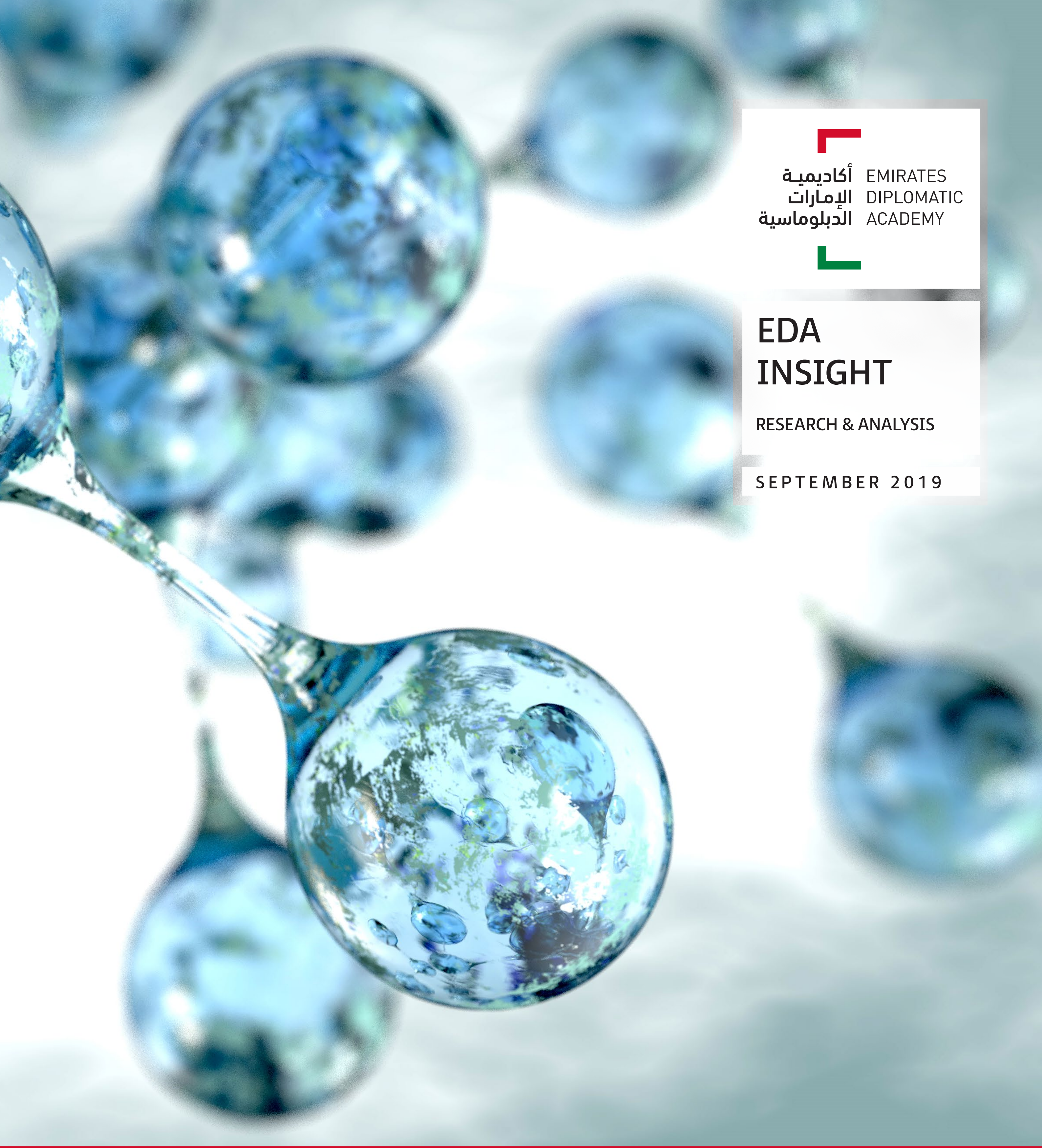

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Breakthrough of Hydrogen Technologies until 2030:
Chances and Risks for Gulf Countries, International Policy Implications

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Executive Summary

◊ The year 2018 saw the emergence of a broad social movement demanding stringent policies for climate change mitigation in Europe and other world regions. Widespread meteorological extreme events consistent with rapid global warming are stoking this movement. Especially in Europe, it has already changed the political landscape in a number of countries as green parties have scored record votes. Therefore, policymakers in many countries are sharpening their emission reduction targets for 2030 and 2050.

◊ At the same time, strong interest in an integrated hydrogen economy is emerging, where hydrogen would become a key fuel for transportation, industrial uses and even electricity generation. Countries as diverse as Australia, China, European Union (EU) member states and Japan are embarking on far-reaching strategies for a hydrogen economy, starting with the support of fuel-cell electric vehicles (FCEVs) but reaching beyond the transport sector.

◊ Hydrogen production technologies are manifold: feedstocks include fossil fuels and renewable electricity. At present, the costs of 'green' hydrogen, which is produced with renewable electricity, are still about five times higher than those of gas or coal-based hydrogen. An expansion of green hydrogen production, however, is likely to close the gap within less than a decade. Especially promising are emerging technologies that allow to use hydrogen as a fuel in existing thermal power plants without major refurbishment.

◊ The Gulf region faces a significant risk of oil exports becoming squeezed by a successful hydrogen revolution in the next decades. At the same time, Gulf countries are blessed with abundant solar energy resources that can easily be used for green and low-cost hydrogen production at large scale. Therefore, it is recommended that they proactively participate in this revolution, also given the region's long experience with pipeline and ship transport of other flammable materials. Early movers are likely to benefit from scale effects and become leaders in the market, especially if there are lock-in effects for hydrogen supply chains – i.e. hydrogen importing countries wanting to continue to procure from suppliers with which they have long-term experience.

◊ The UAE is already a leader in the Middle East with the first solar hydrogen electrolysis plant under construction in Dubai and a fledgling FCEV fleet. Given its success in bringing down the cost of solar, the UAE would be in an excellent position to achieve the lowest global cost of green hydrogen production. With both the World Expo hosted by Dubai and the G20 presided by Saudi Arabia in 2020, the UAE could leverage either of these platforms to establish, and host, a high-profile **International Hydrogen Economy Initiative** (IHEI). This initiative could serve as a policy coordination tool between hydrogen importers and exporters, initially focusing on accelerating interactions between the Gulf region – a potential supplier – and Japan and the EU who both are likely to become key hydrogen importers in the next decade based on their self-defined energy policy targets.

The Issue

For many years, the international negotiations on the UN Framework Convention on Climate Change (UNFCCC) have been aiming to limit global temperature increase to a level that is not dangerous for humanity. Over the last 20 years, governments of many key countries have introduced numerous policies to reduce greenhouse gas (GHG) emissions. Nevertheless, global GHG emissions are still growing due to the consumption and production of goods and services increasing more quickly than the GHG emissions intensity of the production process is decreasing.

In the past, policy makers have shied away from implementing effective climate policy instruments with stringent targets. The reasons for this are manifold and range from pushback from industrial lobbies through concerns related to costs, jobs and international competitiveness, to fears of taking unpopular decisions and disgruntling potential voters.

On the international level, an agreement on mandatory, ambitious GHG reduction targets has so far been prevented due to the requirement to achieve consensus in the UNFCCC decision-making process and, consequently, the inability to achieve consensus about distributing the required reductions among countries. The Kyoto Protocol, which would have allowed such an approach, was replaced by the Paris Agreement which is a pure 'bottom-up' system with non-mandatory, self-determined national GHG reduction pledges ('NDCs'), which for most countries still lack the required level of ambition to avoid dangerous climate change. Moreover, in various key countries populists have come to power on an openly 'climate sceptic' platform since 2016, exemplified by US president Trump and Brazilian president Bolsonaro.

Recently, however, the political landscape has started to change drastically in key regions. The acceleration of global temperature increase from 2014 onwards and extreme weather events, such as the unprecedented European drought in 2018, historical temperature records in North-Western Europe shattered by over 2°C in June and July 2019, and repeated heat waves in Australia, India, Japan and the Middle East, combined with what has become a global grassroot movement, *Fridays for Future*, do not only create public awareness but also strong political pressure.

As a consequence, key economic regions such as the EU are now preparing for real and ambitious emission reductions. In late 2018, the European Commission announced the target to become CO_2 neutral by 2050.[1] The Commission's legal proposal is now being processed by the European Parliament and Council which normally takes one to two years before formal adoption.

In the meantime, over the past decade numerous scientists, inventors and practitioners have put enormous efforts into developing technical solutions for GHG reduction. The success of technologies in the field of renewable energies such as wind and solar power is uncontested, and in many areas they are now the cheapest electricity generation options.[2] However, renewables still suffer from the challenge of providing baseload power due to their intermittency and the still high costs of electricity storage.

Less noticed to date, but intensively discussed in expert circles, is the progress in the development of innovative hydrogen technologies. They have the potential for far-reaching interventions within the next couple of years. If only some of this potential materialises, the vision of hydrogen economies – where hydrogen replaces coal, oil and natural gas and becomes the dominant fuel, particularly for heating and vehicles – can become reality within one to two decades. Hydrogen solutions could also be linked with intermittent renewable energy technologies to further optimise outputs and cost-effectiveness.

The emergence of hydrogen economies might lead to a significant reduction in global demand for conventional fuels such as coal, natural gas and oil. While this is a significant risk for any oil-exporting country, there might also be strategic chances for Gulf countries to benefit economically from this future demand. In order to be well-prepared and in a position to take early action, a systematic and comprehensive analysis is required.

This EDA Insight provides an overview of the current global climate and energy policies, the state of hydrogen technologies and demand today and until 2030. From this, it derives recommendations for how Gulf countries could position themselves in the emerging hydrogen markets, also with a view to economic diversification.

2020s: Tipping Point of Global Energy and Climate Policies?

Underpinned by a probable further expansion of the public movement to aggressively engage in GHG mitigation policy, Europe is likely to again become a global leader in climate policy. In July 2019, the designated new European Commission President Ursula von der Leyen, announced that she will increase the ambition of the current GHG emission reduction targets with a view to achieve a 50% reduction (compared to 1990) by 2030, and GHG-neutrality by 2050.

In light of the insufficient level of ambition in existing NDC targets and increasing public pressure to act on climate change, UN Secretary-General António Guterres convened a UN Climate Summit in September 2019, with the objective to agree on concrete plans to enhance the NDCs by 2020, 'in line with reducing greenhouse gas emissions by 45 per cent over the next decade, and to net zero emissions by 2050'.[3]

A potential Democratic successor to president Trump in the US and a reinforcement of East Asian and Oceanic climate policy engagement together could lead to a 'tipping point' in the early 2020s towards ambitious climate policies both on the national and international level.

With regards to the hydrogen economy, a joint leadership between Europe, Japan and Australia could emerge. In a global comparison, Europe has been providing the highest governmental R&D budgets for hydrogen and fuel cells since 2011 – between US$250–400 million annually.[4] Japan has the objective to become the first hydrogen economy in the world and aims to reduce its strong dependency on imported fossil fuels, which currently cover 93% of the country's energy use.[5] 'Green' hydrogen, derived from renewable energies, as well as 'brown' hydrogen, made CO_2-free through carbon capture and storage (CCS), have been identified as technological solutions both for national energy security and the climate change challenge. Japan currently provides approximately US$150 million in governmental R&D support for hydrogen per year.[6]

In Australia, an intense political discussion about a shift from being a fossil fuel to a hydrogen exporter has erupted in recent years. The country, being the world's largest net coal exporter (with approximately 32% of global coal exports,[7] is well-aware that coal has no long-term perspective and is heavily investing in the development of hydrogen production.

Over the last years, the Morrison government has invested about AU$100 million (US$70 million) to develop Australia's hydrogen industry. In June 2018, Japan and Australia signed a memorandum of understanding designed to address 'contemporary energy challenges', including hydrogen. A 'cooperation in establishing a future hydrogen supply-chain and industry' has high priority for the two countries.[8]

Since 2016, China too has ramped up research spending on hydrogen technologies to a level of about US$100 million per year, apparently due to a very strong interest in finding clean alternatives to coal and diesel, which are the main sources of high local air pollution levels in key cities. In 2000–2010, the US invested over US$400 million per year in hydrogen R&D, but has drastically lowered its engagement, to US$100 million annually today.[9]

To conclude, Australia, China, the EU and Japan are currently the most active countries working towards hydrogen economies, with Australia having a focus on the hydrogen production side and the EU and Japan on the consumption side. China's role is still unclear – it has potential to generate large demand, but could also build strong domestic supply chains.

With increasing pressure to effectively fight climate change, governments in these countries/regions can be expected to intensify public efforts to allow a quick development of green hydrogen economies.

Overview of the State of Hydrogen Technologies and Demand Today and Until 2030

From 2000–2018, global hydrogen (H_2) demand has increased by 65%, from 70 Mt H_2 to 115 Mt H_2.[10] Traditionally, most hydrogen has been used in the chemical industry, for fertilizer production, metal treatment and food production.

Interest in using hydrogen as fuel for private and commercial vehicles developed in the late 1970s due to the oil price shocks and scenarios of quickly decreasing oil reserves. Bringing fuel-cell driven cars to technical and commercial readiness took quite some time, also due to the fact that – as we know today – oil reserves were not as limited as thought in the early 1980s and price levels remained at moderate levels (thus decreasing pressure for technological innovation).

But since the early 2000s, the first fuel-cell driven cars and SUVs are on the road (see Box 1), and the global industry initiative Hydrogen Council (see Box 2) estimates that by 2030, close to 10% of cars sold in key industrialised countries could be hydrogen-driven fuel-cell electric vehicles (FCEVs).[11]

In 2018, the South Korean car producer Hyundai announced a production capacity target of 0.5 million FCEVs for 2030 with an investment volume of US$6.7 billion.[12] The German-based technology provider Bosch expects that in 2030 20% of all electric vehicles

Box 1: Electric Vehicles (EVs) Versus Fuel Cell Electric Vehicles (FCEVs)

Electric vehicles (EVs) are driven by electricity that is stored in an on-site battery. Charging can take place at home or a public EV-charging stations. While the technology has progressed significantly in the last decade, its key challenges remain, including limited range, weight of the batteries and long recharging times (1 to 14 hours, depending on the capacity of the charger). Additional problems associated with EVs are the environmental impacts of battery production.

Contrary to this, fuel-cell electric vehicles (FCEVs) are powered by hydrogen that is converted in a fuel-cell into electric energy. FCEVs therefore do not need as large a battery as EVs. Hydrogen is stored in a tank similar to that for gasoline/diesel in conventional cars, and the re-fuelling process is quick. The range of FCEVs is comparable to that of a conventional car. Today's challenges include that hydrogen cars are still very expensive due to the lack of mass production and that the underlying infrastructure, such hydrogen fuel stations, has yet to be built.

worldwide will be FCEVs.[13] It recently engaged in a strategic partnership with Powercell Sweden, aiming to start commercial serial production of hydrogen fuel cells for heavy-duty commercial vehicles. Other world leading car-manufacturers such as Daimler, Toyota, Honda and Renault have built FCEVs that are ready for the market. Ford, TATA Motors and Indian Oil Corporation have built prototypes and are undergoing road trials. To conclude: despite a slow onset, FCEVs are now about to reach a critical momentum, and so is the required infrastructure, which includes hydrogen fuel stations.

Fuel-cell driven cars are only one market segment within the transport sector. The first hydrogen-powered trains built by Alstom started operating in the public regular service in Germany in 2018, and several communities have ordered dozens of additional ones. Hydrogen-driven buses are operated in several cities worldwide – currently with a low but increasing scope.

However, perhaps the most important aspect is that increasing demand for hydrogen is not limited to the transport sector. Industry as well as large technology providers such as Siemens and General Electric have started preparing their power and industrial plant technologies, such as burners and torches, for being capable of utilising H_2-blended fuels. Examples range from hydrogen boiler designs (e.g. from Mitsubishi-Hitachi Power Systems), to hydrogen-to-steam generators where water gets injected into the combusted hydrogen/oxygen stream and to non-catalytic, flameless oxidation technologies. All these initiatives could accelerate global hydrogen demand tremendously.

Last but not least, technologies are emerging that would allow efficient utilisation of hydrogen in conventional thermal power plants by the mid-2020s without the need for major refurbishments, thus directly replacing fossil fuels such as coal, natural gas or oil. This has the potential for a quick revolution of the global electricity generation system. In 2018, about 40% of global

Box 2: Industry Initiative – The Hydrogen Council

The Hydrogen Council, launched in early 2017 at the World Economic Forum in Davos, is a global CEO-led advisory body providing long-term vision on the role of hydrogen technologies towards a global energy transition – in mobility as well as in the power, industrial and residential sectors.

As of mid-2019, the Hydrogen Council is composed of over 60 CEOs and chairpersons from large, global companies such as 3M, Airbus, Air Liquide, Air Products, Alstom, Anglo American, Audi AG, BMW GROUP, BP, China Energy, Cummins, Daimler, EDF, ENGIE, Equinor, Faurecia, General Motors, Great Wall Motor, Honda, Hyundai Motor, Iwatani, Johnson Matthey, JXTG Nippon Oil & Energy Corporation, Kawasaki, KOGAS, Linde, Plastic Omnium, Royal Dutch Shell, Sinopec, The Bosch Group, Thyssenkrupp, Total, Toyota and Weichai.

The Council invites governments and key society stakeholders to join the companies in discussing the contribution of hydrogen to the energy transition and to collaborate to create an effective implementation plan.

The main outputs so far have been the coordination and funding of studies to support further development of the hydrogen industry. The Council for example contributed the 'Future of Hydrogen' report with the International Energy Agency and Japanese Ministry of Economy, Trade and Industry (METI), published at the G20 Summit in Osaka in June 2019.

For more information, see: Hydrogen Council, 2017, *Hydrogen Scaling Up: A Sustainable Pathway for the Global Energy Transition.*

electricity generation was fuelled by coal and oil,[14] equalling to a total installed capacity of 2,500 GW.

Assuming that by 2030, 10% of the installed capacity – or 250 GW, equivalent to 250 large-scale lignite power plants – would be converted to hydrogen fuel, the additional hydrogen demand would be 120-170 million tonnes of pure hydrogen annually. Comparing this to today's hydrogen consumption of 70 million tonnes/ year demonstrates the tremendous potential of the future hydrogen market.

As will be discussed in more detail below, given the renewable energy potential of the Gulf region, this brings outstanding opportunities to Gulf Cooperation Council (GCC) countries to not only diversify economically but also tap into new energy export market segments, as hydrogen has the potential to replace coal, and thus has a much broader demand spectrum compared to oil.

There are many different technological options to produce hydrogen, based on fossil fuels or electricity. They include steam methane reformation of natural gas (SMR), coal gasification and different forms of electrolysis such as proton-exchange membrane (PEM) technologies. The former two types of technologies lead to GHG emissions, the latter are emissions-free if the electricity comes from renewable sources.

Until today, the key challenge for scaling up hydrogen to a level that it can fuel whole economies is the high level of hydrogen production costs. SMR based on natural gas without carbon capture, utilisation and storage (CCUS) currently has the lowest cost and is therefore the most widespread option for hydrogen production. Costs range from US$0.9/kg H_2 (Middle East) to US$1.8/kg H_2 (Europe) and increase by approximately US$ 0.5/kg H_2 if carbon capture and storage (CCS) is added.[15] Today's costs for producing hydrogen from renewable electricity using PEM electrolysis reach US$4.2–5.2/kg.

The cost gap between fossil and 'green' hydrogen thus currently reaches a factor of five. However, it is likely to fall rapidly. Forecasts for 2025 expect a 60% decrease in green hydrogen production costs, to US$1.6–1.9/ kg.[16] This is mainly due to improvements in the scale of operation and improved capacity factors. At that level, fossil and green hydrogen will be in the same cost range, and national carbon pricing policies would then shift the balance in favour of the 'green' hydrogen producers. This is because carbon pricing schemes make fuels that result in carbon emissions more expensive. Hence, if hydrogen production results in CO_2 emissions, these emissions would be accounted for in the emission balances of companies subject to the carbon pricing scheme. As a result, these companies would rather buy green hydrogen than 'black' hydrogen (i.e. produced from fossil fuels without CCS) or brown hydrogen (i.e. produced from fossil fuels, but with CCS).

It is important to keep in mind that even brown hydrogen production results in CO_2 emissions of 1–2 kg CO_2/ kg H_2 under CCS[17], compared to 0 t CO_2/kg H_2 for green hydrogen.

A largely scaled-up demand for hydrogen could lead to even more rapid cost decreases due to scale effects. The next section looks at emerging policies that could drive such an accelerated scenario.

International Governance Frameworks and Policies Impacting Hydrogen Demand and Technology Development

Globally, the first initiatives for governance of large-scale hydrogen infrastructures are emerging on the fringes of larger policy processes. The Group of Twenty (G20) has started to address the issue under the Japanese presidency in 2018/2019. It was set as a priority following a Hydrogen Energy Ministerial meeting held in Tokyo in October 2018, which brought together representatives of 21 countries. At a special meeting in June 2019, the 'G20 Karuizawa Energy Innovation Action Plan' was agreed which stresses the role of hydrogen.[18]

Under the Clean Energy Ministerial (CEM, set up by the US in 2009), a dedicated Hydrogen Initiative launched in 2019 has brought together Canada, the EU, India, Japan, Korea, the Netherlands, New Zealand, Norway, Saudi Arabia and the US. Its initial focus will be on promoting successful deployment of hydrogen within current industrial applications, enabling deployment of hydrogen technologies in transport and exploring the role of hydrogen in meeting the energy needs of communities. The International Energy Agency (IEA) serves as coordinator.

The initiative with the longest history is the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE), established in 2003, with the aim to accelerate the transition to clean and efficient energy and mobility systems using fuel cells and hydrogen (FCH) technologies. It has 20 members including the largest emerging economies (Brazil, Russia, India, China and South Africa), Australia, Japan and various smaller countries, mostly from Europe. The Gulf Region so far is not represented.

Box 3: Examples of Political Hydrogen Initiatives / Programmes in Selected Key Countries

- In the European Union, a €170 million project for hydrogen-fueled cars is currently in its second phase – to demonstrate the practicability of FCEVs and to expand the hydrogen fuel station grid in the EU.
- China, with its burgeoning population of motor vehicles, aims to shift vehicles away from fossil fuels quickly in order to reduce local air pollution, which has emerged as one of the key political challenges for the government. After a successful electrification of short distance vehicles, with 250 million two-wheelers and 0.4 million city buses currently on Chinese roads, Wan Gang, Minister of Science and Technology, is now aiming to roll out FCEV buses and trucks for long-distance transport. Various Chinese cities are putting additional FCEV buses on the roads, with Shanghai aiming at 3,000 by 2020. In 2018 alone, China invested US$12.4 billion into supporting hydrogen fuel cells for vehicles.
- Japan recently reiterated its target to become the world's leading hydrogen economy and has developed a comprehensive hydrogen strategy aiming to achieve cost parity of hydrogen with fuel gas and liquified natural gas (LNG). For reaching this target, Japan has already invested US$1.5 billion in R&D over the last years. For the 2020 Tokyo Olympics, US$380 million will be spent on 35 hydrogen fuel stations and 6,000 FCEVs; the national target for FCEV rollout for 2030 is 0.8 million.
- In February 2019, the construction of the first Middle Eastern solar water electrolysis facility started in Dubai, operated by Dubai Electricity and Water Authority and with a 250-tonnes annual capacity. It uses technology of the German company Siemens. The Expo 2020 Dubai will operate FCEVs with the hydrogen generated by the facility. The first hydrogen filling station in the Middle East was opened in Dubai in October 2017. A total of 55 Toyota Mirai FCEVs are running on the UAE's roads, and Air Liquide et al. estimate that 12 hydrogen fueling stations would be sufficient to cover the nation's hydrogen fuel demand, Also, Abu Dhabi Police has announced plans to convert its vehicle fleet to FCEVs by the 2050s.

Sources used: Air Liquid, Khalifa University, Al Futtaim Motors, 2018, *Hydrogen Mobility: Hydrogen Mobility in the UAE*, authored by Maram Awad, October 2018.

As the IEA points out in its landmark study 'The Future of Hydrogen' commissioned by the Japanese G20 presidency, the number of countries with policies that directly support investment in hydrogen technologies is increasing, as is the number of targeted sectors.[19] By mid-2019, about 50 hydrogen supporting policies and incentives were active globally. The most active countries were Australia, China, the EU and its member states, India, Japan, Korea, New Zealand, South Africa and the US (in particular California) (see Box 3).

Besides policies and measures that target hydrogen directly, national climate and energy policies can have a huge indirect impact on the economic attractiveness of hydrogen. For example, carbon pricing through GHG emissions trading schemes, CO_2 taxes/fees or taxes on fossil fuels can play a key role in closing the cost gap between green and fossil hydrogen as well as conventional fossil fuels.

Strong carbon pricing might make the European Union the most attractive hydrogen market for the years to come. The EU emissions trading scheme (EU ETS) covers emissions from more than 11,000 heavy energy-using installations (power stations and industrial plants) and thus around 45% of the EU's GHG emissions. The latest reforms of the EU ETS are showing their effect: since mid-2017, prices for the so-called EU-allowances (equalling the permit to emit 1 t CO_2-eq) have more than quadrupled and reached record levels of €30/t CO_2 in July 2019.

CO_2-prices at this level can become an effective and quick game-changer, as they increase the economic attractiveness of CO_2-free hydrogen compared to fossil fuels. Take the example of coal-fired power plants: older plants typically emit about 1 t CO_2/MWh. If an innovative hydrogen technology allows the refurbishment of that plant and a fuel-switch to green hydrogen, then a 500 MW power plant can free about 3.5 million EU-allowances per year – equalling about US$110 million/year, or US$1 billion during a nine-year compliance period.

Those numbers show that hydrogen may quickly become economically viable – and potentially even highly attractive – in countries with strong climate policies. It is important to note that it is likely that countries such as the EU will define hydrogen eligibility criteria, which would mean allowing only green hydrogen from renewable energies and rejecting hydrogen produced from fossil fuels (even if it has a CCS-component).

Once a certain level of hydrogen demand is established, significant production cost reductions can be expected. The history of renewable electricity generation costs is an instructive example of such an effect. Globally, levelised costs of electricity generation have fallen by 77% for solar photovoltaics (PV), by 45% for concentrated solar power (CSP) and by 34% for onshore wind between 2010 and 2018.[20] This analogy shows that the sizeable cost reductions for green hydrogen production can be achieved with sufficient demand in a few years. It therefore appears that hydrogen is very close to a tipping point.

Gulf Country Interests in Today's and Future Hydrogen Markets – Analysis of Chances and Risks for Oil Exporting Countries

So far, many – but not all – policymakers in the GCC countries have hoped that the sustained global increase in energy demand would override any attempts to decarbonise economies and thus allow to continue to sustain GCC economies mainly on oil and natural gas exports. A successful hydrogen revolution would jeopardise this basic tenet, as it would lead to a replacement of oil and natural gas in all sectors of the economy – transport, industry and electricity generation.

In order to prevent such a scenario, GCC policymakers will have to decide how and when to engage proactively in the hydrogen economy. The worst case would be that policy makers in the region take a decision too late and by then the region has already been left behind by other world regions that have built a full hydrogen infrastructure.

GCC policymakers may think that their contribution to a hydrogen economy could be based on cheap fossil feedstocks. This may be true in the short term, but not in the long term. From a climate policy point of view, only CO_2-free hydrogen is interesting. Contrary to this, hydrogen production based on coal, natural gas or fossil-fuel-based electricity will lead to GHG emissions (unless combined with CCS) and is therefore unfavourable. Hence, the world will demand CO_2-free hydrogen that can either be produced from renewable-energy based electrolysis or from for example natural-gas based SMR combined with CCS.

It must be noted that CCS is often seen as environmentally problematic due to the risk of future leakages or seepages and the decrease in energy efficiency due to energy consumption for capture. Consequently, one can assume that demand for green hydrogen from renewable energies will be higher and a price premium may emerge. Another scenario is that key importers such as the EU will define restrictions that only allow renewable-energy derived hydrogen to be used without carbon penalties. It is important to keep in mind that the EU has always opposed CCS projects under the UNFCCC. **For these reasons, one can expect a significantly higher and more stable demand for green hydrogen than for brown or even black hydrogen.**

Many countries and regions that will have a high hydrogen demand – such as the EU and Japan – do not have sufficiently attractive resources for solar and wind installations required to produce the hydrogen to cover their demand. This gives a competitive advantage to countries with abundant resources such as the Gulf region which is situated in the world's sun belt. In the context of a hydrogen economy, this endowment can become a crucial basis for a high competitiveness as producers of hydrogen for export. If GCC countries were to adopt this role, it would even allow them to retain the basic business model of the oil era which is based on cheap production of a universally used fuel for transport and heat generation.

In contrast to the oil business, in a hydrogen economy, Gulf countries will compete with a broader set of countries that can be roughly equated with the members of the International Solar Alliance[i] and some places with abundant wind energy such as Argentina, Chile or Peru. But many of these countries, especially in Africa, are lacking the investment capital and business environment to rapidly engage in hydrogen production and export.

If initial investments in renewable energy are made at a level sufficient to generate economies of scale, and coupled with an appropriate transport infrastructure, the first mover will generate a lock-in in terms of customer retention, especially if the country manages to agree on long-term delivery contracts. This has been seen with natural gas delivery in the past. Ideally, the GCC would develop a joint strategy to maximise cost reduction. This strategy could – based on the past

[i] For more information see: http://isolaralliance.org/

successful efforts of the UAE – be aimed at achieving the lowest solar electricity generation costs in the world – achieved by the PV and CSP components of Dubai's Mohammed bin Rashid Al Maktoum Solar Park.

With regard to transport infrastructure, the region's decades of experience with pipeline and shipping infrastructure can also be harnessed to implement a hydrogen pipeline and port network able to deliver hydrogen to the whole world.

An International Policy Framework to Facilitate Gulf Countries' Participation in Emerging Global Hydrogen Markets

The early 2020s are likely to see the emergence of a global hydrogen economy, driven by heavyweight frontrunners such as Japan, the EU, China and Australia. While the two latter countries have sufficient domestic renewable electricity potential to generate their own hydrogen supply (China alone had a curtailment of 100 TWh renewable electricity in 2018 which could have been put to good use in hydrogen production), Japan and the EU do not have a significant domestic hydrogen generation potential.

Therefore, both Japan and the EU will need to identify regions that could produce, process and transport hydrogen in the required quantities and become preferred trade partners. The GCC countries have historically close oil trading relationships with these regions which can be built on. GCC countries can also become technology partners for key players from Europe and Japan, as exemplified by the Siemens–DEWA collaboration on the pilot solar hydrogen plant in Dubai (see Box 3). While the UAE has so far been more of an observer in terms of international governance and events focused on hydrogen, the upcoming World Expo 2020 provides an excellent opportunity to become seen as a proactive player in the field.

A high-profile **International Hydrogen Economy Initiative** (IHEI), launched for example in the context of Saudi Arabia's G20 presidency in 2020 – going beyond the current international initiatives in scope and resources – could even further enhance the profile of the region. In order to be successful, such an initiative would need a permanent administrative infrastructure which could be offered by either the UAE or Saudi Arabia.

Here, the successful experience of the UAE in hosting the International Renewable Energy Agency (IRENA) could be harnessed. Within a decade, IRENA has become a premier hub for renewable energy-related data and an opinion leader, convener of high-level debates and facilitator of project investments in developing countries. It is therefore recommended for the UAE to rapidly undertake:

- A detailed strategic assessment of the economic potential for green and brown hydrogen with the time horizons 2030 and 2050, including a technical and economic cost-benefit analysis looking at different options for hydrogen production, storage and transportation;
- A detailed and comprehensive analysis of hydrogen, energy and climate policies in key countries and regions that will likely become hydrogen importers with the time horizons 2025, 2030 and 2050;
- Proactive participation in international discussions under G20, CEM and IPHE on hydrogen standards, including transportation, safety and environment; and
- A pilot initiative for green hydrogen export and use under the market mechanisms of Article 6 of the Paris Agreement on climate change. This could be conducted jointly with the EU, given that the new European Commission is likely to engage more proactively in market mechanisms, with Switzerland where hydrogen is gaining significant domestic policy traction, or with Japan which has proactively been using its Joint Crediting Mechanism (a bilateral carbon offset mechanism) as an Article 6 pilot. Such a green hydrogen pilot could be built on the DEWA solar electrolysis plant and signed at the World Expo 2020.

If the IHEI idea gains traction, it could serve as a policy coordination tool between hydrogen importers and exporters. In order to generate mutual benefits, exporters could commit to hydrogen export price reductions indexed on export volume increases, while importers would sign long-term contracts ensuring viability of the investments. Moreover, the definition of international standards for hydrogen transportation and safety as well as joint investments in international transport infrastructures could be orchestrated through the IHEI.

List of Acronyms and Abbreviations

CCUS – carbon capture utilization and storage
CEM – Clean Energy Ministerial
CO_2 – carbon dioxide
CSP – concentrated solar power
FCEV – fuel-cell electric vehicle
FCH – fuel cells and hydrogen
GHG – greenhouse gas
H_2 – molecular hydrogen
IEA – International Energy Agency
IPHE – International Partnership for Hydrogen and Fuel Cells in the Economy
IRENA – International Renewable Energy Agency
LNG – liquefied natural gas
PV - photovoltaic
NDC – nationally determined contribution (Paris Agreement)
SMR – steam methane reformation of natural gas
PEM – proton-exchange membrane
UNFCCC – UN Framework Convention on Climate Change

Endnotes

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