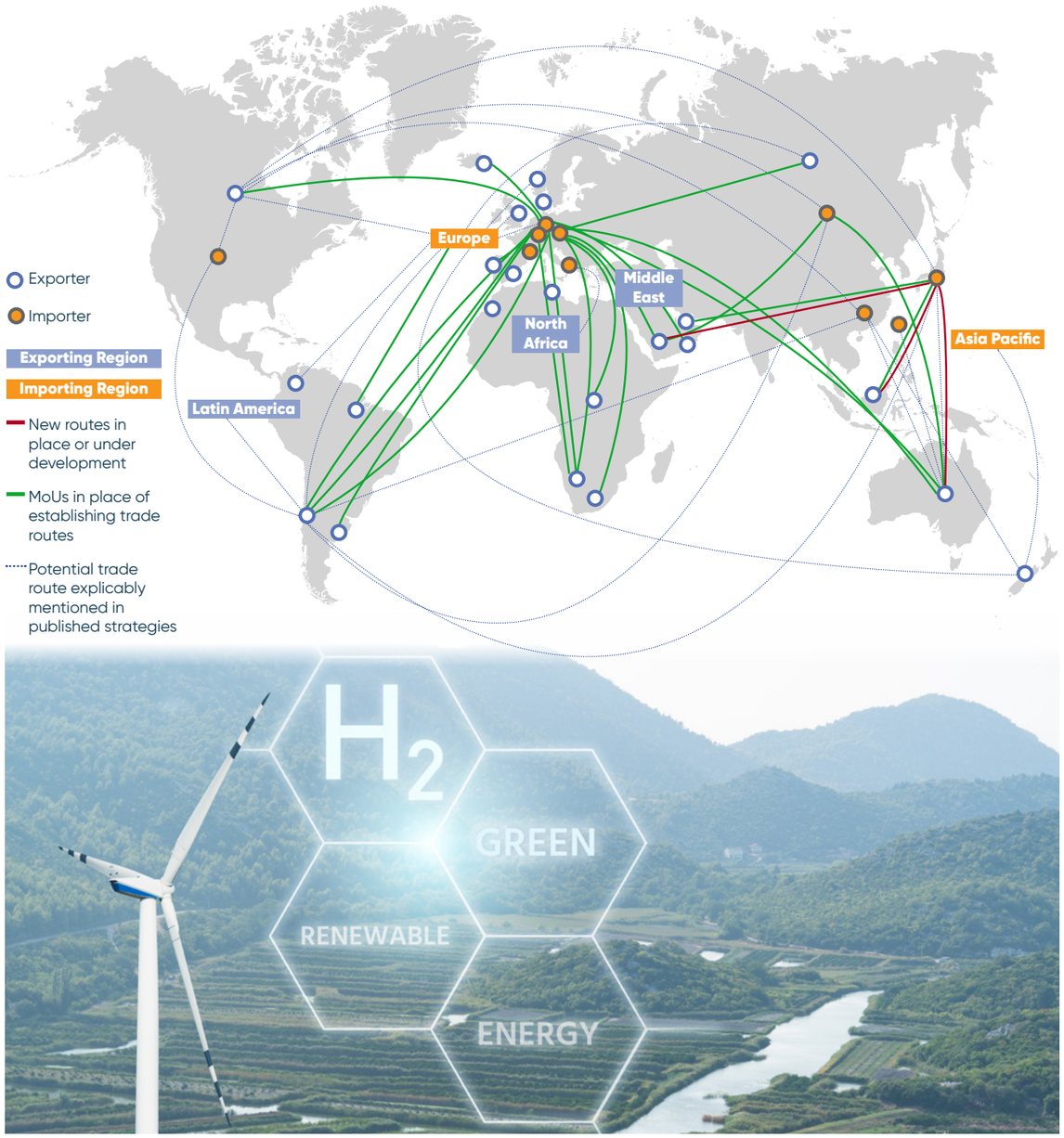


Source: Goldman Sachs

1.2 Hydrogen's Role in the Energy Transition

Clean hydrogen can be a critical relief valve in what is an extremely tall world order: meet the world's 47% rise in energy demand[1] and hit demanding climate targets, both by 2050. So far, 135 countries have committed to net zero, with 235 cities, 116 regions and 695 companies doing the same. This is out of 198 countries, 1,177 cities, 713 regions and 2,000 companies being tracked.[2] We expect to see this differentiation narrow as confidence builds that clean hydrogen can dramatically help cities, regions and companies reach their climate goals.

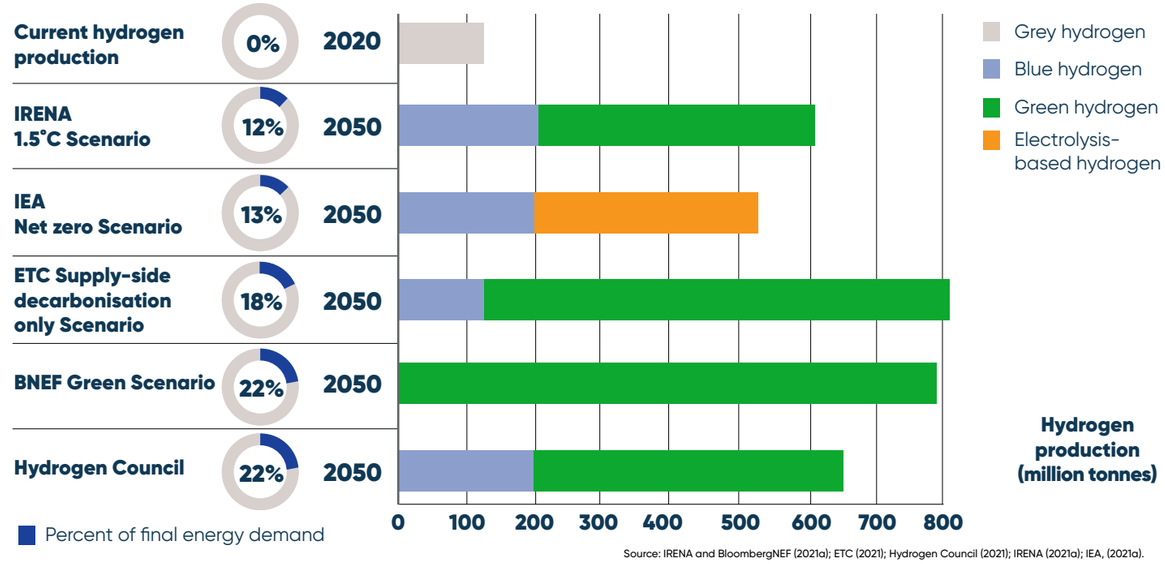
Exhibit 3: Routes, Plans, Agreements – Expanding network of hydrogen



Up, up, up

Hydrogen is already with us on an industrial scale worldwide, but current production is responsible for the annual CO_2 emissions equivalent to those of Indonesia and UK combined – nations home to approximately 340 million people.[3] Therefore, the focus is fast pivoting to the clean hydrogen market – green and blue options – and its usefulness in global decarbonisation, with the market expected to grow at a CAGR of over 14% between 2020–2026. The pipeline of new projects is growing fast. Within the next decade, global demand for green and blue hydrogen could climb by 50%. By 2030, this would translate into an annual CO_2 emissions abatement equivalent to the total volume of CO_2 emitted by UK, France and Belgium combined.[5] Overall, low carbon hydrogen has the potential to account for 20% of the world's total carbon abatement by mid-century – making it a fundamental part of reaching the 1.5°C climate scenario detailed in the Paris Agreement.[6]

Exhibit 4: Global hydrogen demand (2050)



Source: IRENA and BloombergNEF (2021a); ETC (2021); Hydrogen Council (2021); IRENA (2021a); IEA, (2021a).

Notes: The International Energy Agency refers to "fossil-based with CCUS" (carbon capture, utilisation and storage) and "electrolysis-based" hydrogen. The Hydrogen Council projects that 60-80% of hydrogen production will be renewables based, with the rest "low-carbon", which it defines as "hydrogen produced from energy sources of non-renewable origin with a carbon footprint below a defined threshold". Current hydrogen production includes hydrogen created as by-product from other processes.

Support the broader ecosystem

Building any new energy market impacts the broader ecosystem, both positively and negatively. While the positive aspects of a clean hydrogen market are well-documented, we must not forget to find solutions for the potential challenges. For example, the rise of the clean hydrogen economy could cause more than a 50% increase in global power demand and calls for 33.3% of global average installed renewable power capacity per year.[7] It also carries significant water needs, with volumes likely reaching approximately 7bcm by 2050. Meanwhile, electrolyser and fuel cell manufacturing can drive annual demand for nickel and PGMs by 5% and 18%, respectively. It will also spur a multi-fold increase for the more niche mineral iridium.[8]

1 Energy Information Administration (EIA); 2 ZeroTracker.net; 3 IEA Energy Outlook 2018; 4 Arizton Advisory and Intelligence; 5 Hydrogen Council; 6 Hydrogen Council; 7 Goldman Sachs; 8 Goldman Sachs

Main Projections: Hydrogen use by 2050 in IRENA's 1.5°C Scenario

- Hydrogen and its derivatives account for 12% of final energy use and 10% of CO_2 emissions reductions. They play a role in harder-to-decarbonise, energy-intensive sectors like steel, chemicals, long-haul transport, shipping and aviation. Hydrogen also helps balance the supply of and demand for renewable electricity and serves as long-term seasonal storage.
- Some 5,000GW of hydrogen electrolyser capacity are needed, up from just 0.3GW today.
- The electricity demand to produce hydrogen reaches close to 21,000TWh, almost the level of global electricity consumption today.
- The production of green hydrogen and its derivatives will use 30% of the total electricity demand in 2050.
- At least 66.6% of total production is green hydrogen, with the rest coming from blue hydrogen.

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1.3 Clean Hydrogen in MENA

The MENA region is one of the world's most vulnerable to the negative impact of climate change, so diversifying towards a greener energy basket is vital. Therein lies the potentially monumental role that clean hydrogen can play across the region, especially for oil-centric economies in the Arab Gulf and the less affluent economies in the region that seek better energy security. The diverse nature of geography, societal needs, government oversight, regulatory advancement and financial maturity means every country's progress within MENA – home to approximately 570 million people – will differ. But overall, the region has started its journey very well.

Exhibit 5: Map of MENA

Robust renewable growth

The MENA region has some of the largest and cheapest solar and wind projects in the world, benefitting from high solar irradiation levels, strong and regular wind (in certain areas) and large land area – all of which support the growth of a low carbon hydrogen market. For example, it is home to superlative projects, such as the world's largest solar PV plant (Al Dhafra in Abu Dhabi) and the world's largest reverse osmosis desalination plant (Taweelah in Abu Dhabi).[1] Egypt announced its Integrated Sustainable Energy Strategy 2035, which is emphasising the growth of renewable to 20% by 2022 and 42% by 2035. With this growth, Egypt is aiming to generate 61,000MW of renewable energy by 2035.[2] Further to the west in Morocco, renewables make up almost two-fifths of the country's electricity capacity, which also lays claim to some of the world's largest clean energy projects.[3] Sizeable and very competitively priced renewable energy projects are also making progress elsewhere, such as Saudi Arabia and Oman. All this progress has been recently supported by declarations by Saudi Arabia, the UAE and Bahrain that they will target net zero by 2060, 2050 and 2050, respectively.

Regional goals

Highlights in the Middle East

The MENA region has numerous growth plans and projects underway, all of which reflect countries' seriousness. Here we detail a small selection of the many developments. The world's biggest oil exporter and OPEC linchpin, Saudi Arabia, plans to be the world's biggest hydrogen exporter by 2030, exporting volumes in the neighbourhood of 4 million tonnes, the country's Energy Minister Prince Abdulaziz bin Salman al-Saud said in late-2021.[4] With about 60% ($149 billion) of the Saudi budget in 2021 derived from oil, the Kingdom needs to diversify income sources as world demand for fossil fuels shifts.[5] A large step in the Kingdom's endeavour is the development of a major green hydrogen project at its futuristic city of NEOM, which is under construction. The first shipment of green ammonia is expected in early 2026, with the $5 billion project anticipated to mark the world's largest green hydrogen project, supplying 650 tonnes per day and saving 3 million tonnes of CO_2 per year.

Fellow OPEC member, the UAE, is targeting a 25% share of the global clean hydrogen market by 2030.[6] Among the many projects across the country, Siemens Energy, the Dubai Electricity and Water Authority (DEWA) and Expo 2020 Dubai recently collaborated to establish the Middle East's first solar-powered green hydrogen plant at the Mohammed bin Rashid Al Maktoum Solar Park in Dubai.

Combined, the UAE, Saudi Arabia and Oman are set to produce 3 million tonnes per year of hydrogen in the 2030s, with Oman's 14GW Al Wusta among the world's most ambitious to date.[7] Plus, state-owned QatarEnergy (QE) signed an agreement with Shell in late-2021 to work together on blue and green hydrogen projects in the UK, and Kuwait and Iraq are working on their next steps for clean hydrogen projects.

Highlights in North Africa

In North Africa, Morocco is a first mover, creating a National Hydrogen Commission in 2019 and publishing a green hydrogen roadmap in January 2021. By 2030, the country envisages a local hydrogen market of 4TWh and an export market of 10TWh, which, taken together, would require the construction of 6GW of new renewable capacity and support the creation of more than 15,000 direct and indirect jobs.[8] The latter is notable considering MENA has one of the world's highest rates of unemployed youth, causing economic and societal strain.

The Egyptian government is planning to announce its $40 billion hydrogen strategy before June 2022, which will include plans for a production capacity of 1.4GW by 2030. The government of Egypt and the Suez Canal Economic Zone (SCZone) are also currently reviewing offers for green hydrogen projects in the SCZone, with the host country of COP27 *(See page 18: Preparations for COP27 in Egypt)* expected to announce a collection of hydrogen projects during the global climate gathering this November.[9] Meanwhile, the Ministry of Energy and Mineral Resources has embarked on a strategy to enable Jordan, technically and legislatively, to produce green hydrogen from its growing renewable energy portfolio.[10]

Feeding intensifying demand

The MENA region's expanding population only emphasises the need for a clean hydrogen economy – it will be decisive to meeting rising energy needs without rising CO_2 emissions. Between 2025-2030, the populations of Iraq, Bahrain and the State of Palestine will grow by almost 50%, while countries like Sudan, Syria and Oman are expected to see increases of approximately 40%. Egypt will experience the largest population increase in absolute terms, with 60 million more people between 2015-2050, followed by Iraq with 45 million and Sudan with 42 million more people. Plus, children and young people (0–24-year-olds) already account for nearly half of MENA's population, a demographic which tends to have higher energy needs and expectations.[11] Overall, the region's population could reach 724 million people by 2050[12] – a 27% growth on today.

1 Clifford Chance; 2 Mordor Intelligence; 3 BBC; 4 Reuters; 5 Financial Times; 6 S&P Global Platts; 7 S&P Global Platts Analytics; 8 IRENA; 9 Energy and Utilities; 10 Jordan Times; 11 UNICEF; 12 Statista

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Section 2:
Market Growth of Clean Hydrogen in MENA

2.1 Growth Areas for Hydrogen

Part of clean hydrogen's great appeal is its potential to be applied across many, many industries. Five applications are most prominent. One is to replace existing feedstock. For example, 38.2 million tonnes of hydrogen were used for oil refining in 2018 and in steel making *(see below: In Focus)*. Clean hydrogen can also be used to help decarbonise residential and central heating systems (though this is less relevant to swathes of MENA). Crucially, hydrogen is also a much-needed route for energy storage. Clarifying storage options remains a major hurdle, but some studies suggest that it would make financial sense to use green hydrogen for energy storage applications with a duration of 13 hours or more, using today's technology.[1] Using it as an alternative fuel and in fuel cell vehicles is also being explored *(see opposite: Fuel evolution)*.

In Focus: Iron and steel industries

Collectively, these are responsible for about 9% of anthropogenic CO_2 emissions worldwide, due to the massive use of coal. Producing one tonne of steel releases about 1.85 tonnes of CO_2 emissions into the atmosphere. Replacing coal by hydrogen generated with renewable energy – like green hydrogen – would help spur decarbonisation in these hard-to-reach industries. The switch will not happen overnight. Producing the necessary amounts of hydrogen for a full decarbonisation of the steel industry would require an increase in electricity production in the order of 20%, thus requiring an even more determined expansion of renewable production, going beyond the replacement of current fossil electricity generation. Therein lies an advantage for MENA, home to well-established and world-leading renewable energy projects, plus many more in the pipeline.

Source: Europa

Fuel evolution

Road transport

FCEVs are powered by hydrogen. They are more efficient than conventional internal combustion engine vehicles and produce no tailpipe emissions – they only emit water vapour and warm air. Similar to conventional internal combustion engine vehicles, they can fuel in less than four minutes and have a driving range over 300 miles. FCEVs and the hydrogen infrastructure to fuel them are in the early stages of implementation.[2] Some estimates expect the market to be worth $46.89 billion by 2028, registering a CAGR of 68.52% during the forecast period (2021 - 2028).[3] Interest in MENA is also growing. For example, Hyzon Motors announced plans last year to build an assembly plant in Saudi Arabia's NEOM city, which will have an annual capacity for the assembly of up to 10,000 fuel cell commercial vehicles.[4] One estimate expects an immediate market for 25,000 forklift trucks and other material-handling fuel-cell vehicles in the US, compared to just 7,600 hydrogen-powered cars on the road – a trend likely echoed in MENA over the coming decade.[5]

Aviation

Technological improvements allow aircraft flying today to be up to 80% more fuel efficient compared to 60 years ago. However, further reductions are becoming more and more challenging. The efficiency of flight has increased considerably, but moving large numbers of passengers (100-400) at a high speed, over a large distance, will always require significant energy.[6] Liquid hydrogen's properties could play a transformative role in aviation's decarbonisation. In its liquid form, it contains about 2.5 times more energy per kilogram than kerosene, which means planes can travel more lightly or they can carry heavier loads to make fewer trips. When burning, hydrogen only produces water vapour as a by-product, since the fuel has no carbon content to start with. Hydrogen combustion also produces up to 90% less nitrogen oxides than kerosene fuel and it eliminates the formation of particulate matter.[7] This is highly relevant for MENA, which has an established flight network. The GCC is also home to some of the world's biggest airlines and Dubai Airport regularly tops the list of hosting the greatest throughput of international passenger traffic. Companies are increasingly responding to this growing economic and social opportunity, including Siemens, TotalEnergies and Abu Dhabi's Masdar's agreement for a demonstrator plant in Masdar City to produce SAF from green hydrogen.[8]

Shipping

Shipping is a critical link to globalisation, with 90% of the world's trade carried on water. Accordingly, total global bunker demand could increase from about 300 million tonnes today to reach at least 400 million tonnes by 2050. One of the most promising candidates to meeting this demand while reducing CO_2 emissions is liquid ammonia.[9] It is far easier to transport and store than pure hydrogen, it can slot into existing infrastructure and as an existing market, it is easier to scale up to help reach bunkering demand. This is particularly noteworthy if you consider that if just 30% of shipping switched to ammonia as a bunker fuel, then the current production – 80% of which is used in the fertiliser industry – would have to nearly double.[10] Accordingly, the Abu Dhabi National Oil Company (ADNOC) is conducting a joint study agreement with Japanese companies – INPEX Corporation (INPEX), JERA Co., Inc. (JERA), and a government agency, the Japan Oil, Gas and Metals National Corporation (JOGMEC) – to explore the commercial potential of blue ammonia production in the UAE. In Morocco, plans for a new green ammonia project have been revealed, with production estimated to reach 183,000 tonnes per year by 2026 – potentially the country's largest green ammonia and green hydrogen project. The Hevo Ammonia Morocco project is being developed by Ireland-based green hydrogen technology company Fusion Fuel and Middle Eastern construction company Consolidated Contractors.[11]

Prioritise safety

As with all fuels, testing and modelling needs to be fine-tuned to hydrogen's unique properties and safety considerations. For example, hydrogen operators must be alert to the fact that working with natural gas [in pipelines, for example] can be very useful for starting hydrogen operations in shipping, but there are vital differences. For one, hydrogen requires certain types of steel and welded connections, rather than fittings.[13]

1 Green Tech Media, National Renewable Energy Laboratory (NREL); 2 US Department of Energy; 3 Market Research Future; 4 Electrive; 5 McKinsey; 6 International Air Transport Association (IATA); 7 IATA; 8 H2View; 9 TotalEnergies, Jérôme Leprince-Ringuet, Vice President, Marine Fuels; 10 LR; 11 Argus Media; 12 DNV; 13 DNV

2.2 Key Alliances – Regional and International

Alliances abound within MENA and between MENA and other regions, notably Europe and Asia – both eager hydrogen importers. Europe will have to import 50% of its hydrogen needs in the next few years, for example. And Germany may need to import 75% of its demand – therein lies the need for collaborations with budding exporters in MENA.[1] Building a R&D and import-export network has been a clear goal of countries in MENA that are advancing their hydrogen agendas, especially Saudi Arabia, the UAE, Oman, Egypt and Morocco. Knowledge sharing has certainly climbed to the top of the list of priorities *(see page 17: Knowledge Sharing)* and within that, many partnerships, MoUs and deals have been secured. Here is a small selection of examples to reflect the flurry of activity across MENA in the last year.

Highlights in the Middle East

In the UAE, Masdar and French multinational utility company ENGIE have agreed to study the development of a globally cost-competitive green hydrogen facility, which could be operational by 2025 with capacity of up to 200MW to supply Fertiglobe's ammonia production plants at Ruwais in Abu Dhabi. This follows a strategic alliance between the two in late-2021 to explore the co-development of a UAE-based green hydrogen hub. The two companies are looking to develop projects with a capacity of at least 2GW by 2030, with total investment in the region of $5 billion.[2]

This all builds on the gathering of expertise in a deal between Mubadala Investment Company (Mubadala), ADNOC and ADQ last year to establish the Abu Dhabi Hydrogen Alliance. The Alliance partners will collaborate with the intention of establishing Abu Dhabi as a leader of green and blue hydrogen in emerging international markets.[3] In the UAE, ADNOC is also keen to explore hydrogen market with India's public and private sectors as the country, home to 1.3 billion people, plans how to meet its soaring energy demand while hitting its net zero goal by 2070.[4]

Plus, ADNOC recently signed a MoU and joint study agreement with counterparts in Germany to accelerate collaboration in clean hydrogen. The German government's National Hydrogen Strategy expects clean hydrogen demand of up to three million tonnes per annum by 2030, of which around 60% is anticipated to be imported. Demand may also grow to over 11 million tonnes per annum by 2050. The German-based energy company Uniper is joining Oman's Hyport Duqm renewable hydrogen project to provide engineering services and negotiate an exclusive offtake agreement for green ammonia from the facility. Saudi Arabia and Germany are also planning on working together.

Deepening Asian alliances mean Saudi Arabia and South Korea have agreed to work together in developing the hydrogen economy. The Kingdom's Public Investment Fund (PIF) recently signed a tripartite MoU with South Korean steelmaker POSCO and contractor Samsung C&T to develop an export-oriented green hydrogen project in the Kingdom.[5]

Highlights in North Africa

Egypt has signed a MoU for a $5 billion project with Norway's Scatec to build its first green ammonia plant in the Suez Canal Economic Zone (SCZone). The green ammonia plant near the Red Sea port and industrial zone of Ain Sokhna would have production capacity of one million tonnes annually with the potential to expand to three million tonnes.[6] Siemens Energy has also signed a MoU with the Egyptian Electricity Holding Company to jointly develop hydrogen-based industry in the country, which will have export capabilities.

Jordan and Fortescue Future Industries (FFI) are partnering to conduct studies with a view to developing green hydrogen production through potential large-scale wind and solar energy production facilities.[7] Meanwhile, Morocco's Ministry of Energy, Mines and Environment (MEME) has agreed to work closely with the International Renewable Energy Agency (IRENA) to accelerate the energy transition, specifically advancing the country's green hydrogen economy.

1 S&P Global Platts; 2 Masdar; 3 Clifford Chance; 4 Gulf Business; 5 Zawya; 6 Reuters; 7 Solar Quarter

Section 3:
Focus Areas for Clean Hydrogen in MENA

3.1 Securing Competitive Price Points

As a new market, forecasts vary as to when clean hydrogen will become competitive with grey hydrogen and fossil fuel markets. The consensus in recent years was that this point would be reached by the late-2020s. But rapid momentum to support clean hydrogen across MENA and worldwide appears to be accelerating this trajectory.

Some anticipate that green hydrogen will become cost-competitive with grey hydrogen within two years. This would see the cost of green hydrogen fall from $3.70/kg today to just over $1/kg in 2035 and around $0.75/kg by mid-century.[1] We witnessed this switch when the recent spike in European natural gas prices meant that green hydrogen was cheaper to produce than highly polluting grey hydrogen.[2] While blue hydrogen is cheaper today than green hydrogen, the situation should reverse by 2030 in the vast majority of countries,[3] including those with cheap gas (such as some Middle Eastern nations). However, price forecasts for this emerging energy market are likely to shift and should be considered as an approximate guide only.

Outlook for electrolysers

Electrolyser costs are declining due to economies of scale, new entrants to the market, greater automation and increased modularity. Reductions for solid oxide electrolysers are set to be the most dramatic in the next 6-8 years, with alkaline and PEM costs likely to slide by 35-50% by 2025.[4] The MENA region will have to strategise how to develop its own facilities and alliances with those already playing a leading role, such as China, in order to remain competitive in this fast-growing market. Electrolyser manufacturers delivered 458MW in 2021, which could at least quadruple in 2022, to between 1.8-2.5GW. China will account for up to 66% of total demand.[5]

1 Rethink Energy; 2 Recharge; 3 BloombergNEF; 4 Wood Mackenzie; 5 BloombergNEF

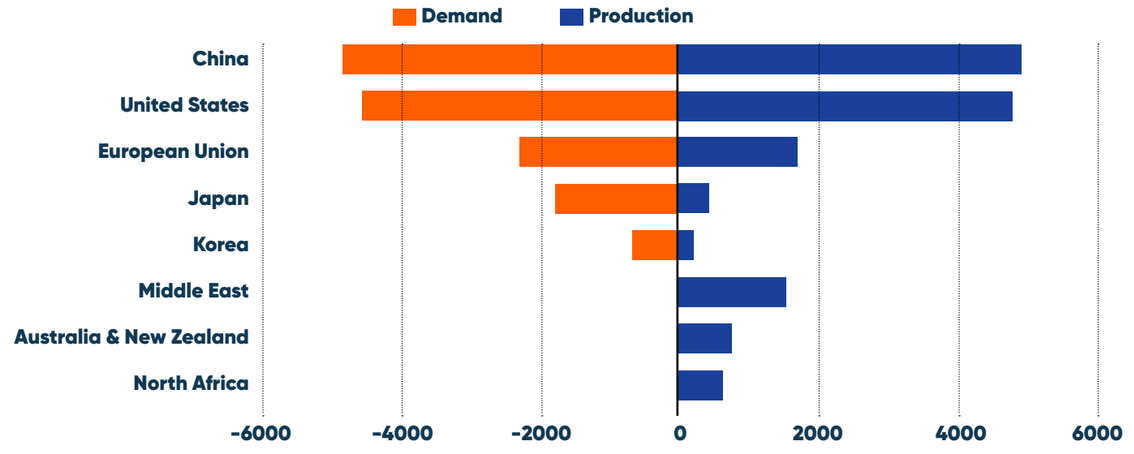
3.2 Overview of Transport Infrastructure

Hydrogen is the lightest element on earth, which affects how it is transported. For example, the mass of one gallon of gasoline is approximately 2.75kg where one gallon of hydrogen has a mass of only 0.00075kg. Therefore, it must be either pressurised and delivered as a compressed gas, or liquefied, in order to be transported at volume.[1]

Much needs to be considered across MENA, including plans to repurpose existing pipeline infrastructure in the long-term, similar to Europe's plans to change 40,000km of natural gas pipelines for hydrogen use by 2040. While MENA has well-established pipeline infrastructure, much of it is fragmented. A similar challenge lies in identifying transport routes for varying destination points: urban versus cross-border versus rural. Investing more efforts to unite primary pipeline and distribution connection points – including those that can support Europe's import demand – is a cornerstone of making a clean hydrogen economy a reality in MENA. The same attention is needed when examining the validity of shipping hydrogen. Some analysts argue it makes more economic sense to ship ammonia (NH3), a hydrogen derivative.[2] Ammonia is a more proven technology within existing supply chains (current global production is 176 million tonnes per year[3]) and it has greater energy density than pure hydrogen.[4] Some MENA countries are actively exploring this route. In September 2020, state-owned Saudi Aramco exported the world's first shipment of carbon neutral ammonia to Japan, with the 40-tonne delivery helping deepen both nations' import-export ambitions.

Whatever the means, up to 30% of global hydrogen volumes have the potential to be involved in cross-border transport – a higher percentage that today's highly profitable and influential market for natural gas. MENA, Latin America, Australia and Iberia could emerge as key clean hydrogen exporting regions, while Central Europe, Japan, Korea and parts of Eastern China are earmarked as leading importing regions.[5]

Exhibit 6: Demand – Production dynamic based on announced pledges (2050)



Source: International Energy Agency (IEA)

Location matters

Where hydrogen is produced can have a huge impact on the cost and best method of delivery. For example, a large, centrally located hydrogen production facility can produce hydrogen at a lower cost because it is producing more, but it costs more to deliver the hydrogen because the point of use is farther away. Comparatively, distributed production facilities produce hydrogen on site so delivery costs are relatively low, but the cost to produce the hydrogen is likely to be higher because production volumes are less.[6] Accordingly, the chosen transport model for hydrogen must be a holistic decision for countries in MENA.

Today's expensive means of transporting hydrogen needs to become more cost-efficient, while boosting hydrogen purity and significantly minimising hydrogen leakages is imperative. Of course, safety is the biggest priority. Testing and modelling needs to be finetuned to hydrogen's unique properties. For example, there are uncertainties about the behaviour of cryogenic hydrogen, as well as thresholds, when detonations occur.[7]

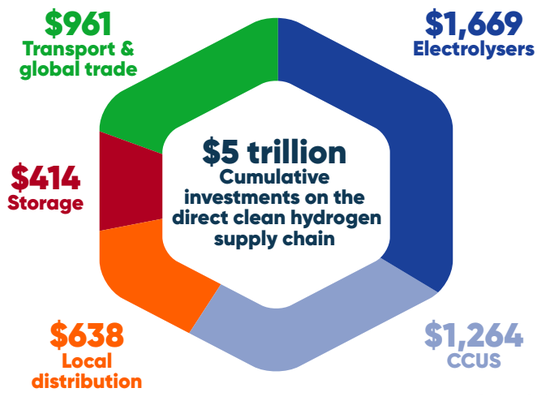
1 US, Office of Energy Efficiency & Renewable Energy; 2 Recharge; 3 UK's Royal Society; 4 Wood Mackenzie, Recharge; 5 Goldman Sachs; 6 US, Office of Energy Efficiency & Renewable Energy; 7 DNV

3.3 Establishing Financing Ecosystems

Building a financial ecosystem for the $174 billion global hydrogen market[1] echoes the economic steps taken to achieve solar and wind power generation markets – just far faster. As with those markets, public and private financial instruments and grants will help underpin innovation and early-stage development[2] – both vital in whetting investors' appetite in MENA and worldwide. Other instruments like equity participation can also allow venture capitalists to play a leading role by investing in early-stage companies with high growth potential.

Plans to introduce subsidies must be carefully managed as the region is home to many nations that have long subsidised energy and commodity products (especially oil, gas and water). Several of these nations have been rolling back on these expensive programmes that often burden national treasuries – a financial and social loss more acutely felt amid volatile oil prices and climate targets. While subsidies would provide a foundation of support for budding clean hydrogen markets and encourage energy investors – both existing and prospective – they should be implemented with a clear exit strategy in mind.

Exhibit 7: Investment Outlook: $5 trillion required in the global clean hydrogen supply chain to reach net zero



Goldman Sachs

Green debt builds

Debt is an integral part of building an ecosystem at scale, both in MENA and globally. Greater maturity in green debt will increasingly feed into making sizeable debt packages specifically for clean hydrogen more common. Overall, green and sustainable debt issuance in MENA hit $18 billion in 2021, climbing by 122% year-on-year.[2] While this is a relatively small compared to global volumes – $1.62 trillion in 2021, up from $765 billion in 2020[3] – it is extremely meaningful for a region which has only recently entered the sphere of green financing.

Other landmark deals for green financing in 2021 included Egypt's debut $3 billion green loan, Abu Dhabi's Etihad Airways' $1.2 billion sustainability-linked loan and Masdar Abu Dhabi Future Energy Company's $100 million revolving green loan. Egypt's decision to be the first sovereign in the region to issue a green bond in September 2020 helped trigger this strong tide of green financings. The $750 million, five-year deal was significantly oversubscribed[4] – a welcome sign for other nations keen to do the same. Proceeds from the debt sale will be used to finance or refinance green projects in sectors such as transportation, renewable energy and energy efficiency.

Putting a price on carbon

There are mixed views on the impact pricing CO_2 emissions can have on quickening the growth of a clean hydrogen market. Some say carbon pricing is instrumental to generating the high financial sums required up to 2050 to build a global clean hydrogen economy and that all financial stakeholders need visible goalposts for their planning and implementation, especially as carbon prices above $100 per tonne are anticipated. With only 65 carbon pricing initiatives worldwide so far – covering 21.5% of global emissions in 2021 – there is much work to do.[5] Others argue that while carbon pricing is very relevant, countries and corporates' net zero targets will more effectively drive clean hydrogen demand this year. Hydrogen projects will be built to show compliance with emission reduction targets, with assumed low carbon prices and free allocations denting the effectiveness of carbon pricing schemes.[6]

1 IRENA; 2 H2View, Société Générale; 3 Zawya, Bloomberg's Capital Markets League Tables; 4 Reuters; 5 World Bank; 6 BloombergNEF

3.4 Focus on Knowledge Sharing

The gargantuan undertaking of crafting a hydrogen economy in MENA cannot fall to one company nor one country – there are simply not enough decades left to mitigate the worst effects of climate change. This means ideas and innovations must be funnelled into addressing the many multifaceted challenges. More tangible progress is urgently needed. This can come in many forms: more pilot projects and more advancements in transport and storage solutions, for example. Creating and implementing these solutions requires more collaborative spirit than ever.

On the rise

In early 2020, Dii launched the MENA Hydrogen Alliance, which brings together private and public sector actors as well as science and academia to kick-start green hydrogen economies. In late-2020, many of the world's green hydrogen leaders united under the Green Hydrogen Catapult Initiative to cut costs below $2 per kilogram, to transform energy across most carbon-intensive industries and ultimately accelerate the race to zero emissions. One year later, in November 2021, the initiative announced a commitment for 45GW of electrolysers will be developed with secured financing by 2026 and targeted commissioning in 2027. This is nearly double the initial target (25GW). The founding partners include Saudi Arabia's ACWA Power.[1]

Among the many other global initiatives worldwide, the World Economic Forum (WEF) has launched the Accelerating Clean Hydrogen Initiative as part of its Climate Action Platform. It has been a longstanding supporter of the clean hydrogen agenda since 2017, having supported the Hydrogen Council and the establishment of a hydrogen Innovation Challenge in partnership with Mission Innovation. It also helped create the Mission Possible platform to help transition hard-to-abate sectors to net zero emissions by 2050.[2] The Hydrogen Council also works proactively in this space, with the global CEO-led coalition now consisting of 134 companies from across the globe, representing the entire hydrogen value chain.[3]

President Biden announced the launch of the First Movers Coalition in late-2021 as a platform for companies to harness their purchasing power and supply chains to create early markets for innovative clean energy technologies. Clean hydrogen is a focus, with more than 25 large companies as founding members, including Amazon, Boeing, Fortescue, Volvo, AP Moller-Maersk and Vattenfall.[4]

H2Zero was also launched late last year with 28 companies in sectors including mining, energy, vehicle and equipment manufacturers and financial services. Pledges across three categories relating to hydrogen were made: demand, supply and financial or technical support. Demand-side pledges focused on replacing grey hydrogen with green or blue hydrogen, with the potential to reduce CO_2 emissions by more than 14 million tonnes per year. On the supply side, the pledges added up to more than 18 million tonnes per year of lower carbon hydrogen, which could help the world avoid around 190 million tonnes of CO_2 emissions annually.[5]

1 UNFCCC; 2 World Economic Forum (WEF); 3 Hydrogen Council; 4 Baker Botts; 5 Baker Botts

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Section 4: Conclusion

4.1 Impact of Macro Economic Outlook

Treasuries and boardrooms across the globe remain on tenterhooks due to the ongoing nature of the COVID-19 pandemic, but some have undoubtedly fared better than others. Generally, MENA has a positive outlook with real GDP growth at 5.2% in 2022 and 4.6% in 2023.[1] High vaccination rates in parts of the region particularly buoyed investors' confidence in 2020 and 2021, with the robust momentum flowing into 2022.

This was especially clear in the GCC – the UAE was regularly reported as having the best rate of vaccinations worldwide[2] – with their proactivity expected to underpin average non-oil real GDP growth of approximately 3% this year.[3] A gradual recovery in tourism is also anticipated, directly accounting for up to 10% of GDP across MENA's non-oil economies.[4] Plus, investing in climate-resilient technology, such as clean hydrogen, has been flagged as a key step for continually bolstering the MENA's economic stability.[5]

An uptick in net zero commitments by governments and leading corporates has only intensified during the pandemic, which certainly helps energy investors, and those new to the energy sphere, feel more comfortable supporting both traditional and renewable energy growth. While it may seem counterintuitive at this stage, both are deeply intertwined in the success of reaching climate goals.

Impact of hydrocarbons

A significant reduction in oil and gas funding in recent years is hitting energy companies' budget and, *in extremis* their willingness to explore and support greener energy markets, like clean hydrogen. Upstream investments in oil and gas in 2021 were depressed for a second consecutive year at $341bn – nearly 25% below 2019 levels.[6] Such is the squeeze that Saudi Arabia's Oil Minister, Prince Abdulaziz bin Salman al-Saud, warned last December that global oil production could plummet by 30% by 2030.[7] More than half (56%) of the 500 respondents to a survey at Gulf Intelligence's UAE Energy Forum in January this year agreed. Plus, traditional energy companies' investment profiles will be affected by the fact that half of the world's fossil fuel assets could be worthless by 2036 under a net zero transition[8] – a paradigm shift which could represent hundreds of billions of lost capital.

Hydrogen growth: Fossil fuel plays a crucial role

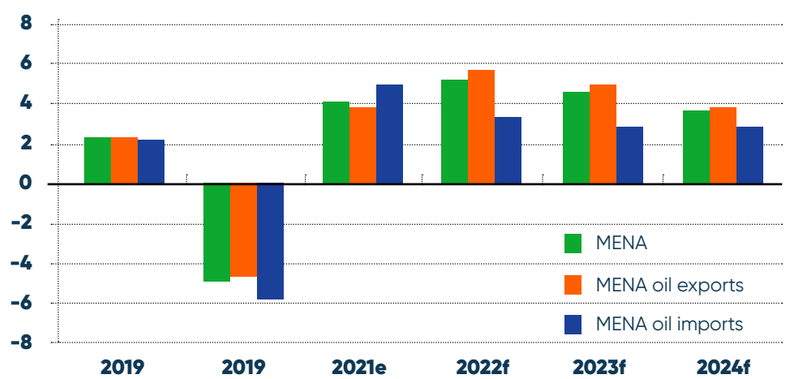
The International Energy Agency's (IEA) recent global roadmap to net zero by 2050 shows the world's demand for oil will need to decline from more than 90 million barrels a day to less than 25 million by 2050. This would result in a 75% plunge in net revenues for oil-producing economies, many of which are dominated by a public sector that relies on oil exports and the revenues they produce. An energy transition that fails to engage with fossil fuel-producing countries and their needs could have profound implications for regional and international security and the stability of global energy markets. If oil revenues start to decline before producer countries have successfully diversified their economies, livelihoods will be lost and poverty rates will increase. In a region with one of the youngest and fastest growing populations in the world, economic hardship and increasing unemployment risk creating broader unrest and instability.

Source: Ali Allawi, Deputy Prime Minister & Minister of Finance - Republic of Iraq and Dr Fatih Birol, Executive Director, International Energy Agency (IEA); first published in The Guardian.

Positive outlook

Investments in the energy transition – and this includes transitioning oil and gas – reached a record high of $755 billion in 2022.[9] This was up on the $595 billion in 2020, marking a 27% year-on-year climb. Plus, $160 billion of investment up to 2050 was pledged by the UAE last December to hasten renewable energy development, as part of its net zero target by mid-century – the first country in MENA to set such a climate goal.

Exhibit 8: MENA – Real GDP growth percentage (2019-2024)



Source: IHS Markit

1 IHS Markit; 2 FT Covid-19 Tracker; 3 Fitch; 4 Fitch; 5 International Monetary Fund (IMF); 6 International Energy Forum (IEF), IHS Markit; 7 Reuters; 8 Nature Journal; 9 BloombergNEF

4.2 Preparation for COP27 in Egypt

The next UNFCCC's Conference of Parties, also known as COP, will be the 27th such annual event. This year, it will be held in Egypt's coastal city of Sharm el-Sheikh from the 7th – 18th November. Next year's event, COP28, will be held in the UAE, which gives the MENA a unique global climate platform for two consecutive years. How the world views climate has dramatically changed in the last seven years, since the Paris Agreement was signed during the COP in the French capital in 2015. The political, financial and social influence driving COPs and the progress achieved during the event has mushroomed nearly beyond recognition since the inaugural event in Berlin in 1995.

Pinning down strategies

The number of countries with a hydrogen strategy doubled in 2021, to 26 nations. This figure could nearly double again this year, reaching 48 by COP in November.[1] We must also consider how evolving hydrogen strategies from the world's economic behemoths (the US, China and India in particular) will impact other countries' goals and rate of change in the lead up to Egypt's hosting. Attention is also greatly focused on progress reports from some of the world's biggest hydrogen projects in the MENA – notably Egypt, Saudi Arabia, the UAE and Oman *(see below: Breakthrough Agenda)*. The same applies to developments on carbon pricing mechanisms – a deeply important yet complex piece of the puzzle to building a global clean hydrogen economy by 2030.

We expect to see solutions for transporting hydrogen develop by COP27, as this will be a prime focus area of the global conference – without affordable transport, aspirations for a global clean hydrogen market cannot flourish. It is likely that ammonia, which helps companies transport large volumes of green molecules across borders, will support growth until hydrogen pipelines become more viable, for example.[2] With an established supply chain, shipping ammonia is already a far easier option.

1 BloombergNEF; 2 BloombergNEF

In Focus: Breakthrough Agenda

One of the few hydrogen-specific actions to come out of COP26 was in a plan called the Breakthrough Agenda, launched by UK Prime Minister Boris Johnson at the beginning of the talks in November 2021. It was backed by 42 world leaders, including the US, India and China, whose countries collectively represent 70% of global GDP. The Agenda called to make affordable renewable and low-carbon hydrogen globally available by 2030.[1] Three of the signatories are in MENA: Egypt, Morocco and the UAE.

Q4 2021: Breakthrough Agenda was launched at COP26, including the Glasgow Breakthroughs.

Q1 2022 to Q2 2022: Report on the State of Transition due. Analysis of progress against the objectives and the opportunities for and benefits from enhanced cooperation; led by the IEA with IRENA and HLAC and broader engagement.

Q1 2022 to Q2 2022: Convene leading initiatives in each sector, including clean hydrogen. Exploring better coordination, gaps and enhanced actions to achieve each Breakthrough goal; informing and being informed by the draft State of Transition Report.

Q3 2022: State of the Transition Ministerial. Ministers meet alongside MI & CEM Ministerials to discuss the State of the Transition report's findings and review and agree proposals for enhanced collaborative action, including on clean hydrogen.

Q4 2022: New leaders-level commitments. New and enhanced commitments from existing and new participating countries, for enhanced ambition and action and for new sectoral Breakthroughs, including clean hydrogen. The process is then replicated in subsequent years.

1 Wood, UNFCCC; 2 UNFCCC

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4.3 Key Expectations in 2022

Intensifying excitement surrounding the growth of clean hydrogen across MENA means hopes for extraordinary developments this year are high. This shines an increasingly bright spotlight on the market's potential, as well as the areas that must be improved to achieve ambitious goals. But it is also somewhat risky, in that deflating overly high hopes can dash appetite in government, business, academia and the public – potentially curbing positive momentum in 2023.

Therefore, it is paramount that all stakeholders tread a line of both optimism and realism this year. Clean hydrogen can transform the way the world operates by mid-century, welcoming a new era of greener energy that protects plants, people and profit. But getting there is a marathon, not a sprint: stakeholders in the MENA cannot safely gallop from a standing start.

We must all keep innovatively pushing to achieve this great change, leveraging our centuries of collective experience in energy markets to overcome hurdles. Ultimately, what we do in the next decade will help tens of billions of people live a better life this century, not to mention the wildlife and natural ecosystems of our planet. But we must get these first steps right.

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