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The H_2 Handbook

Legal, Regulatory, Policy, and Commercial Issues Impacting the Future of Hydrogen

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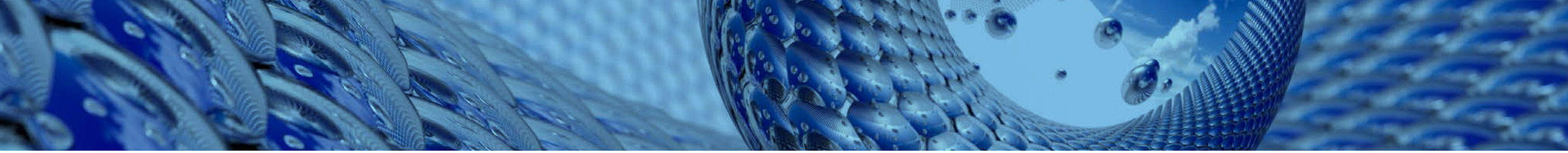


PART I -
MENA AND THE EMERGING HYDROGEN ECONOMY

I. MENA and the GCC

The Middle East and North Africa region (MENA) stretches from Morocco in the far northwest of Africa to Iran in the Middle East. The core MENA states are reflected in Figure 1 below, but MENA can also be said to include other countries such as Sudan and Djibouti in Africa, as well as Turkey and Azerbaijan in the Caucasus.

Figure 1.

The major financial powerhouses of MENA are the oil- and gas-rich countries of the Arabian Peninsula: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates (UAE). In 1981, the leaders of these six nations established the Cooperation Council for the Arab States of the Gulf (GCC). The purpose of the GCC was to establish a cooperative framework, which would allow coordination, cooperation, and integration between the member states in all fields.

II. The Emerging Hydrogen Economy

A. An International Trend Toward Clean Energy

In 2015, 196 nations—all of whom are party to the United Nations Framework Convention on Climate Change (UNFCCC)—entered into the Paris Agreement; a milestone marking the development of a cohesive, international approach to address climate change. The Paris Agreement is a legally binding international treaty on climate change, signifying the arrival of a global, government-led approach to mitigate climate change, limit global warming, and to realize net-zero greenhouse gas (GHG) emissions by 2050.

Across governments and industry, there is a developing awareness that the emerging hydrogen economy could be vital to efforts to reduce emissions, decarbonize key industrial sectors, and satisfy the Paris Agreement. Governments and corporations (both public and private) are investing in hydrogen, researching its potential as a clean energy fuel that could be central to a global energy transition, and moving away from hydrocarbons and towards clean, net-zero emission fuels. U.S. President Joe Biden has pledged to set the United States on the path to becoming a clean energy economy with net-zero emissions by the year 2050, which would require a huge shift away from hydrocarbon energy sources.

The World Bank estimates that the MENA region contributes approximately 7 percent of the world's total carbon dioxide

emissions, with the GCC countries among the world's top ten polluters per capita.[1] Furthermore, the economies of MENA countries, specifically those in the GCC, are heavily reliant on the export of oil and gas, meaning they risk exposure to any substantial reduction in the global demand for hydrocarbons.

However, the international shift towards green energy presents an opportunity for countries across MENA, especially given the abundance of solar energy across the region, which can be used to produce green energy fuels such as hydrogen. Governments across MENA are therefore well placed to be at the forefront of the international trend towards decarbonization and to develop the infrastructure to compete in future sustainable energy markets.

Hydrogen is likely to be a critical part of the energy mix as the world strives to decarbonize, meaning there will be a rapid increase in global demand between 2021 and 2050. Key net importers of green hydrogen will be markets in Asia and North America, as well as Europe. While European states push ahead with hydrogen initiatives, it is recognized that domestic European production would not be sufficient to decarbonize hard-to-abate industries in the short term or for European nations to achieve their emission targets under the Paris Agreement. Clean fuels such as hydrogen are expected to displace around 10.4 billion barrels of oil (or its equivalent) by 2050, which represents 37 percent of global oil production.

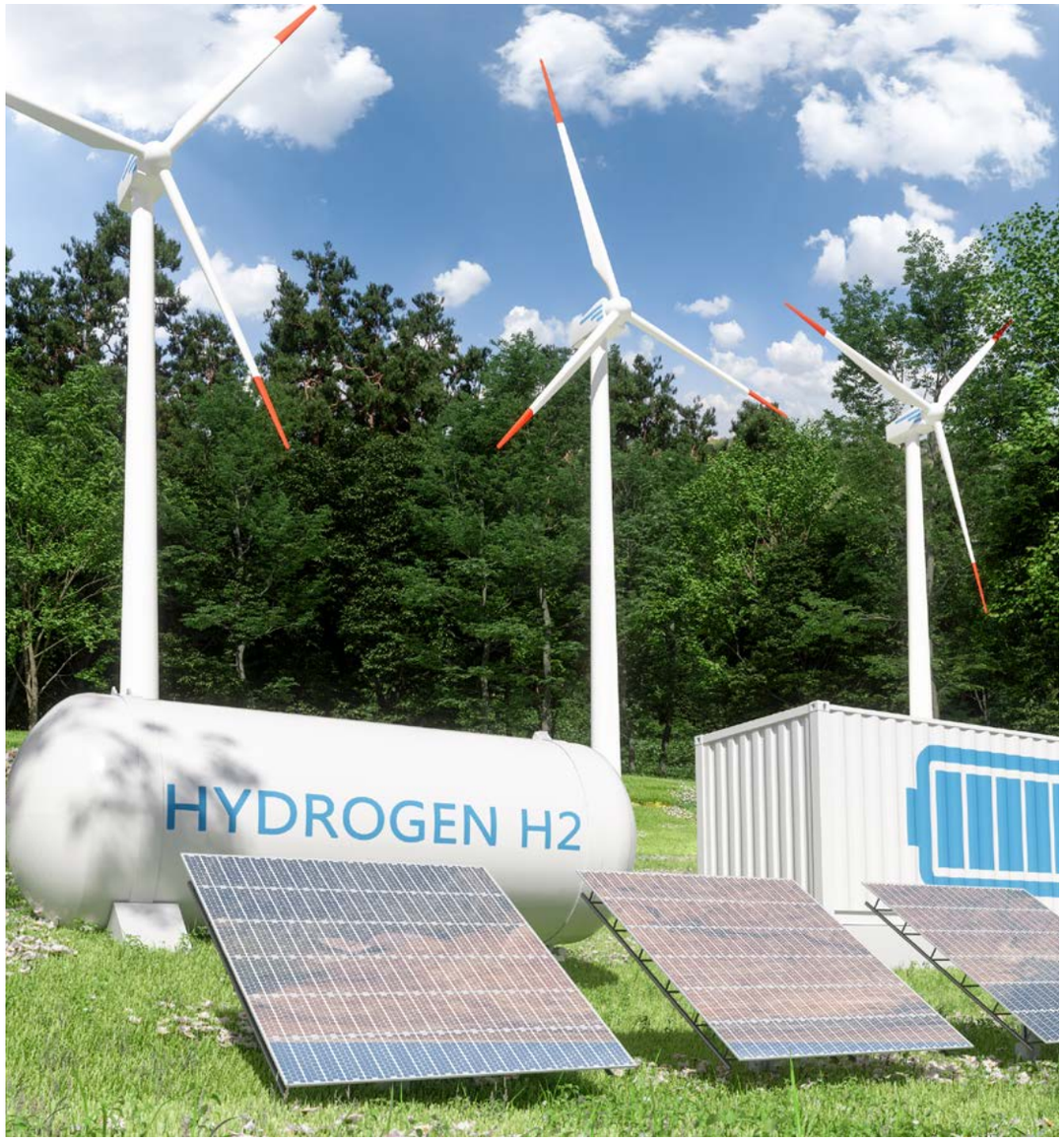
B. What is Green Hydrogen?

As of 2021, approximately 95 percent of the global hydrogen supply is produced using fossil fuels, mostly natural gas. Existing dedicated hydrogen production facilities rely on natural gas feedstock or the gasification of coal. This results in either "grey" or "brown" hydrogen, depending on whether natural gas or coal is used as the feedstock, respectively. Given the requirement for hydrocarbon to fuel the production of grey and brown hydrogen, together with the associated release of carbon dioxide into the atmosphere as a byproduct of the process, grey and brown hydrogen are not sources of clean energy, despite the absence of emissions when the hydrogen is combusted. The carbon footprint of the grey and brown hydrogen process can be reduced by the use of carbon capture utilization and storage (CCUS) technologies, producing what is known in the industry as "blue" hydrogen, resulting in a significant reduction in the emissions profile. "Green" hydrogen, however, is a zero-carbon fuel produced through electrolysis. Water is split into its constituent parts of hydrogen and oxygen using renewable energy, e.g., from wind or solar, to power the electrolysis process.

Green hydrogen has tremendous benefits, since the hydrogen molecule stores clean energy from renewable sources. Hydrogen can be converted to ammonia (one nitrogen atom bonded to three hydrogen atoms), which is an easy molecule to transport, as the energy density of ammonia by volume is nearly double that of liquid hydrogen, facilitating shipping and distribution. In the form of ammonia, energy can be transported to energy markets, such as Europe, Asia, and North America, where the ammonia can be converted back to hydrogen for use as a fuel.

Hydrogen can potentially decarbonize sectors that are hard to electrify due to the challenges presented by energy storage and demand (i.e., where batteries would be too big and heavy), including haulage, heavy industry like steel manufacturing, and heating. As a method of storing renewable energy, hydrogen presents a viable alternative to batteries.

Green hydrogen is seen as an integral component of the global effort to decarbonize the world's energy industry in the near future.



[1] https://www.worldbank.org/en/home.

C. The Potential Scale of the Hydrogen Economy

It is estimated that global demand for green hydrogen could reach 530 million tonnes by 2050, with a global export market worth US$300 billion. Analysts at Barclays have estimated that the hydrogen economy could be a US$1 trillion market by 2050, "potentially saving 5 gigatonnes in CO_2 emissions a year."[2]

To achieve the Paris Agreement's "two-degree scenario" by 2050 (see **PART II, II** below), global energy-related carbon dioxide emissions will have to be reduced by 60 percent. The Hydrogen Council, which is an industry-led effort to develop the hydrogen economy established in 2017, considers hydrogen to be "a central pillar of the energy transformation required to limit global warming."[3]

The natural properties of hydrogen give it enormous potential in the world's energy future, supporting its production from low-carbon technologies. The hydrogen molecule is stable, lightweight, and easy to store. Its energy content is three times greater than typical hydrocarbons such as petrol, and when used as fuel, the only byproduct is water (i.e., steam). It can be readily produced at an industrial scale, and it can be stored for long periods of time with minor losses. It can be used to store renewable energy, which can counteract the intermittency of renewable power generation.

The Hydrogen Council asserts that hydrogen can play seven major roles in the energy transition, and "across all seven roles, hydrogen could account for almost one fifth of total final energy consumed by 2050," and up to 25 percent of the energy required for road transport. The seven roles identified by the Hydrogen Council are:[4]

- Enabling large-scale renewable energy integration and power generation.
- Distributing energy across sectors and regions.
- Acting as a buffer to increase energy system resilience.
- Decarbonizing transportation.
- Decarbonizing industrial energy use.
- Helping to decarbonize building heating and power.
- Providing clean feedstock for industry.

Hydrogen has quickly become a major energy source of the future. It is one of the few renewable energy sources that is, as of 2021, economically viable and sufficiently advanced technologically to be produced on an industrial scale. Because it can be stored, as hydrogen or ammonia, it can also be used to store energy from fluctuating sources of renewable energy such as solar and wind. Its storability allows for international energy distribution, and it can link renewable-abundant regions, such as MENA, with markets that will be net-importers of clean energy, such as Europe. Furthermore, both hydrogen and ammonia can be stored as strategic power reserves. The stage is therefore set for hydrogen to be a major element of the world's net-zero emissions future.

D. Utilizing Green Hydrogen

If nations are to make satisfactory contributions to the reduction of GHG emissions, as agreed under the Paris Agreement, the development of green hydrogen technology and infrastructure will be a critical element of the process of decarbonizing the energy industry. However, to transition the energy economy (including transport) from hydrocarbons to hydrogen will require enormous investment in the development of the infrastructure needed to produce, store, transport, and distribute hydrogen. Barclays has estimated that "over the next 30 years, $500 billion in capex will be needed for hydrogen production equipment—and similar amounts for distribution infrastructure."[5]

The reality is that there is very little hydrogen infrastructure in place as of 2021, meaning that governments will need to take proactive steps to facilitate the development of the necessary technology and infrastructure, in conjunction with state power companies and private corporations. This will require government funding, as well as incentives for companies to invest in hydrogen, the implementation of domestic regulations in terms of emission targets, and the utilization of hydrogen as an energy source.

E. The Potential of Green Hydrogen in MENA

Across MENA, and specifically in the GCC, governments are beginning to explore the potential of hydrogen. This is an important step in the strategic long-term vision of transitioning towards a clean energy economy as domestic oil and gas reserves are depleted and as the demand for hydrocarbon products diminishes as the world strives to reduce GHG emissions.

Across MENA there is an abundance of renewable energy, including solar and wind power, which can be used to power green hydrogen production. At the Leaders' Summit on Climate, held between the United States and the UAE in 2021, Sultan Ahmed Al Jaber, the UAE's Industry and Advanced Technology Minister and UAE special envoy for climate change, said:[6]

> Due to early investment and policy choices, the UAE now enjoys the lowest-cost solar power in the world, enabling further competitiveness in our industries and services.

The availability of low-cost renewable energy, coastlines with existing port infrastructure, an abundance of unpopulated low-cost land, and relatively cheap capital means that hydrogen

[2] https://www.investmentbank.barclays.com/our-insights/the-hydrogen-economy-fuelling-the-fight-against-climate-change.html.

[3] https://hydrogencouncil.com/wp-content/uploads/2017/11/Hydrogen-scaling-up-Hydrogen-Council.pdf.

[4] https://hydrogencouncil.com/wp-content/uploads/2017/11/Hydrogen-scaling-up-Hydrogen-Council.pdf.

[5] https://www.investmentbank.barclays.com/our-insights/the-hydrogen-economy-fuelling-the-fight-against-climate-change.html.

[6] https://middleeast-business.com/united-arab-emirates-participation-in-biden-leaders-summit-on-climate/.

production could be more economical in MENA than in other parts of the world.

The oil and gas producing nations of the Gulf are geographically well positioned, with proximity to North American, Asian, and European markets. They already have extensive energy infrastructure in place, including refineries, storage and bunkering facilities, and pipelines. It is likely that existing infrastructure could be repurposed for hydrogen, meaning that the Gulf states may not have to develop infrastructure from scratch.

In the GCC states, there are a number of large state-owned energy companies (e.g., Aramco in Saudi Arabia, Abu Dhabi National Oil Company (ADNOC) in the UAE; Qatar Petroleum and Qatargas, and the Kuwait Petroleum Corporation). These companies have significant expertise in energy infrastructure and logistics, and the skills and experience of the GCC's energy industry workforce can be transferred to the emerging hydrogen industry. The state-owned energy companies also benefit from having access to substantial financial resources and already have industrial infrastructure in place, which could be utilized for hydrogen production, storage, and transport. These state-owned industry leaders have been taking steps towards the use of hydrogen; for example, Saudi Arabia's Aramco recently made a shipment of blue ammonia to Japan. The introduction of hydrogen technology into the GCC's well-established industrial energy sector will allow the GCC states to reduce their carbon emissions while simultaneously modernizing their industrial base and ensure economic growth in the world's net-zero emissions future. However, government leadership will be necessary if state-owned companies are to emerge as frontrunners in the emerging hydrogen economy. In context of the recent environmental shareholder activism for carbon targets to be identified and achieved, the focus on clean energy will become more pronounced.

International demand for oil and gas is expected to diminish as nations look to reduce their carbon footprints. The nascent hydrogen industry appears poised to fill the energy gap. However, there is not yet a huge demand for hydrogen within MENA, and the development of the hydrogen industry is expected to focus on international markets. That said, MENA governments may still look to emerging local demand for green hydrogen and to establish domestic and regional markets.

F. The Cost and Utility of Hydrogen Technology

The development of green hydrogen production at scale will need to balance cost and utility. The technology for the production of green hydrogen exists, but in terms of cost, it is not yet able to compete with fossil fuels. To bring costs down, the hydrogen industry needs to be scaled up, and there now exists the public and political drive for this to happen.

As of 2021, global annual consumption of hydrogen is between 70–80 million tonnes. It is primarily produced from fossil fuels and used in industry, for example, in the production of ammonia and steel. Green hydrogen should eventually replace grey or blue hydrogen in industrial applications, but the global demand for green hydrogen is forecast to rise up to 530 million tonnes per year by 2050, as it becomes more widely used as a fuel.

The International Energy Agency (IEA) has assessed the cost of producing green hydrogen (based on 2018 data) as ranging between US$3–7.5 per kg.[7] The Hydrogen Council has set a target price point as US$2 per kg (delivered).[8] According to the Hydrogen Council, only when this target is achieved can green hydrogen be viable for use across heavy industry.[9] There is therefore some way to go before the production of green hydrogen is cost effective. However, the IEA assessment reflects green hydrogen production in small-scale projects, including pilot projects. In regions with access to affordable renewable energy, with existing energy infrastructure in place, it is likely that the scaled-up production of hydrogen would significantly decrease the production price.[10] There is also a potential market for green hydrogen in the Gulf, where it can be used in traditional heavy industrial processes, for example, in the production of ammonia and steel, as well as for oil refining. If these industrial sectors shift to the use of green hydrogen, this further reduces costs, since transportation is regional rather than global.

With an abundance of solar energy, MENA countries are well placed to develop green hydrogen facilities as part of the global drive to decarbonize the energy sector. However, while production costs may be lower in MENA than elsewhere in the world, transporting green hydrogen to demand centers, e.g., the European and Asian markets, can be costly, particularly since transport infrastructure has not yet been developed. For states across MENA to actively participate in the emerging hydrogen economy, the supply chain infrastructure must be put in place, which will bring down the cost of getting the product to market.

Potential options for transport include shipping liquefied hydrogen, or converting hydrogen into ammonia for shipping, as per Aramco's first shipment of green ammonia to Japan in 2020. Moreover, it will be important to begin the transition towards the use of green hydrogen within MENA, creating a regional demand where the green hydrogen is produced. Establishing markets in close proximity to the production facilities would reduce the need for long distance transport.

The development of a broad international framework will be necessary to develop the hydrogen industry to an industrial and commercially viable scale. This would need to include involvement

[7] https://www.iea.org/.

[8] We note the very recent announcement of U.S. Secretary of Energy Jennifer Granholm launching an "Energy Earthshot Initiative" focused on the development of hydrogen at a scale sufficient to bring the price down to US$1 per kilogram by the year 2030: https://www.energy.gov/articles/secretary-granholm-launches-energy-earthshots-initiative-accelerate-breakthroughs-toward.

[9] https://hydrogencouncil.com/en/.

[10] MEED: Winning the hydrogen rush, 27 April 2021.

from governments, state-owned energy companies, sovereign wealth funds, and the private sector—in terms of capital, expertise, and resources. The French asset management and investment firm Natixis has estimated that some US$300 billion will need to be invested into hydrogen infrastructure by 2030 if the emerging hydrogen economy is to achieve an economy of scale that can bring down costs across the value chain, making the fuel a tenable replacement for hydrocarbons.[11]

The green-hydrogen market will be driven by major net-energy importers, such as Europe and Asia. Government support and innovation will be needed across these markets to develop the necessary infrastructure to transition towards clean fuels. The development of the necessary infrastructure requires an international strategic approach and cooperation, though decisions need to be made about whether hydrogen should be transported by pipeline, liquefied and transported by sea or road, or converted into ammonia for shipment. Such decisions are likely to be determined on a case-by-case basis by each country or even by specific market participants.

G. Corporate Interest in MENA's Hydrogen Future

In MENA, governments will need to take the lead in the transition to the hydrogen economy; national policies need to be developed alongside the necessary legal and regulatory frameworks. Public funding needs to be made available, along with schemes to incentivize companies to transition to clean energy, for example, tax breaks for reducing emissions and penalties for polluters. In the GCC, led by their respective governments, state-owned energy corporations will need to drive the transition from hydrocarbons toward clean energy technology. Simultaneously, governments and state-owned organizations will need to work hand in hand with the private sector, where there is access to capital, knowledge, experience, and existing energy infrastructure. It is expected that industry heavyweights, such as the United States' Cummins, Japan's Mitsubishi Heavy Industries (MHI), Germany's Siemens Energy, and South Korea's Hyundai, among others, will be important players in the emerging hydrogen economy.

Since the signing of the Paris Agreement in 2015, governments across MENA have made it clear that they intend to develop hydrogen production and transportation facilities and be part of the world's emerging hydrogen economy. A number of steps already have been taken by GCC governments to develop the necessary infrastructure, such as the formation of the Abu Dhabi Hydrogen Alliance and the initiation of hydrogen projects in countries such as the UAE, Oman, and Saudi Arabia. Regional projects, with an estimated value of around US$10 billion, are planned, with key projects such as the Neom Green Helios Fuels project in Saudi Arabia and the US$2.5 billion Acme green hydrogen-based ammonia facility in Duqm, Oman, setting the benchmark.

With MENA governments setting out clear ambitions to develop hydrogen infrastructure, corporations operating in the clean energy sector are beginning to show interest in the Middle East. For example:

- Mitsubishi Power, a subsidiary of MHI, is supplying three gas turbine generators for the 2,400 megawatt (MW) Fujairah F3 independent power producer project; this has the potential to develop into a clean energy project, since the turbines can operate on a 30:70 hydrogen to natural gas mix, with the capacity to increase the hydrogen utilization up to 100 percent.
- Germany's Siemens Energy has entered into a public-private partnership for a joint venture with Dubai's state utility Dubai Electricity & Water Authority (DEWA) and Expo 2020, which was delayed to the COVID-19 pandemic. The plant will produce hydrogen for use in hydrogen vehicles at Expo 2020, but it also will be able to accommodate future applications and test platforms for the different uses of hydrogen, including transport and industrial applications. Siemens Energy has earmarked AED25 million (approximately US$6.8 million) for this project.[12]
- Indian firm Acme Group is investing in a US$2.5 billion green hydrogen and ammonia plant in Oman's Special Economic Zone at Duqm (SEZAD), which could establish Oman as a regional green energy hub, with storage and transportation facilities complementing the development of green hydrogen production plants.[13]
- Fusion Fuel, an Irish company listed on Nasdaq, which makes electrolyzers, has agreed to work

[11] MEED: Firm says piping hydrogen to Europe is feasible, 16 March 2021.

[12] MEED: Dubai inaugurates green hydrogen plant, 19 May 2021.

[13] MEED: Middle East forges hydrogen path, 28 March 2021.

with the Lebanese engineering and construction firm Consolidated Contractors Company to develop green hydrogen plants across MENA. The parties have agreed to cooperate on projects involving the production of green hydrogen for potential clients in the refining and petrochemical industries in order to reduce their carbon footprint.[14]

There is also a developing trend towards an international, collaborative approach to bring down the cost of hydrogen production. One such initiative is the United Nations' Green Hydrogen Catapult project. Launched in 2020, seven of the world's largest energy companies, including Saudi Arabia's ACWA Power, announced a global coalition to accelerate the scale and production of green hydrogen in an effort to transition the world's most carbon-intensive industries—including power generation, chemicals, steelmaking, and shipping—towards clean energy. The Green Hydrogen Catapult initiative would like to see green hydrogen industry leaders, including ACWA Power, CWP Renewables, Envision, Iberdrola, Ørsted, Snam, and Yara, drive down the cost of hydrogen to US$2 per kg by 2026, approximately half its current price. The partner companies aim to do this with 25 gigawatts (GW) of green hydrogen production by 2026, equivalent to a 50-fold increase in production.[15]

H. The Status of Hydrogen Projects in the GCC and MENA

One of the stated objectives under Article 4 of the GCC charter is "to stimulate scientific and technological progress in the fields of industry."[16] In regard to the exploration of hydrogen and its potential as a major global fuel and a replacement for oil and gas, there is state-driven research across GCC states. However, the approach so far is piecemeal, with governments developing their own energy visions and launching localized pilot projects. Hopefully, this will pave the way for regional collaboration, which will allow the GCC states to work together to drive down the costs of hydrogen production, storage, and transportation.

A number of projects now are underway across the GCC and MENA. While the GCC states are the major players in terms of energy production in the Gulf, there are other nations across MENA that are developing renewable and clean energy technologies that can combat climate change, particularly Egypt. The key projects and research and development programs that are underway in MENA are detailed in **PART V** below.

[14] MEED: CCC partners with Irish firm for hydrogen schemes, 9 May 2021.

[15] https://racetozero.unfccc.int/green-hydrogen-catapult/.

[16] https://www.gcc-sg.org/en-us/AboutGCC/Pages/Primarylaw.aspx.

PART II – INTERNATIONAL AGREEMENTS ON CLIMATE CHANGE

In order to understand the commitment of the Gulf states to developing clean energy, it is important to understand the background of the international agreements to which they are party.

I. The Kyoto Protocol

The Kyoto Protocol was adopted on 11 December 1997, but did not come into force until 16 February 2005. It is an international agreement, signed by 192 countries, to operationalize the UNFCCC by committing signatories to limit or reduce GHG emissions in accordance with agreed individual targets. The convention requires signatories to adopt policies and measures to mitigate their GHG emissions and to report periodically.

Currently, all six of the GCC states and Egypt are party to the Kyoto Protocol.[17] However, the Kyoto Protocol differentiated between "developed" and "developing" states, and it only set binding targets for 37 developed nations,[18] which did not include any MENA states. Belarus was subsequently added to the list of countries with binding targets, bringing the number of states with established emission targets up to 38. The Doha Amendment was circulated in 2012, whereby a number of the signatories extended their target periods up to 2020.

Despite the fact that there were no concrete steps established under the protocol for the Gulf countries, the fact that all GCC states and Egypt signed the Kyoto Protocol confirms that they are mindful of the need to combat climate change by reducing emissions.

[17] The GCC incorporates: the United Arab Emirates, Saudi Arabia, Qatar, Bahrain, Kuwait, and Oman.

[18] Annex B, https://unfccc.int/sites/default/files/resource/docs/cop3/l07a01.pdf#page=24, this has now been amended to include Belarus.

II. The Paris Agreement

The Paris Agreement is a legally binding international treaty on climate change. It was adopted by 196 Parties at the 21st Conference of Paris, on 12 December 2015, and entered into force on 4 November 2016.[19]

The overarching aim of the Paris Agreement is to enhance the global response to climate change and limit global warming. Some of the key aspects of the Paris Agreement include:

- **Long-term temperature goal:** Limiting the global temperature increase to well below 2°C compared to pre-industrial levels (the "two degree scenario"), while pursuing efforts to limit the increase to 1.5°C.
- **Global peaking and "climate neutrality":** In order to achieve the temperature goal, signatories should aim to reach the global peaking of GHG emissions as soon as possible and undertake rapid reductions thereafter.
- **Mitigation:** The Paris Agreement requires all signatories to contribute to the overarching temperature goal by establishing domestic targets, known as Nationally Determined Contributions (NDCs). All signatories are responsible for implementing and reporting on their NDCs, pursuing domestic measures to achieve their targets.

While the Paris Agreement does not establish specific emission targets or targets dates for signatories, it is a milestone in the process of multinational cooperation towards tackling climate change; whereby parties have entered into a binding agreement, unifying them in their ambition to undertake multilateral steps to combat climate change and adapt to its effects.

All of the GCC countries are signatories to the Paris Agreement. However, as of May 2021, Iran, Iraq, and Turkey have not yet committed to the Paris Agreement, along with Eritrea, Libya, and Yemen.[20] While the MENA and GCC states are not bound to any specific emissions targets, the Paris Agreement is a guiding principle whereby governments have committed to reduce national carbon footprints.

III. The Net-Zero Producers Forum

Qatar, Saudi Arabia, Canada, Norway, and the United States collectively represent 40 percent of global oil and gas production. In April 2021, these five countries released a joint statement regarding the establishment of a "Net-Zero Producers Forum," agreeing to:[21]

> come together to form a cooperative forum that will develop pragmatic net-zero emission strategies, including methane abatement, advancing the circular carbon economy approach, development and deployment of clean-energy and carbon capture and storage technologies, diversification from reliance on hydrocarbon revenues, and other measures in line with each country's national circumstances.

The primary aim of the Net-Zero Producers Forum is to tackle climate change and is dedicated to developing long-term strategies to reach global net-zero emissions.

When Qatar announced it would participate in the Net-Zero Producers Forum, Qatar's Minister of State for Energy Affairs Saad bin Sherida al-Kaabi stated:

> We believe that our engagement in this forum is an important mission consistent with, and supported by, our ambition to create a better and more sustainable future for humanity.

A source from Saudi Arabia's energy ministry was quoted in the Saudi Press Agency (Saudi Arabia's national news agency), stating:

> Saudi Arabia is a strong advocate of the key role that technology and innovation can play in the campaign to reduce and remove GHG emissions and help the world reach its net zero targets.

The fact that Qatar and Saudi Arabia—key energy producers in the Gulf—have announced their intentions to be a part of this initiative is indicative of their commitment to the reduction of emissions on a global scale and supports the implementation of the Paris Agreement on climate change.

19 https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement.

20 https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-d&chapter=27&clang=_en.

21 https://www.energy.gov/articles/joint-statement-establishing-net-zero-producers-forum-between-energy-ministries-canada.

PART III – A VISION FOR SUSTAINABILITY ACROSS MENA

If the international community is to achieve the goals set out in the Paris Agreement detailed above, there will need to be a transition away from hydrocarbon energy production, which according to the International Renewable Energy Agency (IRENA), "accounts for two-thirds of global emissions in the energy industry."[22]

Hydrocarbons will need to be replaced with low-carbon or carbon-free energy sources, such as blue or green hydrogen. CCUS may be implemented in the hydrocarbon sector as an interim measure to reduce carbon emissions as the hydrogen market develops. But the transition to renewable and low-carbon energy sources will be fundamental in national strategies to achieve relevant targets. However, IRENA has observed that:[23]

> At present, the level of detail contained in NDCs differs from country to country, with little in-depth analysis and limited quantitative information about the role of renewable energy in meeting GHG emission reduction targets.

While the Paris Agreement is the principle international treaty guiding the development of national targets and strategy, the NDCs of many states are not specific enough to be used to set practical emission targets. Similarly, many states have not yet established the legal and regulatory framework that will be necessary to encourage and regulate the emerging hydrogen economy.

Presently, the international approach to developing the hydrogen value chain remains piecemeal, with a lack of international or regional strategy. However, certain of the key energy players across MENA are developing their own national energy strategies and visions, as detailed below.

[22] https://www.irena.org/climatechange.

[23] https://www.irena.org/climatechange.

I. The United Arab Emirates

In 2015, the UAE submitted its first NDC to the UNFCCC, setting out its commitment to reduce carbon emissions and to increase the share of clean power of the total energy mix. Confirming this commitment, the United Arab Emirates submitted its second NDC in December 2020. The UAE's second NDC, reflecting the UAE's "enhanced ambition with the inclusion of an economy-wide emissions reduction target," establishes a 23.5 percent reduction in the UAE's GHG emissions by 2030.[24] The second NDC identifies technological innovation and sustainable finance as key enablers of the UAE's green transition, with a focus on the following key sectors: energy, industry processes and product use, waste, agriculture, and land use change and forestry.

In 2016, the UAE established the Council for Climate Change and Environment, an interministerial, inter-emirate governance body to reinforce policies and strategies on climate change, environmental and sustainable development, and to "create partnerships with the private sector and conduct studies and lead scientific research."[25]

In 2017, the UAE launched "Energy Strategy 2050," which is the first unified energy strategy in the UAE that is based on supply and demand.[26] The strategy aims to increase the contribution of clean energy in the total energy mix from 25 percent to 50 percent by 2050, while reducing the carbon footprint of power generation by 70 percent, potentially saving AED700 billion by 2050. The Energy Strategy 2050 also seeks to increase consumption efficiency of individuals and corporations by 40 percent. In 2021, Minister of Energy and Infrastructure Suhail Al Mazrouei explained that the Energy Strategy 2050 is intended to "diversify the future energy mix, and raise the contribution of clean energy to the total energy mix produced in the country to 50 percent." As part of the Energy Strategy 2050, in order to meet the growing energy demand and ensure a sustainable growth for the country's economy, the UAE government aims to invest AED600 billion by 2050.

One of the main branches of the Energy Strategy 2050 is research, development, and innovation to ensure the sustainability of energy. This has seen the UAE invest in research and development into green hydrogen energy solutions and work hand in hand with the private sector in order to launch joint initiatives.

On the launch of Energy Strategy 2050 in January 2017, Sheikh Mohammed bin Rashid said:[27]

> The Gulf countries are similar in their economic structure, and we hope that we will one day have a unified GCC energy strategy in order to

[24] https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/United%20Arab%20Emirates%20Second/UAE%20Second%20NDC%20-%20UNFCCC%20Submission%20-%20English%20-%20FINAL.pdf.

[25] https://www.uaecabinet.ae/en/details/news/uae-forms-council-for-climate-change-and-environment.

[26] https://u.ae/en/about-the-uae/strategies-initiatives-and-awards/federal-governments-strategies-and-plans/uae-energy-strategy-2050.

[27] Vice President and Prime Minister and Ruler of Dubai, His Highness Sheikh Mohammed bin Rashid Al Maktoum.

ensure sustainable growth for our people and global influence for our economies.

While, as of 2021, there is not yet a unified energy strategy across the Gulf, it is clear that the leaders of the regional governments are beginning to recognize the need to collaborate to develop the clean energy industry.

Similarly, the UAE has recognized the need to draw in expertise from abroad. It is actively pursuing agreements with foreign governments (such as Japan and Korea) and private companies (such as Siemens Energy) in order to develop hydrogen technology and look for ways to develop a supply chain with all of the necessary logistical components. For example, in 2021 the UAE entered into an agreement to research opportunities for hydrogen development with the Japanese government, indicative of the intention to develop a clean energy supply chain from the Middle East, where green and blue hydrogen can be produced, to markets such as Asia, where there is an appetite for clean energy fuels.

In March 2021, in support of the Energy Strategy 2050, the UAE's Ministry of Energy and Infrastructure, in partnership with Khalifa University and IRENA, launched the National Energy Integrated Model (the Model). The purpose of the Model is to support the UAE's ambition to increase the proportion of clean energy in the UAE's total energy mix to 50 percent by 2050. By providing a common framework that brings together stakeholders across the energy sector, the Model is intended to support the formulation of a strategic future for sustainable energy in the UAE, relying on the experience of IRENA and the research capabilities of Khalifa University and drawing on that experience to develop a road map for the development of sustainable energy over the next 50 years.

At the 2021 launch of the Model, Under-Secretary of the Ministry of Energy and Infrastructure for Energy and Petroleum Affairs Sharif Al Olama said:[28]

> The National Integrated Energy Model is a major supporter of the national energy strategy that was launched in 2017; work is currently under process on developing a national energy strategy to harmonize developments in the energy sector at local and global levels, and it takes into account the UAE's orientation towards diversifying energy sources and developing the sector, finding various solutions in addition to traditional energy, in a way that supports sustainable development, national economies, and the country's passage to the next 50 years of achievements, up to the UAE Centennial 2071.

In January 2021, the Abu Dhabi sovereign wealth fund Mubadala Investment Company signed a memorandum of understanding (MOU) with ADNOC and Abu Dhabi Developmental Holding Company (ADQ) by which the parties agreed to form the Abu Dhabi Hydrogen Alliance. The UAE Ministry of Energy and Infrastructure joined the Hydrogen Alliance later in 2021. Through the Hydrogen Alliance, the group is aiming to establish Abu Dhabi and the UAE as a leader in the emerging international markets of green and blue hydrogen, while bolstering the development of a green hydrogen economy in the UAE.[29]

Practical steps also have been taken in terms of implementing pilot projects and preparing the supporting regulatory framework, as follows:

- Dubai's first green hydrogen plant was commissioned in May 2021. DEWA, in collaboration with Expo 2020 Dubai and Siemens Energy, is implementing the green hydrogen project at DEWA's R&D Centre at the Mohammed bin Rashid Al Maktoum Solar Park. It is intended that the plant will produce green hydrogen that will be used to supply vehicles powered by hydrogen fuel cells for use during Expo 2020.
- Complementing this pilot green hydrogen vehicle project is the development of the first set of domestic regulations regarding hydrogen vehicles. The Emirates Authority for Standardization and Metrology (ESMA) has established the first set of regulations regarding vehicles that use hydrogen fuel cells.

In May 2021, the inaugural Middle East Energy virtual event was held, bringing together MENA stakeholders to discuss the regional opportunities for clean energy. At the virtual summit, Minister of Energy and Infrastructure Suhail Al Mazrouei reiterated the UAE's commitment to reduce carbon dioxide emissions and increase clean energy use by 2050. Assistant Under-Secretary of the UAE Ministry of Energy and Infrastructure Yousif Al Ali explained the

[28] https://wam.ae/en/details/1395302914826.

[29] MEED: GCC Clean hydrogen initiative, 23 February 2021.

UAE's commitment to taking a global lead in terms of hydrogen production:[30]

> The UAE is well-positioned to be one of the top producers of hydrogen in the world. The UAE is committed and working with confidence to reduce the nationwide carbon footprint, by working on the demand side, supply-side and working on our different energies and future technologies to reduce our carbon footprint.

While in the UAE the development of hydrogen technology, infrastructure, and legislation remains at a nascent stage, the government's ambition, as set out in its Energy Strategy 2050 and seen through the projects underway in the UAE, is for the country to take a leading role in the world's emerging hydrogen economy, including an ambition to become one of the top global hydrogen producers.

II. Saudi Arabia

In November 2016, Saudi Arabia ratified the Paris Agreement and its Intended Nationally Determined Contribution (INDC) became its NDC. Saudi Arabia's ambition under its first NDC was to "seek to achieve mitigation co-benefits ambitions of up to 130 million tons of CO_2eq avoided by 2030 annually through contributions to economic diversification and adaptation."[31] Saudi Arabia has therefore committed to reduce its carbon dioxide (or equivalent) emissions by up to 130 million tonnes annually by 2030, with the reduced emissions coming "through contributions that have co-benefits in diversifying the economy and mitigate GHG emissions."[32]

In its first NDC, Saudi Arabia set out its intention to diversify its economy, including the development of "renewable energy and energy efficiency technologies to enhance economic growth." Saudi Arabia recognized the need for economic diversification, investment, and renewable energy programs. Given its hydrocarbon industrial base, in an effort to reduce industrial emissions, Saudi Arabia "plans to build the world's largest carbon capture and use plant. This initiative aims to capture and purify about 1,500 tonnes of CO_2 a day for use in other petrochemical plants."[33]

In a world that is moving towards clean energy and away from hydrocarbons, Saudi Arabia is beginning to recognize the importance of developing a clean energy industry. In an effort to reduce its reliance on oil and gas, Saudi Arabia has launched a number of environmental initiatives and now plans to generate 50 percent of its domestic energy requirement from clean energy sources by 2030.

According to Saudi Arabia's Vision 2030, "we will transform Aramco from an oil producing company into a global industrial conglomerate."[34] Under Vision 2030, Saudi Arabia has increased its renewable energy targets, aiming for 27.3 GW within five years and 58.7 GW by 2030.[35] However, Saudi Arabia remains pragmatic in its approach, and while committed to reducing emissions, the country will continue to develop its conventional hydrocarbon energy sector, with plans to "double our gas production, and construct a national gas distribution network."[36]

Saudi Arabia already stands out as a MENA leader in terms of hydrogen projects since it is already building a 5 GW green hydrogen plant, which will provide power for the Neom gigaproject. Furthermore, Saudi Arabia's state-owned Aramco made the world's first shipment of a cargo of blue ammonia to Japan in September 2020.

Of the GCC state-owned energy companies, Aramco appears to be leading efforts to incorporate renewable, clean energy into its operations. As the global demand for low carbon fuel rises, Aramco is developing zero-carbon technologies, such as green hydrogen and CCUS, with plans to develop and implement infrastructure for hydrogen fuel by 2030.

In February 2021, Aramco Chief Technology Officer Ahmed al-Khowaiter said, "we don't see much growth in [the hydrogen] market until 2030, when the infrastructure and policies will be in place."[37] He added that Aramco is targeting Japan and Korea as potential hydrogen markets toward the end of this decade.

III. Oman

Oman's 2015 INDC projected that "Oman will control its expected GHG emissions growth by 2% to be 88714 Gg during the period from 2020-2030."[38] While this target is modest compared to other countries, Oman has identified the need to increase its use of renewable energy and to "develop new legislation on climate change which will support the adoption of low carbon and energy efficient technology."

Oman's Vision 2040 rests on three pillars: people and society, governance, and economy and development. This last pillar includes Oman's ambition to preserve environmental sustainability.[39] One of the identified priorities is "environment and natural resources," whereby:[40]

> The future strategy in natural resource management will focus on developing nontraditional sources of natural resources, such as the use of renewable energy to reduce production cost and subsequently enhance the competitiveness of economic sectors. New infrastructure projects will be geared towards green economy, green strategies and renewable energy production.

The government of Oman has therefore

30 https://www.wam.ae/en/details/1395302935261.

31 https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Saudi%20Arabia%20First/KSA-INDCs%20English.pdf.

32 https://climateactiontracker.org/countries/saudi-arabia/pledges-and-targets/.

33 https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Saudi%20Arabia%20First/KSA-INDCs%20English.pdf.

34 https://www.vision2030.gov.sa/v2030/overview/.

35 https://www.ief.org/_resources/files/events/third-ief-eu-energy-day/turki-al-shehri-24.02-repdo---ief_riyadh_v2-2.pdf.

36 https://www.vision2030.gov.sa/v2030/overview/.

37 MEED: Aramco hydrogen business at world-scale by 2030, 23 February 2021.

38 https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Oman%20First%20NDC/OMAN%20INDCs.pdf.

39 https://omanuna.oman.om/en/home-top-level/eparticipation/oman-vision-2040.

40 https://www.2040.om/Oman2040-En.pdf.

identified the need to explore renewable energy and diversify energy sources, and it is now a national objective to develop "a green and circular economy that addresses national needs and moves consistently with the global trends."[41] Whereas in 2015, none of Oman's energy demand was satisfied by renewable sources, it now targets 20 percent renewable energy consumption by 2030 and 35–39 percent by 2040.

Oman is in the process of developing a renewable energy strategy and encouraging investment in renewable and alternative energy resources. As part of this strategic development, an international consortium was formed in May 2021, comprising Hong Kong-based InterContinental Energy, Oman's energy holding company Oman Oil and Orpic Group (OQ), and EnerTech, a subsidiary of the sovereign wealth fund Kuwait Investment Authority. The consortium aims to develop Oman's green fuel infrastructure, with the ambition of developing a plant that will produce green hydrogen by 2028. The planned plant will be opened in phases, with hopes for the plant to reach capacity by 2038.

The project is intended to be performed in stages, meaning the capital investment will be distributed over a period of about 14 years, commencing in around 2024 when the consortium partners envisage signing the first offtake agreements.

However, the total investment required is estimated to be in the region of US$28 billion, which equates to about 40 percent of Oman's current gross domestic product, so funding for the project remains an issue.

Proposed projects such as this indicate that Oman is taking steps to transition towards clean energy and intends to establish industrial production of green hydrogen and green ammonia in support Oman's economic diversification strategy, but it remains to be seen whether the government will facilitate the access to capital that such projects will require.

Geographically, Oman is well placed to have access to hydrogen markets in Europe and Asia. In the Al Wusta region, there is abundant solar and wind power, with a long coastline giving access to water. In line with Vision 2040, Oman is developing the SEZ at Duqm, Al Wusta Governorate, since it provides a strategic and competitive location to develop large-scale green hydrogen production. Duqm is considered to be very well located for green energy production, given the site's abundant wind and solar resources, its proximity to a thriving industrial zone, the existing port facilities, and easy access to global energy markets, in particular, Europe, Japan, and South Korea, where the greatest demand for green hydrogen and its derivatives exist.[42]

[41] https://www.2040.om/Oman2040-En.pdf.

[42] https://www.chemengonline.com/large-scale-renewable-hydrogen-project-to-launch-in-oman/.

IV. Qatar

The Qatar National Vision 2030 identifies four central pillars to the government's development strategy, the fourth pillar being "Environmental Development." The Qatar National Vision states:[43]

> The environmental pillar will be increasingly important as Qatar is forced to deal with local environmental issues, such as the impact of diminishing water and hydrocarbon resources, and the effects of pollution and environmental degradation, as well as international environmental issues such as the potential impact of global warming.

In 2015, Qatar made a report to the UNFCCC on its INDCs. Referring to the four pillars of the Qatar National Vision 2030, the report asserted that the forth pillar "is of high importance as it seeks to strike a balance between development needs and environmental protection, and supports international efforts to mitigate the effects of climate change."[44] While Qatar's INDCs do not include emission targets, Qatar's report does cover the government's investment in research and development into clean energy and its ambitions for "utilizing clean energy and renewables, reducing emissions to the atmosphere and developing technologies that convert emissions into useful products."

The Qatar government also has raised the necessity for the countries of the Gulf to cooperate to protect and conserve the environment, and it has stated its objective to encourage "regional cooperation to put in place preventive measures to mitigate the negative environmental effects of pollution arising from development activities."[45]

In line with the government's approach to protecting the environment, state-owned Qatar Petroleum (QP) has developed its own "Environmental Sustainability Plan." In 2021, QP launched a sustainability strategy, setting targets to reduce carbon emissions from its upstream and liquefied natural gas (LNG) facilities by 2030. QP aims to reduce carbon emissions at its LNG facilities by 25 percent, reduce emissions from its upstream facilities by at least 15 percent, and cut flaring

[43] https://www.gco.gov.qa/wp-content/uploads/2016/09/GCO-QNV-English.pdf.

[44] https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Qatar%20First/Qatar%20INDCs%20Report%20-English.pdf.

[45] https://www.gco.gov.qa/wp-content/uploads/2016/09/GCO-QNV-English.pdf.

intensity by 75 percent. QP also aims to end outline flaring by 2030 and limit methane emissions, setting a methane intensity target of 0.2 percent across all QP facilities by 2025.

Between 2012 and 2018, the company spent US$900 million on reduced flaring, and it has earmarked a further US$170 million for investment up to the end of 2021. QP also has committed to employing CCUS facilities to capture more than 7 million tonnes of CO_2 annually by 2027. QP also is aiming to add more than 4 GW of renewable energy, reducing Qatar's annual emissions by up to 5 million tonnes per year.

Qatari Minister of State for Energy Affairs Saad Sherida al-Kaabi, who is also QP's chief executive officer, said the sustainability strategy will "play a decisive role in helping reduce the impact of climate change by implementing measures to curb emissions, produce LNG using the latest proven carbon reduction technologies, and compensating for residual emissions where necessary."

Qatar's successful bid for the 2022 FIFA World Cup included a pledge that the event would be carbon-neutral, so the government is clearly alert to the challenges of reducing the country's carbon footprint.[46]

V. Egypt

Egypt contributes around only 0.6 percent of global GHG emissions. Although a low contributor to global emissions, the low-lying Nile Delta is one of the most vulnerable areas in the world in terms of rising sea levels. In response to rising global temperatures, Egypt signed the UNFCCC in 1992, and it signed the Kyoto Protocol in 1999. Sensitive to the fact that the country is vulnerable to rising global temperatures, in 2010, Egypt initiated the for Climate Change, indicating that climate change is high on the agenda of the government.

In November 2015, Egypt submitted a climate action plan to the UNFCCC, identifying its INDC, which became the country's first NDC in 2017. This recognized that "the key for Egypt to mitigate GHGs emissions is to provide appropriate foundations for the development of low carbon energy systems" and one of the pathways for achieving a reduction in carbon dioxide emissions was the "widespread diffusion of locally-appropriate low-carbon energy production technologies."[47] However, Egypt's NDC does not provide quantifiable targets for reduced emissions. Furthermore, its NDC is conditional on the receipt of international funding, to the tune of US$73 billion.[48]

Launched in 2016, and updated in 2018, Egypt's Sustainable Development Strategy, Egypt Vision 2030, is the national agenda regarding Egypt's long-term strategic plan towards sustainable development. Egypt Vision 2030 focuses on three dimensions of sustainable development: economic, social, and environmental. One of the objectives is an "integrated and sustainable ecosystem" whereby "Egypt seeks to preserve both development and the environment through the rational use of resources to preserve the rights of future generations to a safer and more efficient future."[49] Egypt Vision 2030 illustrates the government's determination to diversify the energy mix and to improve the efficiency of electricity consumption.

One example of Egypt's diversification is its wind energy independent power project at Ras Ghareb. Egypt has an onshore wind energy potential of approximately 20,000 MW, which is focused in the Gulf of Suez. With the aim of exploiting this renewable energy source, Egypt's first 250 MW wind-based independent power project is currently under construction in Ras Ghareb, with numerous other utility-scale solar photovoltaic independent power projects also under way in the country.

Egypt is a major gas exporter, with large natural gas reserves. With 2,450 kilometers of coastline and 1,530 kilometers of riverbank along the Nile, Egypt's geography is suitable for the large-scale, low cost production of hydrogen using electrolysis, as well as the production of blue hydrogen, using CCUS technology. Given the abundance of both natural gas and renewable energy sources (notably solar and wind) and its proximity to global energy marketplaces, such as the European Union, Egypt is potentially well placed to establish itself as a hydrogen producer and supplier, and the government is developing its strategic approach to the emerging hydrogen economy.

VI. Kuwait

Kuwait is taking steps to establish a national hydrogen strategy as it continues to assess the role hydrogen may play in its energy transformation. In context of the transition to cleaner fuels and low-carbon energy sources, hydrogen is seen by Kuwait as a fuel of the future and the potential means by which to secure a position in the clean energy market, while reducing the state's dependence on oil revenues which is a key aim of Kuwait's' Vision 2035. The production of blue hydrogen for export is often seen as the natural starting point for an oil exporter such as Kuwait. However, given the abundance of solar energy and existing infrastructure, any future hydrogen policy will likely focus on the potential production and export of green hydrogen. While Kuwait is yet to announce plans for any hydrogen specific projects aimed at export, a hydrogen production facility was previously constructed as part of the Shuaiba refinery which allowed high sulphur heavy crude to be processed. The Shuaiba refinery, which closed in April 2017, was Kuwait National Petroleum Company's (KNPC) first refinery. The tanks and export facilities of the Shuaiba refinery have since been assimilated into KNPC's Clean Fuels Project which itself incorporates Hydrogen Membrane Units to recover and recycle purified hydrogen for use in the Atmospheric Residue Desulphurization process.

[46] https://www.qatar2022.qa/en/news/qatar-on-track-to-meet-carbon-neutral-commitments-for-fifa-world-cup.

[47] https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Egypt%20First/Egyptian%20INDC.pdf.

[48] https://www.researchgate.net/publication/339668565_Egypt's_nationally_determined_contributions_to_Paris_agreement_review_and_recommendations.

[49] https://mped.gov.eg/EgyptVision?lang=en.

PART IV –
THE NEED FOR A LEGAL AND REGULATORY FRAMEWORK ACROSS MENA

As of 2021, there is no overarching strategy for the development of hydrogen across the GCC or the Middle East. Similarly, there is a lack of hydrogen-related legislation in the GCC states, and no specific regulations regarding the development, implementation, or licensing of hydrogen facilities. The limited regulation of hydrogen in countries such as the UAE, Saudi Arabia, or Egypt is indicative of the fact that the development of hydrogen projects remains at an early stage.

While the Gulf states now are investing in clean energy, most of these projects are at the research or pilot stage. So far, only Saudi Arabia has taken the next step; having made the world's first delivery of blue ammonia to Japan in 2020, and Saudi's ACWA Power having signed up for a US$5 billion green hydrogen project in Neom.

In the words of UAE Undersecretary of the Ministry of Energy Sharif Salim Al Olama, speaking at the Siemens Energy week virtual conference in 2020:[50]

> Hydrogen is very high on our agenda, right now we are really at initiation phase…We are in the process of setting the roadmap of where we are going with hydrogen.

The countries of MENA and the GCC already have begun the process of diversifying into clean methods of energy generation. However, in order to maintain and develop economic growth, the regional governments need to establish a strategic policy road map, coupled with an appropriate legal and regulatory framework, to facilitate the emergence of the MENA and GCC states as leaders in the emerging hydrogen economy. Developing a legal and regulatory framework will be a crucial step if the GCC is to attract the fiscal and technological investment that will be essential components to the development of the hydrogen industry in the Middle East.

[50] https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/101920-uae-investing-in-green-and-blue-hydrogen-projects-as-part-of-clean-energy-move-official.

PART V – HYDROGEN PROJECTS IN KEY MENA STATES

A range of factors can affect a country's potential for hydrogen production, including government policy, geolocation, availability of solar power, availability of natural resources (i.e., oil and natural gas), existing industrial infrastructure, and the affordability of finance. Across the GCC and Egypt, there is an uptick in renewable energy projects; in terms of hydrogen projects, most remain at the research and development stage, albeit some projects are underway. Below we consider some of the key hydrogen projects across MENA.

I. The United Arab Emirates

A. DEWA's Pilot Green Hydrogen Project for Expo 2020

State-owned DEWA is developing a pilot green hydrogen mobility project for Expo 2020 (to be held from 2021–2022).[51]

The pilot plant will produce hydrogen using renewable solar energy, store it, and use it for re-electrification, transportation, and other industrial uses. At Expo 2020, green hydrogen produced at Dubai's Mohammed bin Rashid Al Maktoum Solar Park will power a fleet of fuel-cell vehicles. By 2030, the solar park should have capacity to generate 5 GW.

The project is part of DEWA's strategic approach to develop hydrogen technologies in line with Dubai's ambitious clean energy targets, i.e., for 75 percent of its energy to consumption to be satisfied by renewable sources by 2050.

The US$14 million project is a public-private partnership project between DEWA, Expo 2020 Dubai, and Germany's Siemens. The project was tendered in 2018, broke ground in February 2019, and is on track to be commissioned ahead of Expo 2020.

The pilot project should pave the way for large-scale hydrogen projects and allow DEWA and Siemens to refine the production of hydrogen so that the cost of the process can be reduced. In relation to this pilot project, UAE Undersecretary of the Ministry of Energy Sharif Salim Al Olama stated that the competitive prices for solar power in the region will enable Dubai "in the near future to produce a very competitive price for green hydrogen."

B. ESMA Draft Technical Regulations for Hydrogen-Powered Vehicles

Complementing DEWA's pilot green hydrogen mobility project for Expo 2020, ESMA announced that it has completed drafting the technical regulations for hydrogen fuel cell vehicles. Hydrogen-powered vehicles, which are environmentally friendly and emit only water vapor, also will be used for Expo 2020, fueled by locally produced green hydrogen. The UAE is the first country in MENA that has developed regulations for hydrogen-powered vehicles, demonstrating that the UAE intends to be a regional leader in terms of establishing a legal and regulatory framework for low-carbon fuels.

The UAE has implemented a three-tiered approach to developing legislation for more environmentally friendly vehicles. The first step was related to hybrid semi-environmentally friendly cars, the second step related to electric vehicles that are more environmentally friendly vehicles, and the third step was hydrogen vehicles, which produce zero-emissions. ESMA Director-General Abdullah Al Maeeni stated that the third step had to consider hydrogen technology:[52]

> The project covers the general safety requirements that must be met in hydrogen vehicles, in terms of setting requirements for storage tanks used, types and metal manufactured, and tests to be performed on cylinders in particular, as well as the need for safety valves to prevent high pressure inside the cylinder and keep them from different influences.

In March 2021, UAE Vice President and Prime Minister and Ruler of Dubai Sheikh Mohammed bin Rashid al-Maktoum announced the approval of a national system for hydrogen fuel-powered vehicles. Also announced was the approval of a national water and energy demand management program, aiming to increase energy efficiency by 40 percent across the three most energy-consuming sectors: industry, construction, and transport. A shift toward hydrogen-powered vehicles could substantially cut emissions produced by regional transport, such as haulage and, potentially, shipping.[53]

51 MEED: Dubai commissions hydrogen plant, 17 May 2021.

52 https://www.esma.gov.ae/en-us/Media-Center/news/Pages/UAE-develops-first-technical-regulation-of-hydrogen-cell-vehicles-regionally.aspx.

53 MEED: United Arab Emirates announces hydrogen vehicles system, 21 March 2021.

C. Masdar Green Hydrogen Pilot Project

In January 2021 the Abu Dhabi Hydrogen Alliance was formed between Abu Dhabi's ADNOC, holding firm ADQ, and sovereign wealth fund Mubadala, which owns Masdar. The first project to emerge from the Hydrogen Alliance is the Masdar green hydrogen pilot project, which is supported by Germany's Siemens Energy, Japan's Marubeni, Etihad Airways, the Lufthansa Group, the Khalifa University, and the Abu Dhabi Department of Energy. The idea behind the project is to commission a green hydrogen plant that will produce hydrogen fuel for use in local vehicles, such as buses, in Masdar City and to develop aviation fuel for use by Etihad and Lufthansa. There also will be research into the use of fuel in the maritime and shipping industry. The plant design is expected to be ready by the end of 2021, with construction taking an additional two years.[54]

D. ADNOC Research Carbon Dioxide Capture Technology

The UAE is looking at blue and grey hydrogen, capitalizing on its experience in CCUS. The UAE intends to study the technology of CCUS with hydrogen production from fossil fuels.

Currently, state-owned ADNOC, the UAE's biggest energy producer, has the ability to capture 800,000 million tonnes per year of carbon dioxide from Emirates Steel and inject it into its oil reservoirs for enhanced oil recovery.

ADNOC is on track to expand its CCUS capacity at least five-fold to 5 million tonnes of carbon dioxide annually by 2030, capturing the carbon dioxide at its own natural gas plants. ADNOC's Shah gas plant has the potential to enable the capture of 2.4 million tonnes of carbon dioxide, while the Habshan and Bab plants could enable the capture of almost 2 million tonnes.

E. ADNOC Blue Ammonia Facility in Ruwais, United Arab Emirates

ADNOC, in partnership with state holding company ADQ, is planning to develop a 1,000 kiloton blue ammonia project at a downstream facility in the Ta'ziz industrial zone in Ar-Ruwais, Abu Dhabi. The plant will take blue hydrogen, derived from natural gas feedstock as carbon dioxide is captured and stored, and convert it into blue ammonia, which is easier to store and transport as a fuel source.

ADNOC and ADQ are both members of the Abu Dhabi Hydrogen Alliance, which aims to develop hydrogen infrastructure in the UAE and this project is part of the strategy to meet the demand for low-carbon fuels and to establish the UAE as a key hydrogen exporter in the emerging hydrogen economy. ADNOC and ADQ have further plans to develop projects worth US$5 billion at the Ruwais Derivatives Park.

Dr. Sultan Al Jaber, Minister of Industry and Advanced Technology and managing director and group chief executive of ADNOC, stated that this facility "is a significant milestone in the development of our blue hydrogen and ammonia business, building on the UAE's strong position as a producer of competitive, low-carbon natural gas and our leadership role in carbon capture and underground storage."[55]

The project is currently in the design stages, with UK contractor Wood undertaking front-end engineering and design work. Final investment decisions are expected in 2022, and the project should commence in 2025.

F. Mubadala and Snam to Explore Green Hydrogen Potential

Abu Dhabi's sovereign wealth fund Mubadala Investment Company (Mubadala) and Italy-headquartered Snam have agreed to a joint exploration of hydrogen development and investment opportunities across the UAE, as well as globally.

Snam (a gas transmission system operator) is part of the Hydeal consortium, an initiative with ambitions to deliver 100 percent green hydrogen to European markets at €1.5 (US$1.8) per kilogram, including transport and storage overheads, by 2030.

A memorandum of understanding was signed by the companies in early 2021, and the companies released a statement stating their intention to "carry out a number of assessment activities, including technical and economic feasibility studies, to explore potential projects and solutions [that will] foster and promote hydrogen development in the UAE, and elsewhere globally."

Mubadala's chief executive officer of UAE investments, Musabbeh al-Kaabi, described the collaboration as "an extension of our joint efforts to develop a hydrogen economy for the UAE … and [in] advancing the role hydrogen will play to meet future energy demand globally."[56]

Snam has a business unit dedicated to the development of new hydrogen technologies and projects, and it was a pioneer in the blending of hydrogen into existing natural gas pipeline networks. The relationship with Mubadala allows Snam to enhance its presence in the GCC, giving it access to the strategic MENA markets for potential hydrogen production.

G. Mubadala and Siemens to Explore Green Hydrogen Potential

Mubadala and Siemens Energy of Germany have agreed to establish a partnership to push for investment and development into green hydrogen production. Under the partnership, the partners hope to establish an Abu Dhabi-based leader in the synthetic fuels sector. They intend to investigate green hydrogen technology and use technological advancement to drive down the costs of green hydrogen and synthetic fuels production. They intend to utilize renewable energy to produce green hydrogen and synthetic fuels, providing clean and transportable energy to fuel new hydrogen-based

[54] MEED: Masdar hydrogen plant design under way, 16 May 2021.

[55] https://www.thenationalnews.com/business/energy/adnoc-to-build-major-blue-ammonia-facility-in-ruwais-1.1228840.

[56] MEED: Mubadala and Snam to cooperate on hydrogen, 22 March 2021.

economies, supplied from the U. In this way, Mubadala and Siemens Energy will have access to internationally emerging hydrogen markets.[57]

H. ADNOC and GS Energy to Explore Hydrogen Potential

In a virtual summit between ADNOC and South Korea's GS Energy in March 2021, the two companies agreed to explore Abu Dhabi's opportunities in the hydrogen economy. GS Energy has a long-standing strategic relationship with ADNOC, with approximately 10 percent of South Korea's imported oil coming from the UAE. UAE Minister of Industry and ADNOC Group chief executive officer Sultan Ahmed Al Jaber said that ADNOC and GE Energy were "identifying possible areas of investment in Abu Dhabi's emerging blue hydrogen ecosystem." While ADNOC is beginning to explore opportunities, this remains at the preliminary stages, with no targets or projected outcomes.

I. Cooperation Agreement Between the UAE and Japan to Explore Hydrogen Opportunities

In April 2021, the UAE's Ministry of Energy and Infrastructure and the Japanese Ministry of Economy, Trade, and Industry (METI) signed a virtual cooperation agreement to explore hydrogen development opportunities. The aim of the agreement is to expand the joint areas of collaboration and enhance investment in the hydrogen sector, supporting the ambition to accelerate the energy transition towards a low-carbon future.

The agreement was signed by Suhail Al Mazrouei, Minister of Energy and Infrastructure, and METI State Minister Ejima Kiyoshi.

At the virtual conference, Suhail Al Mazrouei explained that cooperation with Japan was an important step towards developing hydrogen production, building the supply chain and transport links between the two countries, and developing the necessary regulations and policies. He stated that the agreement:[58]

> Also aims to open broad prospects for growth and development as part of the two countries' efforts to diversify the energy mix, relying on clean energy, building more partnerships, and strengthening cooperation to take advantage of the opportunities associated with the global leadership of the UAE and Japan in the fields of innovation, technology, and sustainability.

II. Saudi Arabia

A. The Neom Green Helios Fuels Project

In July 2020, Saudi Arabia's utility developer ACWA Power and Neom signed an agreement with U.S.-based Air Products for a US$5 billion hydrogen-based ammonia production facility powered by renewable energy. The project, jointly owned by all three partners, will be based in Neom and will be part of Saudi Arabia's US$500 billion gigaproject in Neom.

The planned facility will include a 20 MW electrolysis plant that will produce hydrogen from solar and wind power, supplied by the technology division of Germany's Thyssenkrupp unit Uhde Chlorine Engineers. The Saudi and German governments have been collaborating on clean hydrogen developments in Saudi Arabia, and in December 2020, the German government confirmed it would contribute around the equivalent of US$1.83 million to the planned hydrogen electrolysis plant.

Once commissioned, the facility intends to integrate 4 GW of renewable solar and wind power, use electrolysis to produce up to 650 tonnes of green hydrogen per day, produce nitrogen by air separation, and produce 1.2 million tonnes of green ammonia per year, which can then be transported around the world to be used to produce green hydrogen for the transport market.

While the project is still in the design phase, there are plans for it to be delivered as early as 2025, which would make it one of the world's first green hydrogen and green ammonia export projects.

[57] MEED: UAE and German firm sign hydrogen pact, 18 January 2021.

[58] https://www.moei.gov.ae/en/media-centre/news/11/4/2021/a-cooperation-agreement-between-uae-and-japan-to-explore-the-opportunities-available-in-the-field-of-hydrogen-development.aspx#page=1.

B. Aramco and Hyundai Oilbank Plan Blue Hydrogen Project

In March 2021, Saudi Arabia's state-owned energy company Aramco announced an agreement with South Korean industrial giant Hyundai to cooperate on a blue hydrogen project. The Hyundai Oilbank Company,[59] which refines hydrocarbons, will import Aramco's liquefied petroleum gas (LPG) into South Korea, where it will be used to produce blue hydrogen. During the production process, Hyundai will capture and store carbon dioxide, which will then be shipped to Saudi Arabia and provided to Aramco for use in carbon-based enhanced oil recovery. Furthermore, Hyundai Oilbank plans to build a LNG boiler by 2024, which will use blue ammonia (produced by Aramco) as feedstock.

Hyundai Oilbank intends to sell blue hydrogen as fuel for vehicles, part of a wider plan to establish 300 hydrogen charging stations across South Korea by 2040. Hyuandi Oilbank also intends to use the blue hydrogen as fuel for thermal power plants and utilize it to power desulphurization processes.

In order to develop the international infrastructure, Korea Shipbuilding & Offshore Engineering Company, a subsidiary of Hyundai Oilbank, is building ships capable of transporting LPG and carbon simultaneously, and it is also planning ammonia carriers as well as ammonia-fueled ships.[60]

C. Aramco Ships Blue Ammonia to Japan

In September 2020, Aramco shipped a cargo of blue ammonia to Japan for use in zero-carbon power generation, supplementing coal and natural gas. This was the outcome of a pilot study into zero-carbon power generations undertaken by Saudi's Aramco and Japan's Institute of Energy Economics, in partnership with Aramco subsidiary Saudi Basic Industries Corporation.[61]

III. Oman

A. Sumitomo and Ara Petroleum Hybrid Hydrogen Project

In March 2020, Japan's Sumitomo and Oman's Ara Petroleum signed a MOU in relation to a hybrid hydrogen project in Oman. They are currently conducting a feasibility study for a project that would involve the production of hydrogen from gases generated as a byproduct of oil and gas production at an Ara Petroleum refinery.

If the project goes ahead, it is expected to produce an estimated 300–400 tons of hydrogen annually from flare gas generated at the site. A 20 MW solar plant will be installed at the site to power the hydrogen production facility, and it is intended that the hydrogen produced will be used as fuel for fuel cell vehicles that Ara Petroleum will introduce at the site.[62]

[59] Aramco has a 17 percent shareholding in Hyundai Oilbank.

[60] MEED: Aramco signs hydrogen cooperation deal with Hyuandai, 3 March 2021.

[61] MEED: Saudi Aramco ships blue ammonia to Japan, 28 September 2020.

[62] MEED: Oman starts hybrid hydrogen study, 25 January 2021.

B. PDO Block 6 Green Hydrogen Project

Petroleum Development Oman (PDO) has engaged Hinicio, a Brussels-based consultancy firm, to undertake a feasibility study for the development of a green hydrogen pilot project within PDO's Block 6 cluster. The feasibility study should take about seven months to complete, and it will allow PDO to evaluate the viability of green hydrogen technologies before any commercial rollout.

According to a local media report citing PDO Corporate Research and Development Adviser Zakiya al-Azri:[63]

> PDO's pursuit of green hydrogen is driven by a desire to reduce its dependence on natural gas for its energy requirements while, at the same time, exploring low or zero carbon fuel alternatives as part of a commitment to reduce greenhouse gases responsible for global warming.

It is likely that the proposed green hydrogen pilot project will be supported by PDO's solar-paneled car park at Mina al-Fahal, Muscat, and the 100 MW Amin solar project.

C. Sohar Port Green Hydrogen Hub

In Oman, there are plans for Sohar Port and Freezone to become the country's first green hydrogen hub by using low-cost solar power to produce carbon-free green hydrogen, which will be used to help fuel clean vehicles and reduce onsite emissions.

The Sohar Port and Freezone is managed by Sohar Industrial Port Company, a 50:50 joint venture between the Port of Rotterdam and the Sultanate of Oman. Sohar is working in collaboration with the Port of Rotterdam, as well as Hydrogen Rise and other international research institutions, to identify cost-effective solutions for the utilization of hydrogen as an alternative to natural gas.

With excellent renewable resource conditions, coupled with the declining costs for solar photovoltaic power generation, Sohar intends to build electrolyzers at the port in order to produce a low-cost supply of green hydrogen, which can be stored for use on demand. Sohar will also be exploring the potential to use green hydrogen to power seagoing vessels.

Mark Geilenkirchen, chief executive officer of Sohar Port and Freezone, explained that "the hydrogen stored for later delivery (via pipelines and trailers) will be used by the port's industries and tenants for clean transport and industrial purposes." Geilenkirchen also stressed the need to scale up the hydrogen industry in order to bring production costs down and make hydrogen an economically viable alternative fuel, explaining that an industrial "scale-up will be critical to bring down the costs of technologies for producing and using clean hydrogen, such as electrolyzers, fuel cells and hydrogen production with CCUS."[64]

[63] MEED: Oman awards green hydrogen study, 28 February 2021.

[64] https://www.greenport.com/news101/lng/sohar-plans-first-green-hydrogen-hub-in-oman.

D. Acme SEZAD Green Ammonia Plant

Indian ACME Group has announced a collaboration with the Oman Company for the Development of the Special Economic Zone (Tatweer) and it intends to invest US$2.5 billion to set up a large-scale hydrogen facility in Duqm, Oman, that will be capable of producing 2,200 million tons of green ammonia per day. The two parties signed a memorandum of understanding (MOU), which sets out their ambition to produce green hydrogen and green ammonia from renewable energy, to support the energy transition, and to enable the integration of a higher proportion of renewable energy in both the transportation and manufacturing sectors. The planned facility will produce hydrogen through water electrolysis using renewable energy, and the hydrogen will then be processed into ammonia.

Speaking at a press conference in March 2021, founder and chairman of ACME Group, Manoj Kumar Upadhyay, said, "this is an exciting beginning of global alliances for producing green hydrogen and ammonia—the most important future source of energy that will help decarbonize the world."[65]

Upadhyay also said that the large-scale plant is "strategically planned to cater to international markets for supply of green ammonia across Europe, America and Asia region."[66]

E. DEME and OQ Green Hydrogen Plant in Duqm

In 2020, Belgium-based DEME International NV (DEME) and OQ, Oman's energy holding company, announced a joint project to develop a green hydrogen plant in the SEZAD, along with the Public Authority for SEZs and Free Zones (OPAZ). Duqm has the geographic advantage of abundantly available renewable energy (solar and wind); large, accessible sites; and access to Oman's port infrastructure.

Having jointly conducted a prefeasibility study for the project, which demonstrated the potential for such a project, OQ and DEME have moved to the engineering and design phase of the project. The electrolyzer capacity for the first phase of the hydrogen plant is expected to be between 250 and 500 MW. Following this first phase, the project can be scaled up, with a final capacity of 1 GW.

There are corresponding plans to develop a clean hydrogen facility at Oman's Sohar Port. An OPAZ site on Oman's windy coast has been reserved for the installation of a solar and wind park.

Dr. Ali bin Masoud Al Sunaidi, Chairman of the Board of Directors of OPAZ, said of the project:[67]

> The start of this cooperation between DEME and OQ is very important, not only for the project, but towards the biggest cause of placing Duqm as hub in the Hydrogen Value chain. The step is also complementing the recently announced decision of the Public Authority of Special Economic Zones and Free Zones of dedicating 150 square km of land for green energy projects in the Special Economic Zone at Duqm, in line with the Oman Vision 2040.

The facility is intended to contribute to the decarbonization of the regional industry in Oman, producing green hydrogen and its derivatives (such as green ammonia) for export to the international market, especially in Europe.

F. Oman, Hong Kong, and Kuwait Consortium Plan Green Hydrogen Project

In May 2021, an international consortium was formed, comprising Hong Kong-based InterContinental Energy, OQ, and EnerTech, a subsidiary of the sovereign wealth fund Kuwait Investment Authority. The consortium aims to establish a green hydrogen plant, and it is planning the development of a 25 GW solar and wind farm project in Oman's Al-Wusta Governorate, powering the electrolysis of water sourced from the Arabian Sea, to produce green hydrogen and its derivatives, such as green ammonia, for domestic, regional, and international markets.

The first production from the planned facility is expected from 2028, with the first phase of the project—comprising about one-third of the final capacity—expected to be completed in 2032, with the project expected to reach full capacity in 2038.[68]

IV. Egypt

A. Egypt and Siemens Plan Green Hydrogen Pilot

In January 2021, Egyptian Minister of Electricity and Renewable Energy Mohamed Shaker and Joe Kaiser, chief executive officer of Germany's Siemens, signed an agreement to explore a potential pilot project for the production of green hydrogen in Egypt. Although details of the location, capacity, and technology of the pilot project remain under discussion, the pilot project will be in line with Egypt's clean energy strategy to increase renewable energy sources.[69]

B. DEME Explores Green Hydrogen Production in Egypt

In or around March 2021, DEME signed an agreement with the Egyptian Ministry of Electricity and Renewable Energy, the Ministry of Oil and Mineral Resources, and the Egyptian Navy to conduct studies on the production of the low-carbon fuel in Egypt. This exploratory agreement falls squarely within Egypt's strategy to expand clean and green energy production, as well as increase the share of renewable energy in the electric energy mix.

65 https://www.h2-view.com/story/plans-for-2-5bn-hydrogen-facility-in-oman-unveiled/.

66 MEED: Firm plans $2.5bn hydrogen plant in Oman, 28 March 2021.

67 https://www.chemengonline.com/large-scale-renewable-hydrogen-project-to-launch-in-oman/.

68 MEED: Oman turns into a hydrogen hotspot, 19 May 2021.

69 MEED: Siemens and Egypt plan green hydrogen pilot, 19 January 2021.

PART VI – NEXT STEPS TO ENSURE MENA'S HYDROGEN FUTURE

It is clear that the Middle East and the wider MENA region have huge potential in the green energy sector, including hydrogen, and it will require a strategic, multilateral approach to develop the region's hydrogen potential. Below, we consider the key steps that need to be taken to ensure the countries of MENA can take the lead in the emerging hydrogen economy.

I. Legislation and Regulation

- Specific hydrogen-focused legislation and regulatory frameworks need to be developed and implemented. This includes downstream regulations, for example, regarding the manufacture of fuel cell cars, trucks, and buses.
- A supportive regulatory environment must be established, including a regulatory regime that incentivizes green hydrogen projects, for example, by introducing emissions schemes and providing financial support mechanisms.

II. Investment

- Governments need to allocate sums and create financing opportunities for investment in hydrogen projects and infrastructure, as well as create conditions to attract foreign investment.
- Because the hydrogen market is nascent, financiers tend to apply more onerous lending principles for hydrogen projects. The limited offtake opportunities for green hydrogen can cause concern for traditional debt financiers. Governments should seek to encourage private equity investors and pension funds to fill the liquidity shortfall.
- Sovereign wealth funds of the GCC should be advised to invest in the emerging hydrogen economy.
- Long-term investments must be made in cross-border transport infrastructure.

III. Infrastructure

- MENA countries need to exploit their advantage in terms of abundant solar energy and invest in industrial-scale solar plants alongside the development of technology for scaled-up hydrogen production.
- The MENA region is well placed to provide clean energy; so governments and industry should look for ways in which the clean energy can be utilized locally, developing a regional demand for clean energy that is regionally produced.
- The infrastructure for storing and transporting green hydrogen is not yet in place; exploiting existing ports and industrial infrastructure, MENA countries should focus on the development of integrated hubs that combine green hydrogen and ammonia infrastructure. The development of a reliable, cheap storage solution for renewables could be exported globally.

IV. Public-Private Partnerships

- Further alignment between governments and private sector companies with the requisite knowledge, experience, and capabilities should continue to advance.
- Public-private partnerships (PPP) need to be promoted to foster production and export infrastructure.
- Both the public and private sectors need to take a sensible approach to ensuring appropriate financing, construction, and operational structures can be formulated so as to make the hydrogen market appealing for investment, viable, and competitive. Existing relationships and structures that exist in the MENA PPP sector, for example, can be utilized in the development of green hydrogen plants.

V. Regional Cooperation

- There needs to be support for the utilization of green hydrogen and its fuel derivatives across major industries within the MENA region. This will provide a market for locally produced hydrogen and provide a launch pad for international expansion. For example:
  - » Blending hydrogen into existing domestic and regional gas networks to boost local demand.
  - » Local government deployment of hydrogen-powered public transport vehicles.
  - » Using hydrogen to power state infrastructure, such as airports.
- Regional and domestic carbon-pricing regimes should be developed in order to facilitate regional utilization of green hydrogen and to realize its potential to decarbonize polluting industries.
- As yet, there is no regional strategy for the development of hydrogen infrastructure. Governments across MENA should work together to develop a regional program for infrastructure and logistical development.

VI. International Cooperation

- Attention needs to be given to identifying and developing relationships with potential markets and off-takers in key demand centers such as Europe, North America, and Asia (notably Japan and South Korea).

VII. Government Targets

- Governments, government bodies, and the public sector must ensure that a supportive environment exists from which to build a competitive hydrogen sector and export offering. Governments should consider encouraging investment in clean energy opportunities by reducing or alleviating taxes for green hydrogen projects and potentially consider the introduction of penalties or a higher tax burden for carbon-heavy energy projects.
- National plans and visions should continue to be developed. It may even be necessary to strictly require and enforce decarbonization limits in certain sectors. Hydrocarbons will remain prevalent in the MENA energy portfolio. However, the carbon footprint of the MENA hydrocarbon industrial base can be offset in the short term with the employment of green technologies, such as CCUS.
- Hydrogen production may be prioritized in the region's state-owned oil and gas companies, such as ADNOC, QP, and Aramco. These energy giants will undoubtedly be able to utilize and adapt their traditional hydrocarbon industrial models to green hydrogen, as they already have the infrastructure, expertise, and capital necessary to develop clean energy and hydrogen technology and infrastructure.

GLOSSARY MIDDLE EAST

Acronym	Description
ADNOC	Abu Dhabi National Oil Company
ADQ	Abu Dhabi Developmental Holding Company
Aramco	Saudi Arabian Oil Company
CCUS	carbon capture utilization and storage
DEME	DEME International NV
DEWA	Dubai Electricity & Water Authority
ESMA	Emirates Authority for Standardization and Metrology
GCC	Cooperation Council for the Arab States of the Gulf
GHG	greenhouse gas
GW	gigawatt
IEA	International Energy Agency
INDC	Intended Nationally Determined Contribution (Paris Agreement)
IRENA	International Renewable Energy Agency
KNPC	Kuwait National Petroleum Company
LNG	liquefied natural gas
LPG	liquefied petroleum gas
Mubadala	Mubadala Investment Company
MENA	Middle East and North Africa region
METI	Ministry of Economy, Trade, and Industry
MHI	Mitsubishi Heavy Industries
MOU	Memorandum of Understanding
MW	megawatt
NDCs	Nationally Determined Contributions (Paris Agreement)
OQ	Oman Oil and Orpic Group
OPAZ	Oman Public Authority for Special Economic Zones and Free Zones
PDO	Petroleum Development Oman
PPP	Public-Private Partnership
QP	Qatar Petroleum
SEZ	Special Economic Zone
SEZAD	Special Economic Zone at Duqm, Oman
Tatweer	The Oman Company for the Development of the Special Economic Zone at Duqm
UNFCCC	United Nations Framework Convention on Climate Change

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