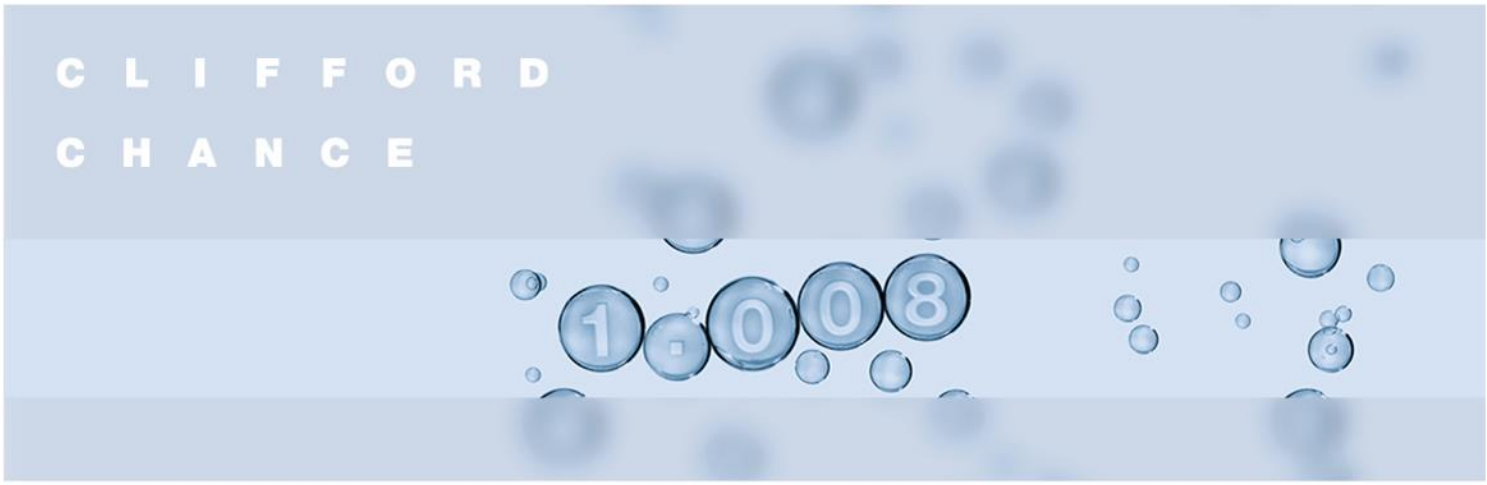

FOCUS ON HYDROGEN: THE NEW OIL IN THE MIDDLE EAST?

The development of clean energy resources continues to evolve across the Middle East. A region more readily associated with conventional energy resources such as oil and gas, the Middle East also has significant solar and wind energy capacity, with some of the world's largest and cheapest solar and wind projects found in the UAE, Saudi Arabia, Oman and Qatar. The region is now looking to diversify its economy through the production of clean hydrogen, capitalising on the availability of existing oil and gas infrastructure and cheap renewable generation.

WHY CLEAN HYDROGEN?

Clean hydrogen is likely to play a significant role in global energy transition and could be instrumental in meeting decarbonisation targets. Owing to its abundance and characteristics, it has versatile applications – be it as a replacement for fossil fuels in chemical production and other industrial processes, as a means of storing and producing electricity or as a fuel source for powering vehicles, ships and trains. It can be stored for significant periods of time and can be readily transported over long distances, making it a potentially lucrative export product for countries that are well placed to produce it.

However, electrolytic hydrogen currently makes up only 4% of global hydrogen production. For clean hydrogen to become a real alternative to the use of fossil fuels, it will need to be rapidly scaled up.

OPPORTUNITIES IN THE MIDDLE EAST

The Middle East (and the GCC countries in particular) have a number of competitive advantages that make it well placed to capitalise on the global shift towards clean hydrogen, potentially enabling it to meet future energy demands not just domestically but also internationally.

Abundance of renewable resources

At a basic level, surplus solar and wind energy can run electrolysers that convert water into hydrogen. The Middle East has some of the largest and cheapest solar and wind projects in the world, benefitting from high solar irradiation levels, strong and regular wind (in certain areas) and, importantly, large areas of land suitable for project development. It is no surprise that the region plays host to superlative projects such as the world's largest solar PV

The hydrogen colour spectrum

The categorisation of hydrogen by colour is determined by the production process applied for its extraction and the underlying source of energy used:

- **Green hydrogen**: production by electrolysis of water in an electrolyser powered by electricity produced from renewable sources.
- **Grey hydrogen**: production by steam methane reforming powered by natural gas.
- **Black hydrogen**: production by steam methane reforming powered by coal.
- **Blue hydrogen**: production by steam methane reforming but the process is made cleaner through the use of carbon capture technology to reduce carbon emissions.
- **Pink hydrogen**: production by electrolysis of water in an electrolyser powered by nuclear energy.
- **Turquoise hydrogen**: production by pyrolysis powered by natural gas or biomass.

plant (Al Dhafra at 2GW) and the world's largest reverse osmosis desalination plant (Taweelah) – both projects on which Clifford Chance advised.

Funding availability

The Middle East region has a history of investing heavily in clean energy projects through a combination of sovereign funds, government backed entities, international investors and lending institutions. Ambitious clean energy targets and governmental support for a regional hydrogen economy suggest that funding should be available in the Middle East for significant investment in this sector (See table on "**Current developments**" below for further detail on some current projects).

Export hub and capability

The Middle East enjoys a strategic location for exports, ideally situated between Europe and Asia, enabling it to take advantage of potential demand to either side of it. This location, combined with the knowhow and availability of existing infrastructure used predominantly for the export of oil and gas, is likely to be an important solution to addressing some of the transportation challenges facing hydrogen projects.

Regulatory environment

There is currently no published regulatory framework for hydrogen projects in the Middle East. In the absence of specific national strategies, however, there are various initiatives being undertaken that have been developed around a variety of hydrogen objectives. New regulations and regulatory frameworks will no doubt arise during the lifetime of pathfinder projects with the potential to introduce significant changes with material cost impacts.

Current developments

The table below provides an overview of some of the key hydrogen projects reported to be currently under development in the region.

Project	Jurisdiction	Description	Parties
Green Hydrogen MoU	Dubai	Emirates Nuclear Energy Corporation (ENEC) and EDF Energy have signed an MoU with the intention of cooperating on various research and development projects exploring the production of green hydrogen, powered by carbon-free nuclear energy.	ENEC and EDF Energy
Abu Dhabi Hydrogen Alliance	Abu Dhabi	Mubadala Investment Company (Mubadala), the Abu Dhabi National Oil Company (ADNOC) and ADQ have signed an MoU to establish the Abu Dhabi Hydrogen Alliance. The Alliance partners will collaborate with the intention of establishing Abu Dhabi as a leader of low-carbon green and blue hydrogen in emerging international markets. The partners will also work together to build a substantial green hydrogen economy in the UAE.	Mubadala, ADNOC and ADQ

Project	Jurisdiction	Description	Parties
Green Hydrogen MoU	Abu Dhabi	Mubadala and Siemens Energy (Siemens) have signed an MoU with the intention of creating a strategic partnership to drive investment and development of advanced technology, manufacture of equipment, and green hydrogen and synthetic fuel production. The initial focus of activity will be in Abu Dhabi and it is intended this will be expanded to international markets over time.	Mubadala and Siemens
Ministry of Economy, Trade & Industry of Japan (METI) Cooperation	Abu Dhabi/ Japan	An agreement between ADNOC and METI to explore cooperation on fuel ammonia and carbon recycling.	ADNOC and METI
Green Hydrogen Pilot Project	Dubai	A $14m green hydrogen plant built at Dubai's Mohammed bin Rashid al-Maktoum solar park. It is the first solar-driven green hydrogen producing facility in the Middle East. "*The plant has been built to accommodate future applications and test platforms for the different uses of hydrogen, including potential mobility and industrial uses*" (Siemens).	DEWA, Expo 2020 Dubai and Siemens
NEOM Green Ammonia	The Kingdom of Saudi Arabia (KSA)	This $5bn green hydrogen-based ammonia plant is one of the world's largest green hydrogen projects and is being developed by ACWA Power and Air Products in the NEOM development in KSA. It will include the integration of over 4GW renewable power from solar, wind and storage; produce 650 tons per day of hydrogen by electrolysis using Thyssenkrupp technology; produce nitrogen by air separation using Air Products technology; and produce 1.2 million tons per year of green ammonia using Haldor Topsoe technology. It is due to come online in the first quarter of 2025.	ACWA Power, Air Products and NEOM (JV partners) Thyssenkrupp and Haldor Topsoe (technology partners)
Hyport Duqm Green H2 Project	Oman	A project to develop a green hydrogen plant in the Special Economic Zone at Duqm, Oman, in cooperation with the Public Authority for Special Economic Zones and Free Zones (OPAZ). The facility's electrolyser capacity is estimated between 250-500MW in the first phase of development.	ACWA Power, Air Products and NEOM (JV partners) Thyssenkrupp and Haldor Topsoe (technology partners)

SECTOR CHALLENGES

Cost and price

Clean hydrogen is currently relatively expensive to produce compared to traditional production processes. According to the European Commission's 2020 hydrogen strategy, green hydrogen costs between approximately $3/kg and $6.55/kg. Fossil-based hydrogen costs about $1.80/kg, whereas the

Commission estimated the cost of blue hydrogen at about $2.40/kg. S&P Global Ratings has stated that the cost of producing hydrogen from renewables will need to fall by over 50% to $2.0-$2.5/kg by 2030 to make hydrogen a viable alternative to conventional fuels, although our experience suggests to us that this price range is still relatively high.

The low cost of gas extraction and the regular announcement of record low renewable generation tariffs in the Middle East could be a key contribution to achieving lower costs, providing yet another, and perhaps the strongest, competitive advantage for the region. Government/public support for the building of (initially oversized) dedicated storage, distribution and export infrastructure will likely be required to ensure that green hydrogen produced in the Middle East is competitive both locally and in export markets.

Steep declines in green hydrogen costs are, however, anticipated in the coming decade, with the cost of green hydrogen expected to become as competitive as blue hydrogen by 2025 and with grey hydrogen by 2030. Factors such as advances in electrolysis technology, decreasing costs of renewables, and increased economies of scale should assist in the reduction of production costs, making green hydrogen an economically viable solution in the longer term.

Blue hydrogen could provide the industry with a boost in this respect, if supporters are able to convince sceptics about the use of fossil fuels in its production. There is technology and market support available for carbon capture, potentially enabling the production of blue hydrogen to act as a transition fuel in the short to mid-term.

Transportation

Cost effective transportation is key to the economic viability of hydrogen supply within clean hydrogen value chain, from hydrogen plant to consumer. Hydrogen can be transported as a pressurised gas or as a liquid from the point of production to the point of use via various methods, including pipeline or in cryogenic liquid form in tankers or trucks.

The construction of dedicated clean hydrogen pipeline infrastructure to enable widespread and international supply is likely to be difficult (for example, from a permitting and land acquisition standpoint) and costly.

Shipping of hydrogen is also costly. In order to be transported by ship, hydrogen must be pressurised, chilled to -253°C and either liquified or converted into ammonia or another form of carrier. In addition, often with the use of a vector, energy is lost in the conversion and re-conversion process.

The development or re-purposing (depending on the technology) of infrastructure for the safe storage, transport and distribution of hydrogen may play an important role in the sector's bankability. Again, the vast experience of GCC nations in marketing and transporting crude, LNG and chemicals is a key building block to meet this challenge. National oil companies and sovereign wealth funds are likely to play an important role in shouldering the cost of the hydrogen storage, distribution and export infrastructure to jump-start the green hydrogen value chain. Targeted safety regulation will also be necessary.

Hydrogen certification

Given the multiple methods for producing hydrogen and their differing 'clean' (or low to zero carbon) credentials, industry players and legislators will need to develop certification systems for guaranteeing the origin of hydrogen and tracking it across the energy supply chain from production, transport to application methods. Aligning regulation internationally and anticipating certification requirements in targeted export markets poses further challenges.

Bankability

While we expect the early stage projects to be predominantly developed on balance sheet, the key to growth is private sector development through bank financing. With ESG and green-linked financings likely to be a long term theme, lender and DFI appetite is expected to be strong. However, as a new asset class, the development of facilities for hydrogen production, give rise to legitimate queries around the bankability of such projects. Key factors that may affect the successful commercialisation of clean hydrogen production include:

- **Bankability** – as a new asset class, lending institutions may require more onerous terms, and investors may be looking for higher returns.
- **Government funding and support** – this will be required in the form of investment into (initially oversized) transport, storage facilities and export hubs as well as potential subsidies (at least during an initial phase) for production or consumption of green hydrogen.
- **National strategies / Policy support** – government hydrogen strategies/road maps and the formulation of targeted legislation across the hydrogen supply chain (including health and safety, licencing and permitting for the production, storage and export of hydrogen) will be key to the attractiveness (or not) of investment in clean hydrogen.
- **Completion risk** – in particular, while the technology is not necessarily new, there is a risk related to constructing and operating electrolysis at a scale never done before, with facilities needing to pass smoothly from the commissioning stage through to an operational plant.
- **Construction contracting structures** – initial transactions will demonstrate the extent to which the technology providers, and contractors, are prepared to assume (or are best placed to bear) construction, completion and performance risks, and in what configuration (consortia, EPC wraps, etc).
- **Securing reliable offtake arrangements** – as an emerging market, initial projects will be highly structured, requiring long-term dedicated sales and purchase contracts, but must at the same time be revolutionary in their nature so as to take into account the development of a more liquid clean hydrogen ecosystem as time goes on.

In order to structure the financing for hydrogen projects, sponsors, lenders and advisers will need to draw on existing industry experience from a range of sectors, such as the power, water and chemical industries and infrastructure, transport and mining projects.

CONCLUSION

Green, and other low carbon, hydrogen is an exciting development for the clean energy sector with considerable potential for the Middle East region. Although challenges exist, not least in terms of the cost of funding the advancement of hydrogen as a widespread, clean energy resource, Middle Eastern heavyweights such as the UAE and Saudi Arabia have ambitious plans for decarbonisation, and there is real optimism in the market for hydrogen to assist with achieving carbon emission reduction targets.

ABOUT

Focus on Hydrogen is a Clifford Chance briefing series covering hydrogen-related developments globally. 1.008 is the standard atomic weight of hydrogen.

For other hydrogen publications, please see our thought leadership page here.

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