WORLD ECONOMIC FORUM

In collaboration with ***Accenture***

Enabling Measures Roadmap for Low-Carbon Hydrogen Middle East and North Africa

Version: December 20th 2023

Preface

Low-carbon hydrogen has an important role to play in the decarbonization of the energy and industry system, particularly in hard-to-abate sectors. Cumulatively, low-carbon hydrogen can contribute to **emissions reductions of as much as 6% of global greenhouse gas emissions between 2021-2050**, according to the IEA's Net Zero Emissions scenario.[1] In addition, low carbon hydrogen presents a tremendous **economic opportunity** for the Middle East and North Africa region, as a vehicle for **economic diversification and domestic employment**.

In the wake of COP28, we see several encouraging developments for realizing the low-carbon hydrogen economy. A few stand out:

- As a first, after decades of climate talks, COP28 concluded with a **landmark deal to 'transition away' from fossil fuels**. Moreover, the final text also **directly calls for an acceleration of low-carbon hydrogen** as a key lever for decarbonizing the energy system and economy.
- **The Intergovernmental Declaration of Intent on Mutual Recognition of Certification Schemes for Hydrogen and Hydrogen Derivatives** (covering 80% of future global trade) **and the global ISO methodology for Greenhouse Gas (GHG) emissions assessment of hydrogen**[2] bring four advantages to the hydrogen market: enhancing hydrogen's position as a new asset class for global investors, assisting in establishing consumer trust and reinforcing the viability of offtake agreements, promoting international trade in hydrogen and its derivatives and advancing hydrogen implementation in emerging markets and developing economies.[2]
- **In the MENA region several countries, including the United Arab Emirates, have set hydrogen production targets. Masdar is targeting an annual global green hydrogen production capacity of up to 1 million tons by 2030[3]**, which is in line with the **UAE's strategy ambition to produce 1.4 Mtpa by 2031 and 7.5 Mtpa by 2040.[4]**

While encouraging, the announcements, commitments and pledges coming off COP28 **mark the start of a long and wide journey towards a low-carbon hydrogen economy**. Importantly, there are **still a range of barriers to overcome** to truly accelerate low-carbon hydrogen developments, including **cost-competitiveness, securing aggregated demand and coherently adopting and implementing standards & global certifications** across a wide range of topics.

The MENA region is in a unique position to unlock its vast renewable energy potential, enabling the shift of oil and gas dominated energy systems towards low-carbon hydrogen value chains. **This Roadmap provides a suite of enabling measures that is carefully attuned to the region's specific challenges and opportunities.** As such, the Roadmap can be used as a **tool for policy development, industry alignment and wider ecosystem creation and collaboration** geared at unlocking the region's low-carbon hydrogen potential. We look forward to working together in the evolving hydrogen ecosystem to transform ambitions into plans and plans into reality.

Yours sincerely,

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Sources: IEA[1], Hydrogen Council[2], Masdar[3], UAE National Hydrogen Strategy[4]

Executive Summary (1/3)

The **Middle East and North Africa (MENA)** region has committed to **reducing GHG emissions by 22%**[1] (from 2030 BAU emissions to 2030 NDC targets). Moreover, **60% of the region's emissions and GDP are already in line with net zero pledges**[1]. Forecasts predict a **doubling of primary energy demand by 2030**[2] following **steep population and economic growth**, increasing the region's decarbonization challenge. Currently, the region is well known for its **leading position in oil and gas production, refining and trade**. In the context of the region's decarbonization journey, **one key opportunity is pivoting towards low-carbon hydrogen* value chains** by capitalizing on existing oil and gas infrastructure, its large available renewable energy potential and proven track record of renewables scale-up, geological storage potential and demographic capital. Pursuing a low-carbon hydrogen play moreover contributes not only to decarbonization ambitions, but also towards economic diversification goals and provide an opportunity for MENA countries to export renewable energy as well as build economic resilience towards a post-oil and gas era.

The World Economic Forum, in collaboration with Accenture, has developed this MENA Roadmap as part of the Accelerating Clean Hydrogen Initiative to identify key enablers to achieve a scaled and mature low-carbon hydrogen market.

The abundant, profitable, and affordable oil and gas reserves in a large part of the region make it challenging to establish competitive low-carbon hydrogen value chains and to shift local demand from grey to low-carbon hydrogen. At the same time, the available renewable energy resources are large enough to also support not only new hydrogen applications but also an export play. That being said, despite there being a clear opportunity, presence of strong low-carbon hydrogen ambitions and the means to support these ambitions (most notably on the Arabian peninsula), similar to other regions across the globe, only a limited number of projects have currently managed to reach Final Investment Decision (FID). In this context, the main purpose of this Roadmap is to shed light on how low-carbon hydrogen value chains in the MENA region can reach its fullest potential through **four key steps**:

1. **Capturing MENA's low-carbon hydrogen position in the context of the global hydrogen market.**
   - While the region represents a modest 4% of global GDP and 6% of the global population[3], it holds a substantial 13% of global hydrogen investments and 8% of projected global hydrogen production capacity by 2030[4]. Moreover, MENA is already an energy powerhouse, with oil and gas exports accounting for 27% of global energy trade.
   - Through its nationally-led energy champions, the MENA region is investing primarily in low-carbon hydrogen production but also offtake projects both within the region and internationally.
   - By 2050, the region's hydrogen and derivatives exports could represent 21% of the global export market[4].
   - The region pursues a variety of value chain configurations, pursuant to national and regional contexts including both pipeline-based export plays and shipping export plays for ammonia and carbon-based products.
2. **Assessing low-carbon hydrogen readiness for six 'high-potential' hydrogen countries.**

The MENA region encapsulates substantial country-by-country variety where context is relevant. To capture a substantial part of the region's state-of-play in low-carbon hydrogen developments, this Roadmap assesses the hydrogen readiness of the region for six 'high-potential' countries, being Morocco, Egypt, Qatar, Oman, the Kingdom of Saudi Arabia (KSA), and the United Arab Emirates (UAE):

- **Morocco:** The dependency on fossil fuel imports have driven a strong development of renewable energy with 4.6 GW already installed. The low-carbon hydrogen strategy of producing up to **30 TWh (~ 0.9 Mtpa)** of green hydrogen **by 2030** includes scenarios for pipeline exports to Europe, shipping, aviation, decarbonizing Morocco's leading fertilizer sector and other new applications. Importantly, Morocco is seen as a gateway linking sub-Saharan Africa and Europe through electricity transmission interconnections and hydrogen pipeline transports along the Atlantic Coast, facilitating renewable hydrogen production and trade. Morocco emphasizes the importance of using low-carbon hydrogen not just as an export, but also to boost its local economy. As such, there is a focus on high-value industry applications such as fertilizers, chemicals, and potentially steel production to diversify the economy. Flagship players in the country include energy leader Masen, fertilizer and phosphate leader OCP. To attract private investments the soon to be announced Offre Maroc will further create an attractive hydrogen investment climate.
- **Egypt:** Egypt is by far the most populous country in the region with a population over 111 mn people. The country aspires to capture 8% of the global hydrogen trade by 2040, representing **up to 10 Mtpa** of renewable hydrogen. A staggering $83 bn of low-carbon hydrogen projects are being explored in the feasibility stage, a majority to be located in the Suez Canal Economic Zone. Geographically, Egypt is in a unique position to capitalize on the 12% of global maritime trade passing through the Suez Canal[5]. As such, Egypt could play a major role in the low-carbon hydrogen and ammonia fuels market for both the energy trade and maritime shipping specifically through sustainable fuel initiatives. Egypt's hydrogen plays span export strategies and decarbonization

**This Roadmap uses the term* *'low-carbon' hydrogen to include blue hydrogen (produced with natural gas abated by CCUS), green hydrogen (produced through electrolysis), and pink (produced through nuclear).*

Sources: World Economic Forum[1], World Bank[2], World Bank[3], Hydrogen Council[4] , AlexBank[5]

Executive Summary (2/3)

strategies in its existing fertilizer, steel and chemicals sectors, with a combined potential offtake market of **1.4 Mtpa**. Projects are oftentimes pursued in collaboration with major international energy champions.

- **Qatar:** While Qatar may be smaller in size compared to its Arab States peers, it boasts the third largest confirmed natural gas reserves globally, estimated to be over 25,000 bcm. As such, the country is a leading LNG exporter, delivering natural gas to Japan, Australia, wider Asia and European markets alike. With a relatively limited renewable energy potential compared to its peers due to land availability constraints, the country focuses on Carbon Capture and Storage/Usage driven low-carbon natural gas and hydrogen production. Despite the country's framework and policies being less extensive and specific to low-carbon hydrogen, large blue ammonia and CCS projects have been announced, notably for fertilizer production, capitalizing on its strong natural gas related industries. Most notably, QatarEnergy is developing the Ammonia-7 project, with a nameplate capacity of **1.2 Mtpa.**
- **Oman:** As of 2023, the country potentially has the most advanced regulatory framework, strategy, and project development policies for hydrogen in the region. The country envisions becoming the largest exporter of renewable hydrogen by 2030 with a production of up to **1.15 Mtpa**, with 50,000 km² of land dedicated for hydrogen project development. Project development is coordinated by Hydrom, Oman's national leading entity responsible for strategy execution. The strategy focuses on exporting hydrogen to both Asia and Europe and also includes decarbonization strategies for existing demand representing **1.1 Mtpa**. The hydrogen sector is seen as a vital post-oil and gas era economic opportunity for Oman.
- **UAE:** The country is capitalizing on a mature oil and gas ecosystem, strong renewables capacity, historic domestic industries, and existing export infrastructure. Policy ambitions of producing **1.4 Mtpa by 2031** and **7.5 Mtpa by 2040** of low-carbon hydrogen include ammonia-based export plays to Europe and Asia and decarbonization and new application strategies in hydrogen hubs, executed by major largely state-owned leaders such as ADNOC, Masdar, Mubadala and TAQA.
- **Saudi Arabia:** KSA represents the largest economy of the Arab League, houses the largest oil and gas production facilities and a vast renewable energy potential. As such, the country is particularly well-positioned to play a key role in the low-carbon hydrogen economy, including export, decarbonization and new applications plays. Clear highlights include the **4 GW** NEOM Green Fuels Hydrogen Project which has already reached FID, and the Northern blue hydrogen and ammonia projects from Saudi Aramco, which leverage key existing ports including Yanbu and Jubail. The country aims to produce **2.9 Mtpa** of low-carbon hydrogen **by 2030.**

Among the six countries **there is a clear presence of both heterogeneity and commonalities**. Heterogeneity is found in the relative importance of export plays versus domestic demand strategies as well as the availability of financial means to support hydrogen plays. For example, the GCC region has a substantially stronger capital ecosystem than the North African region. Vice versa, commonalities are found in the fact that all six countries are dominantly executing their low-carbon hydrogen strategies through project-by-project approaches, oftentimes led by either state-backed national champions or international energy majors in large-scale projects, capturing economies of scale benefits whenever possible.

For each of the six countries selected, the low-carbon hydrogen readiness was assessed by **evaluating the countries' hydrogen opportunity, ambitions and strategies against the Initiative's six barrier framework** to capture where there is a need for enabling measures to accelerate MENA low-carbon hydrogen development. Below the key resulting regional observations are presented per barrier:

- **Standards and certification:** Standard setting remains a crucial activity for the sector to have a low-carbon hydrogen benchmark to orient itself towards. On certification schemes and bilateral agreements, a new ISO methodology for benchmarking hydrogen pathway emissions has been announced and 39 countries signed the Intergovernmental Declaration of Intent on Mutual Recognition of Certification Schemes for Hydrogen and Hydrogen Derivatives at COP28. This demonstrates a move towards larger blocks of internationally and mutually recognized schemes, lowering transaction costs for hydrogen trade.
- **Demand:** Due to the MENA region's proximity to strategic demand centres, such as Europe and Asia, and low-cost resource availability, demand is high. Total announced volumes are 1 Mtpa (2025) and by 3.5 Mtpa (2030)[1]. Countries are adopting varying strategies for demand, either focusing on export or domestic demand to kickstart their hydrogen economy. More detailed regulatory frameworks would encourage hesitant demand and foster further confidence, especially in North Africa, enabling projects to reach FID stage.
- **Infrastructure:** Key features of the region include its mature oil & gas infrastructure and abundant land and renewable energy potential. An opportunity remains for aligning policies, actors and timelines on construction of

Sources: Hydrogen Council[1]

Executive Summary (3/3)

infrastructure, such as roads, ports, grids and desalination plants. A staggering half of state-owned enterprises are aligning policies, actors and timelines on construction of infrastructure, such as roads, ports, grids and desalination plants. A staggering half of state-owned enterprises are developing low-carbon hydrogen based on renewables or carbon capture, utilization and storage capabilities. The region is in the midst of rapidly increasing its renewable electricity production, already on its way to increase renewable capacity from 19 GW mid 2023 to 28 GW by 2024. Countries such as Egypt have demonstrated the ability to ramp up their electricity grids rapidly.

- **Pace of development:** Many of the MENA region's countries have state-backed enterprises, which provide them with advantageous public-private partnerships, and one-stop-shop entities aggregating hydrogen project development and permitting on a national level, such as Oman. Other countries, like the UAE, are ensuring pace by developing the entire hydrogen ecosystem from electrolyzer manufacturing plants to derivative facilities.
- **Technology:** The region is establishing specific low-carbon hydrogen research centres and capabilities, a critical endeavour that relies on technology transfers from foreign partners. Furthermore, the growth of low-carbon hydrogen economies both regionally and globally must coincide with the promotion of the industry's technology supply chain, including critical raw materials and electrolyzers, and the development of workforce skills.
- **Cost:** MENA ranks among the most competitive hydrogen production locations in the world, with expected low-carbon hydrogen production prices of <$1.50 per kg hydrogen in 2030–2035[1]. However, much of the cost enabling measures are outside the scope of control for the MENA region: the magnitude of the cost gap between grey and low-carbon hydrogen is unlikely to be covered by cost reduction measures in the short-term alone (oftentimes by governments). Hence, it is required to valorize green premiums through either supply support mechanisms, higher consumer prices or regulatory frameworks.

Accelerating low-carbon hydrogen developments in the MENA region requires addressing the six barriers mentioned. A clear priority in this is ensuring projects are economically viable which often means focusing on export plays to premium hydrogen markets.

3. KSA and the UAE's hydrogen plans currently show the largest footprint. Hence, a deeper look is given into their regulatory and funding landscapes.

Hydrogen developments in KSA and the United Arab Emirates are particularly of interest for several reasons. KSA stands out in the region for the scale of its projects that have reached FID, illustrating its frontrunning position. Moreover, the UAE's low-carbon hydrogen ambitions, breadth and specificity of its hydrogen policies, both on a national and Emirate level, are pronounced in the region. Illustrating a clear long-term commitment to advancing low-carbon hydrogen value chains.

4. Finally, presenting a selection of enabling measures, stemming from the full report.

To ensure MENA's role as a major low-carbon hydrogen producer, the following five main enabling measures are recommended:

- **Secure further long-term demand offtake agreements to certify development and investments.** Securing demand allows confidence of return on investment. In addition, pushing research and development to gain / decrease cost per unit and bring down the green premium will also promote investments into low-carbon hydrogen.
- **Establish one-stop shops for hydrogen project development, following the example of Oman's Hydrom.** Streamlining the hydrogen development approval processes for permitting, land auctions, regulatory compliance and coordination of stakeholders can contribute to decreasing (perceived) risk and complexity of projects, advancing them to FID stage.
- **Coordinate all actors on the low-carbon hydrogen ecosystem.** Furthering the collaboration of all actors on the entire value chain will help create a more robust and interconnected low-carbon hydrogen ecosystem. Providing shared infrastructure for low-carbon hydrogen projects such as roads, ports and grids / renewables common to hydrogen and derivative projects can encourage demand and investors as it reduces risk and capital expenditure. At a cross-country level, ministries, port authorities and industrials need to combine their efforts to develop supply chains and enable technology transfers.
- **Continue efforts on developing precise policies and global standards and certification.** Reinforcing regulatory frameworks and creating broadly recognized Standards and Certification will encourage domestic and international demand, a crucial factor for projects to reach FID stage.
- **Build skillsets adapted to the low-carbon hydrogen economy.** Emerging technologies require adjusting education curriculums for local economies, reskilling and transferring expertise, as well as creating locally funded research centres. Adequate talent and innovation centres will reduce bottlenecks to further accelerate low-carbon hydrogen projects.

The region encompasses a variety of approaches to low-carbon hydrogen development with each country analyzed actively developing projects. Key to the acceleration will be the clarification of standards and certifications, accelerating required infrastructure and scaling up global market demand.

Sources: World Economic Forum[1]

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INITIATIVE CONTEXT

Since 2020, the World Economic Forum, in collaboration with Accenture, is driving the acceleration of low-carbon hydrogen

Focus of report

1: Enabling Measures Roadmaps

- The Roadmap identifies measures required to boost the low-carbon hydrogen economy and enhance public-private dialogue.
- The Roadmap focuses on 6 barriers to market development and enabling measures to overcome them.
- The initial Roadmaps were launched at COP26 to scale the low-carbon hydrogen market in Europe and Japan; the Roadmap for China was launched in 2023.
- This report is the **Roadmap specific to the MENA region.**

2: Community Engagement

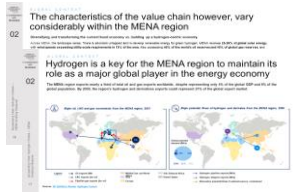
- The Initiative brings together a community of stakeholders from across the hydrogen ecosystem to discuss global trends and topics.
- The community engages in sessions to exchange knowledge and foster collaboration on specific topics such as lighthouse projects and hydrogen policy.
- The community participates in agenda-setting sessions on key required enabling measures coalescing industry and government.

The Enabling Measures Roadmap provides key measures to scale the low-carbon hydrogen market

The objective of this Roadmap is four-fold:

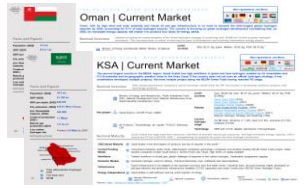
1 Analyze the region's Hydrogen position in the Global Context

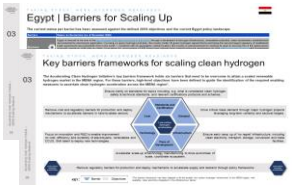
- **To depict the role and dynamics of the MENA region in the development of low-carbon hydrogen***



2 Identify the Barriers: Country Readiness Assessment

- **To specify the market characteristics and developments of low-carbon* hydrogen in 6 key MENA countries against the barriers.**





3 Shape Enabling Measures: Deepdives for UAE and KSA

- **To identify policy, funding and project developments related to low-carbon hydrogen* in the MENA region, and derive key enabling measures required.**

4 Determine Outcomes and Next Steps

- **To summarize indicative outcomes in the MENA region if enabling measured are implemented and objectives achieved regarding low-carbon hydrogen*.**

Defining low-carbon hydrogen. *This Roadmap uses the term 'low-carbon' hydrogen as a technology and production method agnostic, term to indicate hydrogen that is produced with a low-carbon intensity, expressed in kgCO_2eq /kgH_2 produced. Across different jurisdictions, different standards are arising to define what is considered 'low-carbon' hydrogen. For example, the EU's delegated act on 'renewable fuels of non-biological origin' (RFNBO) is requiring hydrogen production to emit less than 3.38 kgCO_2eq /kgH_2 to fall within the EU's RFNBO-scheme. In the US, the Inflation Reduction Act uses a sliding scale to attribute a tax credit of \$3 /kgH_2 for the lowest emissions category (0.45 kgCO2eq /kgH_2) to a tax credit of \$0.6 /kgH_2 for the highest eligible emissions category (2.5-4 kgCO2eq /kgH_2)[1]. The World Economic Forum does not subscribe to one specific low-carbon hydrogen emissions standard but does highlight the importance of ambition fostering lower carbon intensities in hydrogen production to ensure low-carbon hydrogen can achieve an actual and the strongest possible effect on decarbonization efforts.*

Sources: Hydrogen Insight[1]

The geographical focus of this Roadmap is the MENA region

Hydrogen offers MENA countries a unique chance to leverage their resources, geographical location, and expertise to create a sustainable and thriving hydrogen economy.

Key facts

- **Population: 493 mn, representing 6% of global population[1]**
- **CO_2 emissions: 8% of global emissions[2]**
- **Well-positioned to supply 10-20% of global demand by 2050[3]**
- **Current LCOH (blue) in region: USD 1.5-2.5 /kg[3]**

Overview of the MENA region

Google Earth

The MENA region is a key actor in the development of low-carbon hydrogen

The MENA region possesses **the ideal conditions for hydrogen production**, both through blue and green pathways. With its **resource abundance**, **geographical advantages**, **and growing interest in clean energy**, the region has the potential to become a key player in the global hydrogen market, contributing to a more sustainable energy future:

- **Strategic location:** MENA's geographical position facilitates hydrogen export, benefiting from strong business relationships, its proximity to major energy markets and potential trade corridors.
- **Existing infrastructure:** MENA's well-established, well-financed oil and gas infrastructure can be repurposed to support hydrogen production and export, carbon storage for blue hydrogen, reducing costs and enabling integration into the global energy market.
- **Renewable energy potential:** MENA possesses vast solar and onshore wind resources, positioning the region well for green hydrogen production and capitalizing on a rising global demand.
- **Rising interest and regional agreements:** The MENA region experiences a growing interest in hydrogen production and export, with Memorandums of understanding (MoU) and cooperation agreements being signed between MENA countries and for example European countries across the board.
- **Economic diversification and job creation:** Hydrogen investments in MENA promote economic diversification, job opportunities, and technological innovation, as well as reducing reliance on fossil fuels and supporting sustainable growth.
- **Platform for action on MENA sustainability:** The interest into MENA produced low-carbon hydrogen for export could serve as a platform for action on local sustainability transformations by substituting fossil fuel use for low-carbon hydrogen across a variety of end-uses.

Sources: World Bank[1], Climate Watch Data[2], APICORP[3] , Google Earth[4]

Six countries were selected as they lead the development of low-carbon hydrogen in MENA

Methodology for the Country Selection

3 indicators were considered to identify the **6 countries in the MENA region** that should be **prioritized for the study** and understand the potential and current maturity of the hydrogen industry, as well as the enablers available to accelerate its development. Each country was given a prioritization score based on the following criteria:

Overview on the underlying criteria[1]

POLICY MATURITY & AMBITION
Strategy and targets clearly defined, scope / years of coverage, level of instruments (including infrastructure readiness to favour the hydrogen landscape).

PROJECTS
Number and amplitude of low-carbon current projects operational, launched or in design.

FINANCIAL RESOURCES
Potential to finance the hydrogen landscape based on the economy, domestic financing capabilities and GDP per capita.

The six leading hydrogen countries are **the UAE, KSA, Oman, Morocco, Egypt and Qatar.**
Furthermore, **2 countries were prioritized for a policy, funding and projects landscape deep dive**, based on the Country Readiness Assessment results for each country.

Countries Prioritization Score

Google Earth[2]

Countries selected for deep dive analysis on policy and funding

2.1 Prioritization Score[1]

See appendix for detail[1]. Sources: Google Earth[2]

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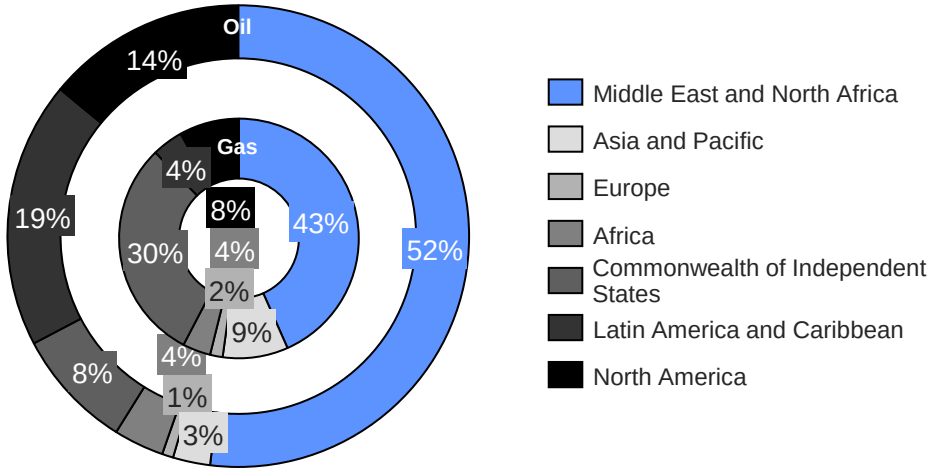
MENA has a leading position in the global energy system

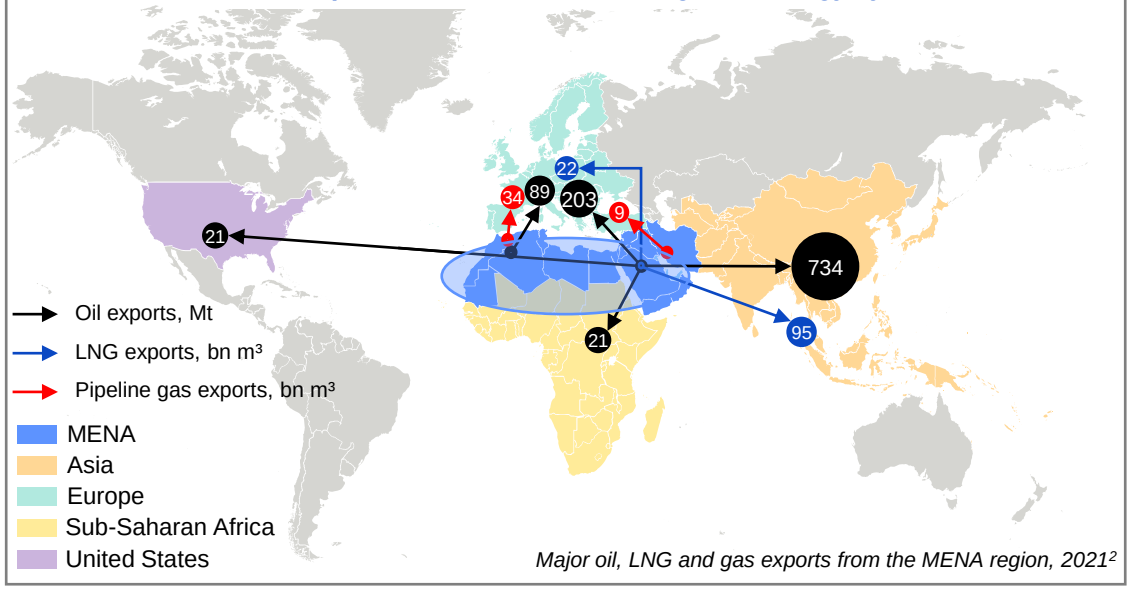
MENA's vast fossil fuel reserves have **positioned the region at the center of the – still predominantly fossil-based – energy system**. Today, the MENA region holds **52% of global oil reserves, 43% of global gas reserves**[1], and accounts for nearly **one third of global energy trade.**[2]

MENA holds vast fossil fuel resources…



World Proven Oil and Gas Reserves, 2021[1]

…that place it at the center of the global energy system



Major oil, LNG and gas exports from the MENA region, 2021[2]

While representing only **6% of the global population** and **4% of the global GDP**, the MENA region holds by far the **largest share in oil and gas reserves** compared to any other region. Importantly, the region's dominance is exacerbated by the fact that there is a substantial gap between any region that comes second.

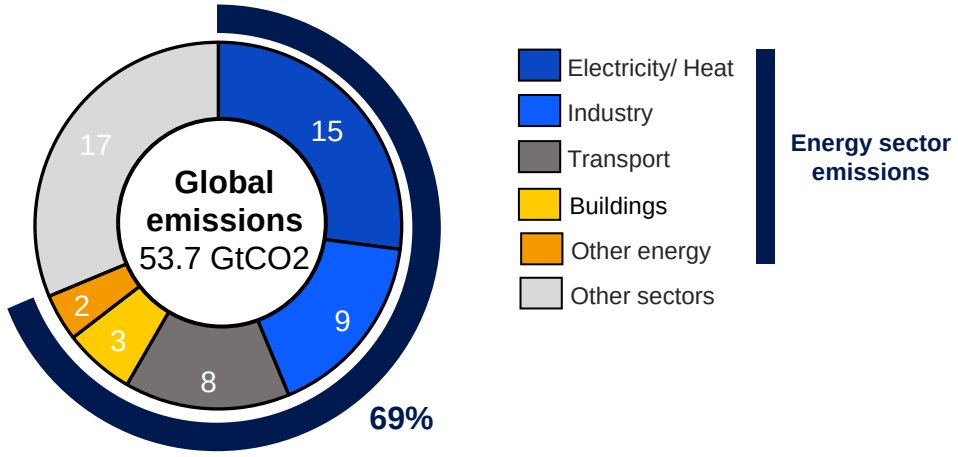
MENA **exports globally**, with **main markets being Asia and Europe.** In 2022, the region exported 19.8 million barrels per day (equivalent) of crude oil and natural gas globally, equivalent to be **worth over $700 billion a year.**[2]

Sources: BP Statistical Review of World Energy 2021[1]*, BP Statistical Review of World Energy 2022*[2]

The global energy system needs to decarbonize at speed and low-carbon hydrogen can play a key role

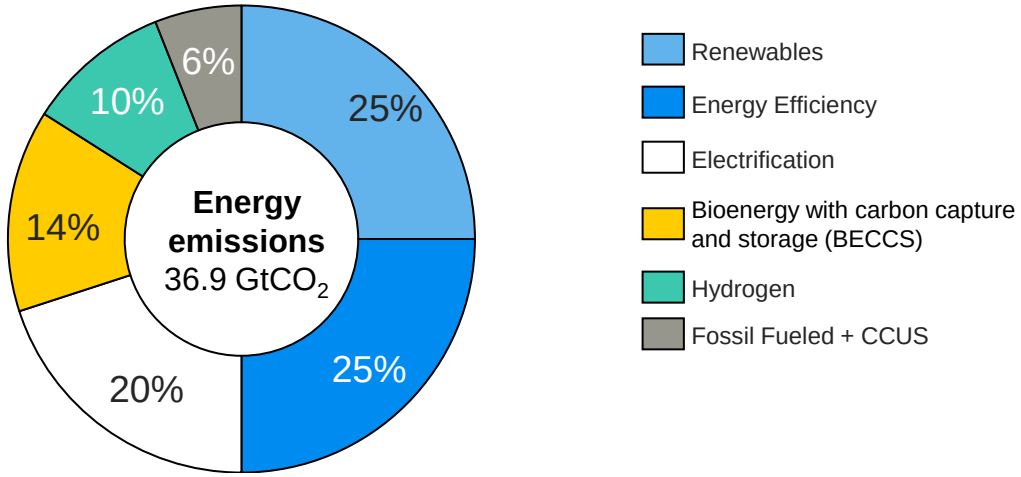
Anthropogenic emissions are at 53.7 $GtCO_2$[1], with energy emissions accounting for 69% of total emissions.[2] On the road towards net zero, energy emissions need to be reduced. Here, low-carbon hydrogen provides a key lever, contributing to up to 10% of energy emissions reductions.[3]

More than two thirds of emissions come from the energy sector



Share of emissions by sector 2020[4]

Decarbonizing the energy sector can be done through multiple avenues, including through the adoption of low-carbon hydrogen



Reducing Emissions by 2050 through 6 technological avenues[3]

The energy sector makes up **69% of global anthropogenic emissions. Low-carbon hydrogen applications are primarily foreseen for industrial applications** (e.g. feedstock, direct reduction of iron and when required high-temperature heat), **flexible electricity production and long-distance / heavy-duty transport applications.** In these chevrons, low-carbon hydrogen will play her role vis-a-vis other decarbonization levers, such as direct electrification and energy efficiency advancements.

Hydrogen can bring up to **10% of emissions reductions in the energy sector.** Although hydrogen's role in this context may seem modest in comparison to other decarbonization levers, **the hydrogen use-case is considered one that is indispensable for hard-to-abate industrial production processes, seasonal energy storage, and balancing the energy system.**

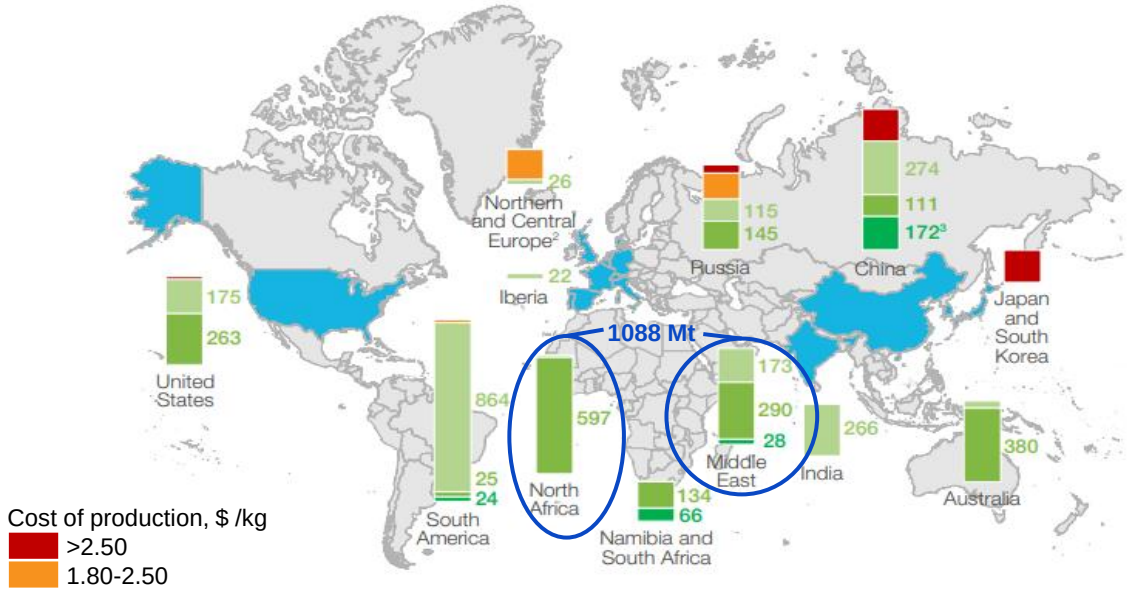
Sources: EDGAR[1], IEA[2], IEA[3], IEA[4]

The MENA region has advantageous conditions and resources to produce affordable low-carbon hydrogen

The MENA region is **well positioned to play a leading role in low-carbon hydrogen** as it is home to a **high renewable energy potential** and can **produce low-carbon hydrogen at a relatively low cost**. Thanks to a combination of **relatively large surface areas of available land, the opportunity to capitalize on existing oil and gas infrastructure, and the geographical proximity to main offtake markets**, the MENA region **may very well capture a large share of the future hydrogen economy**.

- In the Global Hydrogen Flows report from the Hydrogen Council a **techno-economic assessment** is included which estimates the low-carbon hydrogen production potential across the globe. In this study**, the MENA region has the potential to produce up to 1088 Mtpa of hydrogen, which equates to 27% of global hydrogen production potential**.[1]
- While the **actual techno-economic potential may in practice be constrained by a variety of factors**, such as **the attractiveness of the investment climate, local acceptance, and availability of skilled workforce**, the analysis underpins the expectation that indeed the MENA region is likely to be **a highly competitive region for low-carbon hydrogen production and exports**.

The MENA region has a high technical potential for hydrogen production for 2050



Total MENA production potential	**1088**
Global production potential	**4050**

Hydrogen production technical potential, Mtpa (2050)[1]

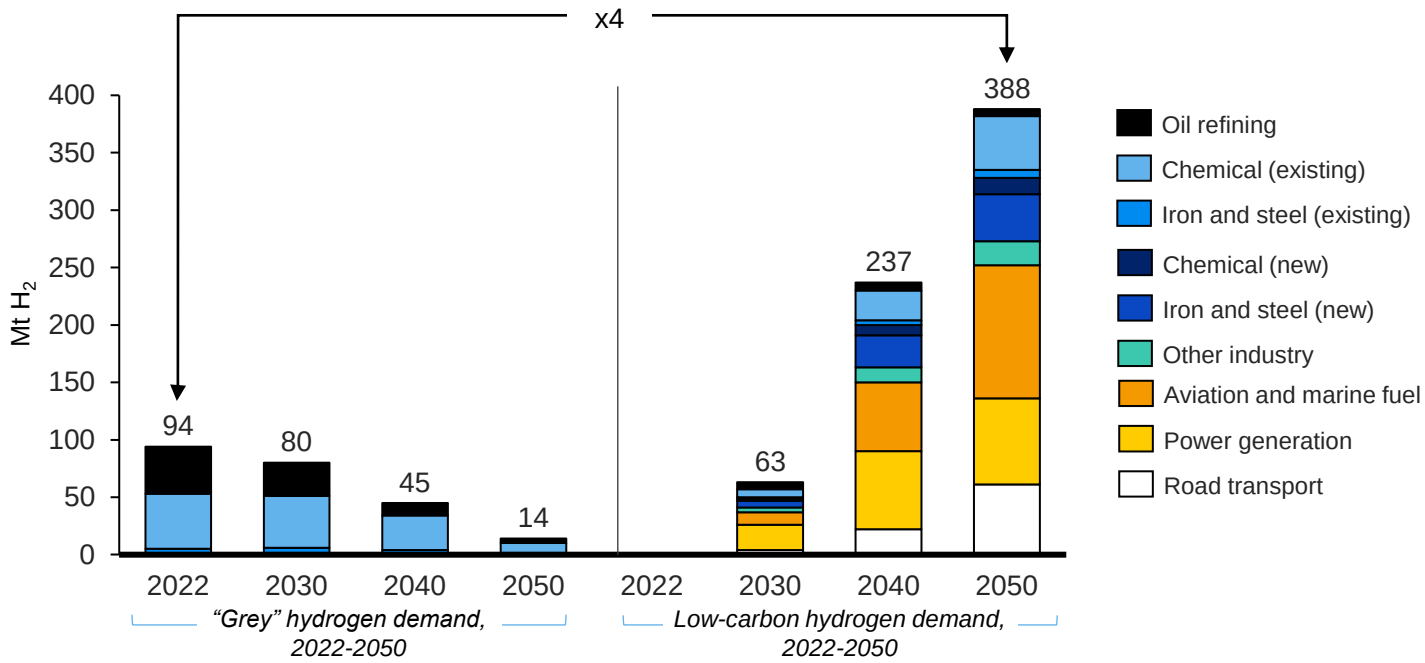
Sources: Hydrogen Council[1]

Hydrogen will also allow the MENA region to maintain its dominant role in the energy economy

To illustrate the potential volume of the developing low-carbon hydrogen market, the IEA's Net Zero Emissions scenario is highlighted. In this scenario, the global hydrogen **demand increases fourfold towards 2050 towards a staggering 388 Mtpa. MENA is strategically situated to cater production for a large share of the global hydrogen demand across multiple markets, most notably Europe and Asia.**

- Driven by increasingly stringent climate policies, such as strengthening carbon taxation schemes and clean energy obligations, hydrogen production by Steam Methane Reforming (SMR) without carbon capture and storage (CCS), also referred to as "grey" hydrogen, is expected to sharply decrease towards 2050, whilst demand for low-carbon hydrogen increases.
- Hydrogen demand **will increase four-fold between 2022 and 2050**[1].
- Hydrogen is expected to be increasingly used for **power generation, aviation, chemical and iron and steel usecases**[1].
- **The hydrogen market size is expected to gain momentum at a compound annual growth rate of 9.3% from 2024 to 2030**[2].

Hydrogen demand across various sectors is increasing at a rapid rate



Global hydrogen demand in the Net Zero Scenario, Mt (2022-2050)[2]

Sources: IEA[1]*, Grand View Research*[2]

MENA boasts numerous advantages on the low-carbon hydrogen value chain, propelling it onto the global stage

The MENA region can rely on its resource availability, existing infrastructure, domestic markets and geographic position to build its low-carbon hydrogen industry.

Hydrogen Generation

- Countries with **abundant land, wind and solar potential** include a stronger focus on the production of **renewable hydrogen and ammonia.** Though this characteristic holds for most countries in the region**,** it's noteworthy to mention that for some countries in the region – such as Morocco – there are less oil and gas assets available, which increases attention towards renewable hydrogen plays.
- **Small countries** like Qatar with limited renewables potential due to availability of land constraints, but with large natural gas deposits, are more inclined to **focus on 'blue' or 'turquoise' hydrogen plays**.
- Current **oil and gas exporters** oftentimes include substantial **blue hydrogen and blue ammonia plays** in their production portfolio, given the existing reserves and infrastructure that can be retrofitted.

Availability of renewables and potential to store carbon, strengthens the region's position as a low-carbon hydrogen producer.

Transmission and Distribution

- Both **port and pipeline infrastructure** is **well developed** in the MENA region.
- The North Africa region has the advantage of already being connected to Europe via gas pipelines (Maghreb in **Morocco**, Medgaz in **Algeria**, the developing SoutH2 Corridor, etc.). Through retrofitting, they can be integrated in the **European Hydrogen Backbone**.
- With several ports close to the **Strait of Gibraltar,** the **Suez Canal** and the **Strait of Hormuz**, the MENA region is well positioned for the **export of hydrogen and hydrogen derivates via marine routes**.
- There are **increasing numbers of agreements for trade corridors**, such as the recent COP28 Public-Private Action Statement on cross-border trade corridors in hydrogen and hydrogen derivatives.[1]

Existing infrastructure and export capabilities, geographic position and agreements for trade corridors will facilitate the transmission and distribution of low-carbon hydrogen from the region.

Local Demand and Export

- The MENA region itself has a large **domestic market potential** for hydrogen such as the **fertilizer** industry (e.g., OCP in **Morocco** or SABIC in **KSA**), the **steel** industry (Hadeed in **KSA** or Emirates Steel in the **UAE**), or the **aviation fuel** industry in the **UAE**.
- **Export markets** are to some extent pre-defined by geography. Whereas the **EU** might be the most feasible market for **Morocco and Egypt**, the countries on the **Arabian peninsula**, especially the more eastern countries, might very well be better situated to cater for the **Asian hydrogen market**.

Utilizing existing domestic industries can help secure demand, along with international demand originating from primarily Europe and Asia.

Sources: Clean Energy Ministerial[1]

Contents

There are six key Barriers and Objectives for low-carbon hydrogen

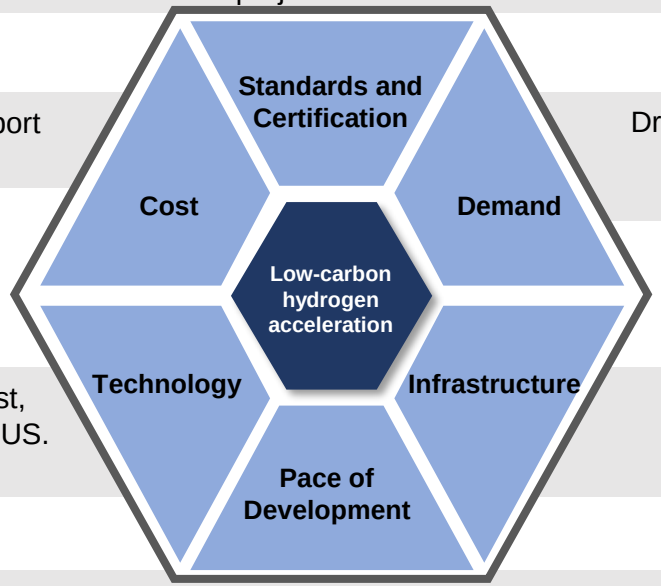
The Accelerating Clean Hydrogen Initiative's key framework holds six barriers that need to be overcome to attain a scaled renewable hydrogen market in the MENA region. For these barriers, high-level objectives have been defined to guide the identification of the required enabling measures to strengthen clean hydrogen acceleration across the MENA region.[1]

KEY: Barrier | Objectives[2]

Ensure clarity on carbon intensity, safety and technical standards and certifications for projects across the value chain.

Remove cost and regulatory barriers for production and support the bankability of projects for investors.

Drive critical mass demand through major hydrogen projects to ensure high supply, and leverage domestic and international targets to create stable, long-term demand.



Focus on innovation and R&D to improve bankability and cost, efficiency and durability of electrolyzers, renewables and CCUS. Adapted skills to deploy new technologies.

Align hydrogen hubs and infrastructure with market creation, ensuring first ramp up of *'no regret'* infrastructure: clean electricity, CCUS, transport, storage, conversion and trade facilities.

Accelerate slow pace of hydrogen scale-up and development to drive economies of scale, coordinating the ecosystem.

Low-carbon hydrogen acceleration

Remove barriers for production and deploy mechanisms to ensure the accelerated establishment of a low-carbon hydrogen economy.

Low-carbon hydrogen acceleration

- The barriers framework has been adapted to fit the broader low-carbon hydrogen environment in the MENA region, with available clean electricity integrated in the infrastructure barrier.[1]
- Objectives enable the operationalization of barriers[2]

The Hydrogen Readiness Assessment has been conducted in a two-step approach

The **objective** of this assessment is to **specify the market characteristics and developments** of low-carbon hydrogen in 6 key MENA countries **against the six key barriers** to support the acceleration of the hydrogen economy.

1

Analysis of the state of play of low-carbon hydrogen in the six markets

- **Facts and figures** regarding the overall economic background of the country
- **Analysis of the current hydrogen sector** including key stakeholders and technologies as well as local markets and production costs
- Overview on the most relevant **policies and funding** schemes
- Identification of **country-specific hydrogen maturity through 6 factors identified to evaluate the advancement of countries on their path to developing a low-carbon hydrogen economy:**
    1. **Oil and gas sector maturity**
    2. **Current funding model**
    3. **Workforce**
    4. **Domestic market**, including from the chemical industry
    5. **Infrastructure**
    6. **Energy independence**

More detail of this maturity scale can be found in the appendix.

2

Detailed assessment against the six barriers to low carbon hydrogen scale up

- Analysis of **key barriers** to scaling a low-carbon hydrogen economy based on a **dedicated framework** developed by the World Economic Forum and Accenture
- The framework addresses **standards and certification, demand, infrastructure, pace of development, technology as well as cost** under the central assumption that overcoming these will accelerate low-carbon hydrogen

Morocco | Current market

WORLD ECONOMIC FORUM

In collaboration with ***Accenture***

Main Agreements and MoUs

Countries:

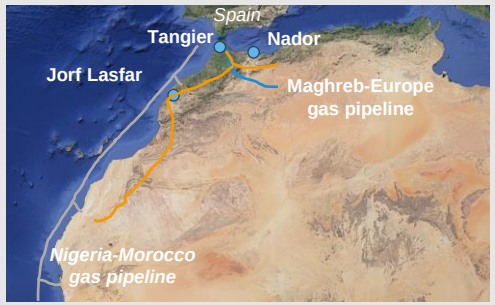
Companies: John Cockerill, Fusion Fuel, Chariot, CCC, Bechtel, TotalEnergies, CWP

Morocco sees low-carbon hydrogen as an opportunity for economic diversification & energy independence. Masen, along with the state-owned fertilizer company OCP, are leading in these developments. The country has ambitious targets of exporting up to 0.9 Mtpa[1] by 2030 and is set to accelerate building infrastructure and continuing to attract foreign investments.

Facts and Figures

Population (2022)	**37.5 mn**
GDP (2022)	**$134.2 bn**
GDP per capita (2022)	**$3,500**
CO_2 emissions (2022)	**114.77 Mton CO_2eq**
Inst. Renewable Capacity (2023)	**4,600 MW**
Crude oil production (2021)	**0**
Natural gas production (2021)	**0.11 bn m³**
Low-carbon hydrogen aim	Export up to **0.9 Mtpa** (30 TWh) by 2030

Infrastructure



- Ports
- Existing pipeline
- Pipeline under discussion
- 380-400 kV electric transmission lines[4]

Sectoral Overview

Masen, OCP and leading energy companies are implementing the detailed 2021 Green Hydrogen Roadmap.

Key players

- Ministry of Energy Transition and Sustainable Development, Masen, MENARES, IRESEN
- National Moroccan phosphate company (OCP), Al Mada (formerly SNI), Nareva, ONHYM (gas / pipelines), SNEP (storage infrastructure)
- John Cockerill, Chariot Ltd., Total, CWP Global, Bechtel, Fusion Fuel Group (Industrial). International Finance Corporation (IFC), European Bank for Reconstruction and Development (EBRD), KfW, EC, WBG, EIB, AfDB (Banks).

LCOH (current)	Estimated green hydrogen production costs: $4.64–5.79 /kg[2]
Policies	National Roadmap for Green Hydrogen (2021) National Sustainable Development Strategy 2030 (2017) Renewable Energy Target 2030 (2015) Port Strategy 2030 (2010)
Current hydrogen usage	Grey ammonia usage in the context of fertilizer production: **1.6 Mt** (2021)
Technology	PEM (Chariot, HEVO) and AEL (Cockerill) Electrolyzers

Sectoral Maturity

Strong renewables deployment serves as a key enabler while the absence of a large and developed O&G sector, requires emphasis on developing critical demand, transport infrastructure and an ecosystem of energy players capable of maturing the sector further.

O&G Sector Maturity	Little domestic production but ongoing ambitions to increase production. LNG terminals construction planned; Maghreb pipeline; distribution infrastructure for imported gas.
Current Funding Model	Projects are financed primarily through a project finance model. Morocco is likely to be eligible for funding and finance opportunities originating from the European Commission and Individual Countries in Europe aiming to foster hydrogen imports from the North African region.
Workforce	No workforce to retrain from oil and gas but university programs and partnerships in place
Domestic Market	Domestic fertilizer industry as local market to ramp up the hydrogen production. OCP is at the forefront of this fertilizer industry.
Infrastructure	Pipeline connections to Europe and existing ports can serve as a stepping stone for low-carbon hydrogen acceleration (Maghreb gas pipeline, ports of Tangier and Nador, Dakhla under development). In addition, the country has already installed 4.6 GW in renewables capacity.
Energy Independence	The country imports 90% of its energy needs.[3]

National Ministries and agencies · National companies · International partners

Maturity: Developing · Emerging · Mature · Highly mature

Considering 1 kg of hydrogen is the equivalent of 33.3 TWh of hydrogen, according to National Academies[1].

Sources: International Journal of Hydrogen[2], IRENA[3], ENTSO-E[4]

Morocco | Hydrogen progress in view

The current status per barrier has been assessed against the defined 2050 objectives and the current Morocco policy landscape.

Barriers	Status on the barriers (as of December 2023)
Low-carbon hydrogen acceleration	Morocco published its high-level framework on hydrogen in its 2021 National Roadmap for Green Hydrogen. The ministry also spoke at COP28 about their Moroccan Vision 2050 and strengthening policy alignment between AGHA countries, with an emphasis on accelerating financing of renewable energy and green hydrogen projects in Africa. Morocco also has a Cluster Green H2 alliance aiming to promote development and collaboration between the ministries and companies. Nonetheless given the lack of previous infrastructure, flexibility and action required, a more detailed regulatory framework is necessary to enable employment creation as well as full vertical and horizontal industrialization on a local level. The country aims for private companies to drive demand and supply for hydrogen, with a 'Morocco Offer' green hydrogen project to be put for investors in 2024. To facilitate this, Masen, the renewable energy agency of Morocco, is to be expanded to being the point of contact for projects. The details of this Moroccan offer have not yet been published by the government.[1] On cost, it is estimated that Morocco can produce green hydrogen at $4.64–5.79 /kg.[2] LCOH estimates vary, with IRENA valuing the levelized cost of green hydrogen between $0.70-$1.40 /kg in 2050.[3] It is noteworthy to mention that when servicing the European market, Morocco holds an edge: the lower cost of pipeline transports versus maritime transports.
Standards and Certification	At COP28, Morocco signed the Intergovernmental Declaration of Intent on Mutual Recognition of Certification Schemes for Hydrogen and Hydrogen Derivatives, covering over 80% of the future global market in hydrogen and its derivatives. The Moroccan Institute for Standardization (IMANOR) has a core function in the certification of green hydrogen and synthetic derivatives. The focus is on ensuring the regulation and standardization of the green hydrogen value chain and on certifying it in the form of guarantees of origin. In addition, Morocco, together with the European Commission and IRENA, has drafted a framework for the international trade in green hydrogen under the Collaborative Framework on Green Hydrogen. The aim was to develop transnational plans for the development of infrastructure, technology and certification.
Demand	In the short term (2020-2030) the country envisions that demand will be driven using hydrogen as a feedstock in local production of green ammonia and export of green hydrogen (between 4-30 TWh by 2030) to countries with ambitious decarbonization goals. In the long term (2040-2050), the published Roadmap sees demand of green hydrogen of between 68-133 TWh by 2040 and 154-307 TWh by 2050, from an expansion of global trade as well as its use in industry, residential heating and transport. The aim is for Morocco to become a hub for green hydrogen in the region, covering 4% of the global hydrogen demand by 2050. Domestic demand is mainly driven by OCP, the state-owned phosphate fertilizer company. As part of the company's green investment plan for 2023-2027, aiming to produce 1 Mtpa of green ammonia by 2027 and eventually replace its entire import demand of 1.5–2 Mtpa ammonia.[4] Other areas such as in the electricity sector for energy storage, or in the transport sector as a fuel, will continue to drive the development of the local hydrogen industry in the future. On international demand, the Green Partnership with the European Union was announced in October 2022 to reinforce cooperation, including on creating new industrial value chains, with potential green steel produced in Morocco.[5] The German-Moroccan Energy Partnership (PAREMA) will also contribute to securing demand from Europe.
Infrastructure	Six green hydrogen projects have been announced[6], including the final investment decision (FID)-stage OCP Group demo project with planned production of 3 Mtpa of green ammonia by 2032[7] and the HEVO and Masen / KfW projects under feasibility. Two other projects are under concept phase: Amun and Guelmin-Oued Noun. The country will need 8 GW of renewables by 2030, 36.7 GW by 2040 and 78.2 GW by 2050. With 4.6 GW of renewable electricity installed today, providing 42% of the electricity mix, Morocco aims to reach 52% by 2030, 70% by 2040, and 80% by 2050. For this, Masen oversees all renewables, targeting an additional 6 GW by 2030, including the multi-stage Noor Ouarzazate Solar complex. Crucial to this succeeding are high-voltage lines to potential production sites on the coast, and water management for electrolysis supply.[8] On exports, Morocco currently has no LNG trains or terminals in operation. As the biggest green ammonia production plant is to be built near Tarfaya in the very south of Morocco, construction of port facilities could be envisioned in Tarfaya. The country is expanding port capacities and increasing exports of phosphates and derivatives with OCP, as announced in the National Port Strategy 2030. Developing ports include the Tanger Med, Nador West Med and Dakhla. A partnership between Tangier and Hamburg for Morocco to export hydrogen was announced in January 2021, and the EBRD has provided €100 mn to evaluate the role of the Nador West Med Port in the hydrogen value chain.[9] Moreover, Morocco holds a strategic advantage in hydrogen exports due to its connection to Europe through the Maghreb-Europe gas pipeline, part of the European Hydrogen Backbone. The Nigeria-Morocco delegated gas pipeline along the Atlantic Coast under consideration would connect the West African countries to Europe via Morocco. In addition, at COP28 Morocco signed the Global Renewables and Energy Efficiency Pledge.

Sources: Argusmedia[1], International Journal of Hydrogen Energy[2], IRENA[3], Middle East institute[4], European Commission[5], IEA[6], Reuters[7], Ministry of Energy Transition and Sustainable Development[8], EBRD[9]

Morocco | Hydrogen progress in view

The current status per barrier has been assessed against the defined 2050 objectives and the current Morocco policy landscape.

Barriers	Status on the barriers (as of December 2023)
Pace of Development	Anticipating a demand of green hydrogen of between 4-30 TWh by 2030, 68-133 TWh by 2040 and 154-307 TWh by 2050 corresponds to an estimated $8.9 bn by 2030 and $75 bn by 2050. Four regions have already been identified as suitable for large-scale green hydrogen projects due to their geographic advantages (regions of Oriental, Guelmin-Oued Noun, Tarfaya, Dakhla). In the short term (2020-2030), the National Roadmap for Green Hydrogen envisions two drivers for accelerating the hydrogen economy in the country by 2030: the use of hydrogen as a feedstock in the local production of green ammonia and the export of green hydrogen to countries with ambitious decarbonization goals. In the middle term (2030-2040), with stricter environmental regulations, the production and export of green hydrogen for synthetic fuels is envisioned. At the same time, hydrogen will be used as an electricity storage vector. Partnerships such as the Green Partnership with UNIDO, the European Union and the German-Moroccan Energy Partnership (PAREMA) will accelerate green hydrogen development through knowledge sharing, financing, and securing demand. In addition, at COP28 to promote sustainable energy development and technology development the Minister of Water and Energy of Ethiopia together with Masen signed a MoU on the creation of the Coalition for Sustainable Energy Access (CSEA).This agreement sets out the foundations for South-South cooperation aimed at significantly developing renewable energies through the exchange of know-how and technologies, in line with the 'Leave No One Behind' principle defined in the United Nations' Agenda 2030. Also at COP28 Morocco and the UAE launched a generation of bilateral cooperation and investment partnerships, including in energy and sustainable development. To be officially announced soon, Offre Maroc will be an entity to accelerate development by centralizing the green hydrogen value chain, facilitating investment for international and national private companies (flagship institutional players will be announced with the publication). For now, Masen is developing a reference project to launch the dynamic of development and demonstrate the competitiveness of such projects in Morocco at industrial scale.
Technology	For electrolysis, current projects consider both PEM and AEM electrolyzers. Through the partnership with John Cockerill, the country plans to build local manufacturing capacity of AEM electrolyzers. In addition, the Green Hydrogen and Applications Park is a research and training platform built in collaboration with the IRESEN and the Mohammed VI Polytechnic University. The training platform has been developed as a research platform on Power-to-X topics such as green hydrogen, ammonia and methanol, as well as water desalination. Partners of this platform include OCP, Fraunhofer and MinesParisTech. Training on renewable energies are available at IFMEREE (Instituts de Formations aux Métiers des Energies Renouvelables et de l'Efficacité Energétique). In addition to this, in August 2023, Chariot Ltd. announced a partnership agreement with Mohammed VI Polytechnic University (UM6P) and Oort Energy to launch a pilot proof of concept 1 MW PEM electrolyzer system at UM6P's Research and Development facility at Jorf Lasfar.[1]
Cost	Morocco could benefit from incentive programmes and financing schemes being deployed by European countries and the European Commission specifically for green hydrogen. For renewables, they use project finance and / or commercial banks. The country plans to build a hydrogen industry and economy heavily through foreign investments. Generally, projects are financed through a project finance model, with capital made available through state-backed companies such as OCP, local banks and / or foreign investments (e.g.Total, Cockerill, Chariot, KfW, EIB, ADB). Among notable foreign investments are the co-financing of the EBRD of the Koudia Al Baida wind farm[2] with a senior loan of €35 mn, and the loan from KfW of €654 mn to support the construction of the fourth power plant of the Ouarzazate solar complex.[3] There exists few state guarantees for green hydrogen projects, as each project developed must have a viable business model over 25 years. Furthermore, Scatec has signed a $100 million loan agreement with the World Bank's International Finance Corporation (IFC), part of a larger partnership to provide a simpler, more affordable, and cleaner offering of power to African utilities, which Morocco could leverage. At COP28, Morocco's Attijariwafa Bank and Schneider Electric signed an MoU to join forces to promote energy efficiency through studying and carrying out technical and financial studies and financing energy efficiency projects.

Sources: Chariot Limited[1], EBRD[2], KfW[3]

Egypt | Current market

WORLD ECONOMIC FORUM

In collaboration with ***Accenture***

Main Agreements and MoUs

Countries:

Companies: AMEA, Siemens Energy, Eni, Acwa Power, Scatec, Fertiglobe

Egypt aims to rank among the world's top 10 green hydrogen producers, leveraging the Suez Canal, with a goal to capture 5% of the global green hydrogen market by 2030. Initially exporting 100% of its hydrogen as green ammonia, the focus will shift to domestic use from 2030 onwards.

Facts and Figures

Population (2022)	**111 mn**
GDP (2022)	**$476.7 bn**
GDP per capita (2022)	**$4,300**
CO_2 emissions (2022)	**377.78 Mton CO_2eq**
Inst. Renewable Capacity (2022)	**6322 MW**
Crude oil production (2021)	**0.6 Mbpd**
Natural gas production (2021)	**67.8 bn m³**
Low-carbon hydrogen aim	Produce **10 Mtpa** by 2040

Infrastructure

Special economic zone — **Pipelines** — **Ports**

Sectoral Overview

The Suez Canal Economic Zone as an enabler of the national green hydrogen strategy.

Key players

- Ministry of Electricity and Renewable Energy, Ministry of Petroleum, New and Renewable Energy Authority (NREA), Suez Canal Authority & SCZone
- Egyptian Electricity Holding Company (EEHC), Sovereign Fund of Egypt, Egyptian Fertilizer Company
- European Bank for Reconstruction & Development, Fertiglobe, AMEA power, Siemens, Eni, EDF, Scatec, DEME, ACWA Power

LCOH (current)	Blue: $1.65 /kg Green: $2.57-6.69 /kg[1], 2050 aim $1.7 /kg[2]
Policies	Egypt Vision 2030 (2016) National Strategy for Green Hydrogen (2022) Integrated Sustainable Energy Strategy (ISES) to 2035 (2016) National Climate Change Strategy 2050 (2022)
Current hydrogen usage	Domestic hydrogen usage **1.8 Mt**[1]
Technology	PEM electrolyzer, KAAP™ (KBR Advanced Ammonia Process)

Sectoral Maturity

The country has signed MoUs worth $83 bn and has a developed energy sector, including high renewables capacity.

O&G Sector Maturity	Producer and net exporter of oil, with 63 tcf of proven reserves (3rd largest natural gas producer in Africa)[3], 3.3bn barrels of oil.[4]
Current Funding Model	Newly established finance with $83 bn worth of green hydrogen deals and 9 agreements at COP27. Collaborations such as an $80 mn equity bridge loan with the European Bank for Reconstruction and Development (EBRD). Several financial incentives for tax reliefs and subsidies.
Workforce	Trainings on green hydrogen such as American University in Cairo and ICESCO, workforce skilled for O&G.
Domestic Market	Domestic sectors include ammonia as fertilizer, steel, petroleum (refiners, petrochemical, methanol, gas derivatives) industries, transportation sector.
Infrastructure	Existing natural gas pipelines, major shipping hub in the Suez Canal Economic Zone, currently 6.3GW installed wind, solar and hydro power.[5]
Energy Independence	Self-sufficient in energy supply from significant oil, natural gas, solar, wind and the hydroelectric power generated from the large dam projects over the Nile: the High Dam, Aswan I & Aswan II.

National Ministries and agencies — National companies — International partners

Maturity: Developing — Emerging — Mature — Highly mature

Sources: Oxford Energy[1], Minister of Electricity[2], United Nations Industrial Development Organisation[3], Privacy Shield[4], Reuters[5]

Egypt | Hydrogen progress in view

The current status per barrier has been assessed against the defined 2050 objectives and the current Egypt policy landscape.

Barriers	Status on the barriers (as of December 2023)
Low-carbon hydrogen acceleration	Egypt is forecast to be one of the top 10 green hydrogen producers in the world, through a developed oil and gas infrastructure, renewables potential, water desalination establishment and potential for electrolysis application. Focusing on green hydrogen primarily, the country holds 19 green hydrogen signed MoUs and being the second largest signatory of multilateral trade agreements and greenfield FDIs in the world[1]; combined with its geographic central location, the country is well positioned for meeting its goal of securing 5% of the global green hydrogen market by 2040 (8% by 2050). From these 19, since hosting COP27 there have already been signed framework agreements for nine green hydrogen projects with investments of $85bn in the Suez Canal Economic Zone (SCZone), an area promoting economic growth through policies, attracting foreign investment and developing new industries.[1] Investments are also supported by available tax incentives and subsidies. However, Egypt wants to primarily focus on an exports play until a more domestic focus in 2030, which means it must address the barrier of distance between the best sites for green hydrogen production (substantially inland) and the access to export routes through seaports in the Suez Canal.
Standards and Certification	At COP28, Egypt signed the Intergovernmental Declaration of Intent on Mutual Recognition of Certification Schemes for Hydrogen and Hydrogen Derivatives, covering over 80% of the future global market in hydrogen and its derivatives. With further action required to remove limits on export potentials and an absence of local regulations and certification to verify the origin and quality of green hydrogen, projects in Egypt will be governed by the existing Gas Market Law No. 196 of 2017. To further push green hydrogen projects to FID stage, the Egyptian cabinet established the National Council for Green Hydrogen and its Derivatives in 2023 to ensure regional and international competitiveness, which will review green hydrogen legislation and regulations. In addition, there are currently no national regulations for brine disposal, essential for seawater desalination.
Demand	Current hydrogen demand in Egypt is around 2% of the global annual demand[1], and the aim is to provide 10 Mtpa of the global hydrogen market by 2040, focusing on green fuel production for the Suez Canal maritime sector. The $83 bn investment would yield up to 15 Mtpa green ammonia and e-methane. Out of the projects contracted, 100% will aim to export in the form of green ammonia and methanol as a phase 1 whilst phase 2 in 2030 will aim for local, domestic usage. While Egypt is already using hydrogen locally to produce steel and petrochemicals, hydrogen is primarily being used to produce ammonia and nitrogen-based fertilizers, given the marine port infrastructure and offtakers (such as from MOPSO, Alexfert / Abu Qeir, SEMADCO, and the East Port Said industrial zone). As of 2022, Egypt's ammonia production capacity stands at 6 Mtpa [2], currently all based from grey hydrogen, with main export demand from India, the Netherlands, Turkey, South Korea and Jordan. Aiming for 2.3 Mt green ammonia by 2030[1] and a market share of up to 8% of the global hydrogen market by 2040, Egypt intends to export 50% of the EU's green hydrogen demand. In addition, Egypt has signed an MoU with the EU (2022) to develop renewable hydrogen. Carbon Contracts for Difference are being considered alongside other demand measures to encourage domestic demand.
Infrastructure	Egypt already has significant energy infrastructure from oil, natural gas and hydroelectric power from the large dam projects over the Nile River. Due to overall water scarcity the seawater has high desalinated water potential for green hydrogen.[2] All 19 MoUs are located in the SCZone, bodies include the New and Renewable Energy Authority (NREA), the General Authority for the SCZone, the Egyptian Electricity Transmission and Distribution Company (EETC), and the Egypt Sovereign Fund, as well as leading companies in the production of renewable energy. The SCZone acts as a top potential cluster for hydrogen, with six ports and 461km^2 of four industrial parks including ammonia, pharmaceutical and petrochemical production facilities. It is also located closely to the El Zaafarna wind farm and future Gulf of Suez wind farms. Recently the SCZone has signed a $1.1 bn MoU for green bunkering in East Port Said and signed a strategic deal with Engazaat and Chint Global for 2 mn sq. meters of a green energy industrial park in Egypt. The Integrated Sustainable Energy Strategy (ISES) to 2035 targets renewable electricity generation of a 100 GW by 2035[2], and aims to create a 70 GW Green Energy Corridor, a strategic initiative that focuses on developing and enhancing the country's power infrastructure. As well as hosting Benban, the largest solar parks in Africa at 1.8 GW, Egypt is starting to develop small scale solar such as its Egypt-PV project. The Egypt Vision 2030 aims to reduce energy sector emission by 10% and have a fully diversified power generation infrastructure by 2050, with a 2035 renewables representing 42% of total installed capacity, equivalent to 54 GW by 2035. Egypt currently has 100 MW electrolysis live in Ain Sokhna, with an aim to have 4 GW electrolyzer capacity by 2030 in the SCZone. Currently Egypt has 6.8 GW of installed wind, solar and hydro power, aiming for 10 GW by the end of 2023. The country has spent $7 bn adapting its grid in the last seven years, including studying a "green corridor" of power lines to transmit renewable energy.

Sources: United Nations Industrial Development Organisation[1], Rosetta Energy Solutions[2]

Egypt | Hydrogen progress in view

The current status per barrier has been assessed against the defined 2050 objectives and the current Egypt policy landscape.

Barriers	Status on the barriers (as of December 2023)
Pace of Development	A total of 29 MoUs has recently been announced in relation to green hydrogen developments in Egypt, some to accelerate the domestic economy and some aiming to promote the development of the SCZone and exports to the EU.[1] To accelerate pace, Egypt's low-carbon hydrogen strategic framework focuses on using pilot projects in the 2020s to then scale up in the 2030s, with full market implementation in the 2040s. On hydrogen usage, in the short-term Egypt will focus on internationally exporting 100% of low-carbon hydrogen as green ammonia and methanol. In the medium-term, Egypt will look at utilization for hydrogen use in hard-to-abate industries and for local offtakers. On the long-term, Egypt will focus on developing more local uses of hydrogen and pipelines such as to Holland, Norway, and Denmark, using the Southern gas corridor and Germany's HyPerLink. With a combination of strong skilled and unskilled low-cost labour, Egypt's green hydrogen strategy is expected to generate 100,000 jobs. From the COP27 signatures, it is expected this will generate 45,000 direct jobs and 230,000 indirect jobs.[2] There are several recently created higher education programs in renewable energy and environmental engineering such as at American University in Cairo and ICESCO, and training centers in the Suez region for the handling of ammonia.
Technology	Various technologies primarily in green hydrogen such as PEM electrolysis, and KAAP™ KBR technology used for ammonia. With 80% of the $83 bn COP27 hydrogen deals signed allocated for technology transfer investments, there is significant scope to develop the technologies required. There is still further development required for transport and export technologies, such as for the conversion, storage and export of liquid hydrogen. However, there is still an overall need for further expert knowledge and awareness on the topic of hydrogen and renewable energy, and capacity on green fuel bunkering. Hydrogen Egypt is an international association with more than 400+ international hydrogen technology companies, specialized investment funds, including 25+ International regions and 30+ international associations, with aims to promote hydrogen technologies, encourage knowledge exchanges and skill transfers between companies and universities and promote the infrastructure for trade of international markets.
Cost	There are 2040 targets for 8% hydrogen global market share and for green hydrogen to increase the country's GDP by $10-$18 bn. $83 bn of agreements were signed at COP27, further promoting development of this nascent industry. The highest investments into green hydrogen projects come from Fortescue Future Industries, Acme and Globaleq, totaling $44 bn.[3] Eni, General Electric and ThyssenKrupp have bid collectively $2 bn to establish green and blue hydrogen plants in Egypt[4], Indian company Ocior has invested $4bn in green hydrogen in the SCZone.[2] The Egyptian Sovereign fund has a specific infrastructure fund which is involved in numerous hydrogen projects, as well as the $80mn equity bridge loan from the EBRD to develop the country's first green hydrogen facility, consisting of a 100 MW electrolyzer, powered by a 55 MW solar PV plant and a 200 MW windfarm. Financial incentives include the green hydrogen incentive package: tax exemptions and refunds such as for equipment or exports of green hydrogen and derivatives; 5 years exemption from stamp tax, and investments subsidized in the amount of 30-50% of the income tax payable from the Ministry of Finance.[1] The EBRD are also investing in bonds supporting Egyptian solar plants.[5] Furthermore, the EU announced at COP27 a contribution of up to €35 mn in support of Egypt's Energy Wealth Initiative.[6] However, the current economic climate indicates reprioritisation; debt levels in Egypt rose to $155 bn in the first quarter of fiscal year 2022/2023 as reported by the Central Bank of Egypt[1], shifting 45% of the country's budget to servicing the debt and prioritizing inflation control. Furthermore, Scatec has signed a $100 million loan agreement with the World Bank's International Finance Corporation (IFC), part of a larger partnership to provide a simpler, more affordable, and cleaner offering of power to African utilities, which Egypt could leverage.

Sources: Rosetta Energy Solutions[1], AhramOnline[2], FD Intelligence[3], Enterprise[4], EBRD[5], European Commision[6]

Qatar | Current market

In collaboration with Accenture

Main Agreements and MoUs

Countries:

Companies: General Electric, Shell, ThyssenKrupp

Qatar is the largest grey hydrogen consumer in the GCC at 6 Mtpa[1] due to hosting the world's largest gas-to-liquids plant. The country, despite lacking a standalone hydrogen strategy, is prioritizing the development of blue hydrogen due to land scarcity. With a goal of achieving net zero by 2050, Qatar also aims to become a major carbon capture and storage hub and has ambitions to invest in hydrogen abroad.

Facts and Figures

Population (2022)	**2.7 mn**
GDP (2022)	**$237.3 bn**
GDP per capita (2022)	**$88,000**
CO_2 emissions (2022)	**194.65 Mton CO_2eq**
Inst. Renewable Capacity (2022)	**824 MW**
Crude oil production (2021)	**1.75 Mbpd**
Natural gas production (2021)	**177 bn m³**
Low-carbon hydrogen aim	Produce **1.2 Mtpa** blue ammonia

Infrastructure

Ports

Sectoral Overview

With the aim of decreasing carbon emissions by 2050, the country, through state-backed companies such as QatarEnergy and QAFCO, is looking into decreasing the carbon content of its current production.

Key players

- Ministry of Energy and Industry
- QatarEnergy, QAFCO, Qatar Investment Authority
- ThyssenKrupp, Consolidated Contractors Company, General Electric

LCOH (current)	Blue: $2.96 /kg Green: Alkaline $2.61 /kg; PEM: $3.31 /kg[2]
Policies	National Vision 2030 (2008) National Environment and Climate Change Strategy (2021) Carbon Capture Roadmap (TBA)
Current hydrogen usage	**6 Mtpa** mainly for GTL[1]
Technology	SMR process powered by solar thermal energy + CCS, Ammonia-7 project: Dual Pressure Synthesis (ThyssenKrupp Uhde® Dual Pressure)[3]

Sectoral Maturity

With 24.7 tcm proven natural gas reserves, Qatar aims to make use of its existing natural gas facilities and is developing a 1.2 Mtpa blue ammonia project and large CCS capacities.

O&G Sector Maturity	World's leading exporter of LNG with the 3rd largest proved natural gas reserves in the world, in the top 10 natural gas exporters.
Current Funding Model	Project finance with strong government backing. Ammonia-7 project financed by QatarEnergy and QAFCO.
Workforce	Reliance until now on international workforce in the oil and gas sector. Qatarization program to increase local workforce in the energy sector.
Domestic Market	Strong domestic industries led by state-backed companies that have the potential to develop the use of hydrogen with CCS facilities: refinery, fertilizer (QAFCO), steel (Qatar Steel), and methanol (QAFAC) industries. QAFCO leading the way with the Ammonia-7 project.
Infrastructure	Well-developed natural gas grids, 4 ports handling LNG, oil, ammonia, methanol and/or urea.
Energy Independence	With its large proven natural gas reserves, Qatar is highly energy independent and sent more than 70% of its LNG exports to Asia and 25% to Europe in 2022.[4]

National Ministries and agencies · National companies · International partners

Maturity: Developing · Emerging · Mature · Highly mature

Sources: Ministry of Foreign Affairs of the Netherlands[1], Platts[2], Thyssenkrupp[3], EIA[4]

Qatar | Hydrogen progress in view

The current status per barrier has been assessed against the defined 2050 objectives and the current Qatar policy landscape.

Barriers	Status on the barriers (as of December 2023)
Low-carbon hydrogen acceleration	With a rapidly increasing GDP, a world leading natural gas market and strong investors, Qatar urgently needs a national hydrogen strategy to define its goals, partners and risks. Qatar is expected to mainly focus on blue ammonia development given its gas-rich resources and infrastructure, using SMR and Uhde® Dual Pressure technologies. Qatar can leverage their abundance of renewable energy potential from furthering solar development and exploring wind.
Standards and Certification	Although regulations are published for electricity generation, transmission and distribution (including solar) by Qatar General Electricity and Water Corporation (Kahramaa), Qatar has not yet communicated on certification for low-carbon hydrogen. In addition, no information has been shared on the certification scheme to be used for the Ammonia-7 project.
Demand	Qatar is using its domestic fertilizer industry to push demand for low-carbon hydrogen through blue ammonia. In 2022 QatarEnergy and QAFCO in alliance with Consolidated Contractors and Thyssenkrupp, announced the Ammonia-7 plant operational to be operational in 2026 with 1.2 Mtpa of production. This plant is not only to reduce the domestic use of natural gas but also to prepare for the upcoming demand in clean ammonia on the market. In parallel Qatar is developing partnerships with countries abroad to facilitate the development of hydrogen production facilities abroad.
Infrastructure	Being gas-rich, Qatar has a well-established energy infrastructure which has the potential of being repurposed for hydrogen. With limited land availability but a large carbon capture and storage (CCS) potential, development is mainly in blue hydrogen through blue ammonia. QatarEnergy and QAFCO have launched the construction of the Ammonia-7 1.2 Mtpa blue ammonia project in Masaieed Industrial City, operational in 2026. So far, the company has captured 3.8 Mt of CO_2eq through its various CCS facilities and is building the North Field East liquified natural gas project which will increase the country's capture capacity from 2-5 Mt of CO_2 per year by 2025.[1] The country has the ambition to store between 7-11 Mtpa of CO_2 by 2030 and 11 Mtpa by 2035[2] through development of with QatarEnergy CCS facilities, and QatarEnergy has signed an MoU with General Electric to collaborate on developing a Carbon Capture Roadmap.[3] Qatar has 4 existing ports already handling LNG, oil, ammonia, methanol, fertilizers and urea (Mesaieed, Ras Laffan, Doha and Halul Island). Qatar's National Vision 2030 outlines aims for 20% renewable energy by 2030 and net zero by 2050, opening its first solar energy plant in October 2022 (800 MW in Al Kharsaah), with another 2 plants online by 2024. There are also studies in place to explore wind potential and waste-to-energy, with one waste management centre in operation.[4]
Pace of Development	Qatar's government has shown a strong commitment to advancing blue hydrogen as part of its broader sustainable energy and environmental goals. Clear example of this ambition is the development of the Ammonia-7 project by QatarEnergy and QAFCO and the MoU to develop a carbon capture Roadmap for the energy sector. To leverage expertise and ensure sound development of projects, Qatar actively engages in collaborations with international partners. Notable partners for the project are Thyssenkrupp and Consolidated Contractors. The country is pushing for a 50% Qatarization of the workforce in the energy sector.
Technology	Qatar has several technology institutes to foster innovation, such as the Qatar Environment and Energy Research Institute, the Qatar Education City, the Qatar Science and Technology Park and the Qatar Shell Research and Technology Centre (QSTP). The latter specifically leads research on Gas-to-X. The Qatar Environment and Energy Research Institute announced in 2022 the creation of a new test facility to examine the interaction of hydrogen with metals to enhance the country's capabilities in corrosion research. Qatar University has developed a training program on Hydrogen Sustainability Energy Solutions.
Cost	Today, the cost of hydrogen in Qatar is estimated at $2.23 /kg for blue hydrogen, $2.61 /kg for Alkaline hydrogen and $3.31 /kg for PEM-hydrogen.[5] Projects in Qatar are financed by state-backed companies on a project-by-project basis. In 2023, the Qatar National Research Foundation launched a fund to explore hydrogen opportunities. Qatar has also been investing abroad in hydrogen projects: the Qatar Investment Authority is considering an investment in a green hydrogen project in Egypt in the Suez Canal Economic zone. A second example of Qatar's implication in hydrogen project abroad is its MoU signed with Shell for the development of green and blue hydrogen projects in the United Kingdom.

Sources: IEA[1], QatarEnergy Sustainability Report[2], General Electric[3], Dentons[4], Platts[5]

WORLD ECONOMIC FORUM

In collaboration with ***Accenture***

Oman | Current market

Main Agreements and MoUs

Countries:

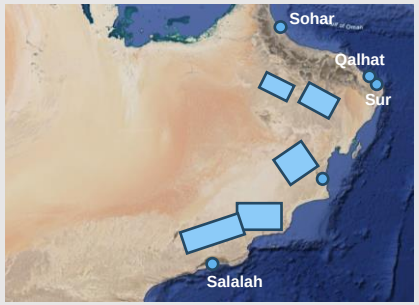
Companies: Linde, Posco, Marubeni, CIP, Shell, bp, Jindal Shadeed, Engie, DEME

Oman, with its high wind and solar potential and robust oil and gas infrastructure, is on track to become the sixth-largest global hydrogen exporter by 2030, accounting for 61% of total hydrogen exports. The country is focusing on green hydrogen development (with blue as a stepping stone) considering that, by 2050, its renewable energy capacity will enable it to produce four times its energy needs.

Facts and Figures

Population (2022)	**4.6 mn**
GDP (2022)	**$114.7 bn**
GDP per capita (2022)	**$25,000**
CO_2 emissions (2022)	**137.24 Mton CO_2eq**
Inst. Renewable Capacity (2022)	**688 MW**
Crude oil production (2021)	**0.97 Mbpd**
Natural gas production (2021)	**41.8 bn m³**
Low-carbon hydrogen aim	Produce up to **1.15 Mtpa** by 2030

Infrastructure



Ports exporting hydrogen or ammonia

Available land for green hydrogen

Sectoral Overview

Hydrom is leading the implementation of the Green Hydrogen Strategy in auctioning over 50,000 km² of land to green hydrogen developers. This one-stop-shop is critical in ensuring the pace of development and involving international energy players.

Key players

- Ministry of Energy and Minerals (MEM), Ministry of National Economy
- Hydrom, Energy Development Oman (EDO), Hy-Fly Alliance Oman Hydrogen Centre, OQ
- Jindal Shadeed, Engie, DEME Concessions, POSCO, Shell, BP, Copenhagen Infrastructure Partners

LCOH (current)	Blue: $3.04 /kg Green: Alkaline: $3.56 /kg, PEM: $4.35 /kg[1]
Policies	Green Hydrogen Strategy (2022) National Strategy for an Orderly Transition to Net Zero (2022) Oman Vision 2040 and the National Energy Strategy (2022)
Current hydrogen usage	**1.1 Mt[2]**
Technology	TBD

Sectoral Maturity

With its strategic export location, at the entrance of the Strait of Hormuz and its key ports, Oman has a high solar and wind potential and an incredible need for infrastructure development, with less than 1 GW of renewable capacity in 2022.

O&G Sector Maturity	Oil and gas has represented around 60% of total export income in the past years[2]. However, leftover reserve volumes are limited.
Current Funding Model	Project finance model with incentives under the form of reduced land fees. Proven funding mechanisms for six projects.
Workforce	Skilled workforce from the oil and gas sector, training program available at the Oman Hydrogen Centre.
Domestic Market	Domestic demand for hydrogen comes from the refinery, steel and chemicals (urea, ammonia, methanol production) sectors.
Infrastructure	Planned strategic export hubs / ports: Salalah, Sohar, Sur and Duqm. 50,000 km² land available for renewables dedicated to green hydrogen, building renewable energy capacity
Energy Independence	Oman exports 68% of its energy production[3], mostly to Asian and European countries.

National Ministries and agencies | National companies | International partners

Maturity: Developing | Emerging | Mature | Highly mature

Sources: Platts[1], IEA[2], IRENA[3]

Oman | Hydrogen progress in view

The current status per barrier has been assessed against the defined 2050 objectives and the current Oman policy landscape.

Barriers	Status on the barriers (as of December 2023)
Low-carbon hydrogen acceleration	Oman is on track to become the 6th largest exporter of hydrogen globally by 2030, and to become a competitive renewable hydrogen and ammonia producer from its renewable resources. It benefits from vast amounts of land and an existing fossil-fuel infrastructure which can be used or repurposed. Its geography also places it conveniently to export to the European and Japanese markets. The country has high ambition; net zero targets by 2050 and renewable hydrogen production targets exceeding current LNG exports. The country has established an independent entity, Hydrom (Hydrogen Oman), to manage hydrogen strategy, auctioning and implementation, with six binding production agreements worth $20 bn already signed. To improve the CAPEX, HYDROM has incentives such as lower cost land fees and is to build shared infrastructure, such as desalination plants and roads.[1]
Standards and Certification	At COP28, Oman signed the Intergovernmental Declaration of Intent on Mutual Recognition of Certification Schemes for Hydrogen and Hydrogen Derivatives, covering over 80% of the future global market in hydrogen and its derivatives. The Directorate General for Standards and Metrology is Oman National Standards entity. No known standards on low-carbon hydrogen have been set yet.
Demand	Total hydrogen domestic demand in 2021 was 1.1 Mt in 2021 of which 0.64 Mt of hydrogen were used in the chemicals sector. The remaining 0.46 Mt were used in refineries and steelmaking, for the direct reduction of iron.[2] The country aspires to become the 6th producer worldwide of green hydrogen and the Middle East's top exporter, and is expected to develop its domestic demand to promote production. To realize this ambition, Oman is targeting at least 1 Mtpa of green hydrogen production by 2030 (2.4 Mt will come online by 2026), 3.75 Mt by 2040 and up to 8.5 Mt by 2050 (which would capture 1.8% of the global hydrogen market).[2] Half of the ten planned hydrogen projects are targeted for exports, mostly under the form of ammonia.[2] Oman has the potential to represent 61% of total 2030 hydrogen exports from the Middle East, ahead of the UAE (20%) and KSA (16%)[2], but to meet the country's 2030 green hydrogen targets, incentives will need to be strong and offtakers found. Domestically, there are already $3 bn investments for a green steel manufacturing facility in Duqm for 5 Mt of low-emission steel, but newer uses also include low-emission fuels for high-temperature heat industry processes.[2]
Infrastructure	Meeting the Oman 2030 hydrogen production targets would require around 50 TWh of renewable electricity.[2] Traditionally in Oman, 95% of electricity generated comes from natural gas and only 0.5% from renewables; there is a necessary rapid ramp-up from the current renewable installed capacity of less than 1 GW. Announcing the net zero by 2050 target in 2022, the Oman Vision 2040 and the National Energy Strategy aims to increase renewables' share in electricity generation mix of more than 20% by 2030 and 35-39% by 2040. At COP28 Oman signed the Global Renewables and Energy Efficiency Pledge. In 2021, 42 TWh was generated through the electricity grid, with 675 MW renewables coming online in 2022. Oman has an array of renewable energy projects in development, with a pipeline to generate 8 TWh or renewables by 2027. Through the Green Hydrogen Strategy, the country has allocated more than 1,500 km² of land for green hydrogen projects, enough for 25 Mt hydrogen. 50,000 km² of land has been identified for green hydrogen production, 16% of the country's land area. Industries currently using grey hydrogen are in Sohar port, and electrolyzers will be situated next to renewable energy production locations. By 2030, the country hopes to have an 8-10 GW electrolyzer capacity, rising to 35-40 GW in 2040 and 95-100GW by 2050. The 10 hydrogen planned projects include an electrolysis capacity over 9500 MW and hydrogen production capacity of 1953 ktpa, with operations to start between 2024-2030.[2] Hydrom has recently begun setting up an infrastructure company that will cater to the sultanate's emerging green hydrogen sector, comprising of OETC, Nama and OQGN. Hydrom has also recently signed a joint study agreement (JSA) deal to set up EU green hydrogen corridor with Zenith Energy and GasLog, to set up infrastructure for the export of green hydrogen to Port of Amsterdam in Netherlands and Europe. At COP28 they also announced a green block to SalalaH2 consortium, signing of an MoU with Siemens Energy and OIA to develop an electrolyzer manufacturing facility and another MoU develop the logistics sector facilitating large-scale hydrogen projects. Many of the projects designated for export are planned in shared industrial hubs, namely ports, such as Duqm, Salalah and Sohar, but to fully connect production, a 2000 km-long pipeline is required, to be built by 2030 in the main production areas. By 2040 Sohar will be connected to the pipeline and by 2050, the whole country will be covered, including connection to neighbouring countries. Out of Oman's five industrial ports (Duqm, Muscat, Salalah, Sohar and Sur), Salalah, Sohar and Sur have existing ammonia infrastructure and terminals. It is likely most hydrogen exporting will be through ammonia, so the 2 remaining ports will need to be evaluated for location and capacity to develop ammonia export facilities. This puts Oman in a strong position for global market trade, but to fulfill the expected demand, Oman will have to expand 20-30 times the current ammonia export capacity.

Sources: Carbon Credits[1], IEA[2]

Oman | Hydrogen progress in view

The current status per barrier has been assessed against the defined 2050 objectives and the current Oman policy landscape.

Barriers	Status on the barriers (as of December 2023)
Pace of Development	The expansion of Oman's hydrogen economy is planned in three phases: market entry and partnership building (2021-2025), growth and diversification (2026-2030), and the establishment of a fully-fledged hydrogen economy (2031-2040). By 2030, Oman anticipates the completion of the Phase A of land tendering for green hydrogen development. Six binding agreements have already been signed with Shell, BP, Copenhagen Infra Partners, Posco, Engie and DEME. These agreements each include mandates to deliver a minimum production of 150,000 tpa by 2030 and 750,000 tpa by 2050. For the country to be able to ensure the quick step up between 2026 and 2030, there is a need for stakeholders in various ministries, public sectors and the GCC more broadly to recognize the significance of hydrogen, to coordinate their efforts, and to establish further regulatory frameworks to advance this initiative. Hydrom's mandate is to spearhead Oman's green hydrogen strategy, which includes delineating government-owned land areas, structuring large-scale green hydrogen projects, managing project allocation to developers, overseeing project execution, and facilitating the development of common infrastructure and connected ecosystem industries and hubs. The creation of integrated hydrogen ecosystems, akin to European Hydrogen Valleys, in Special Economic Zones and Free Zones (OPAZ) is a key focus. Industrial clusters offer a cost-competitive domestic opportunity for renewable hydrogen by replacing its existing use in refining, given that the industry was responsible for 32% of Oman's total emissions in 2021.[1] An independent body – the Oman Sustainability Centre – has been set up to lead and supervize the implementation of Oman's plans and programs for emissions reduction. Oman's energy transition is projected to boost employment by 20-30% by 2050, primarily in the emerging hydrogen economy (57% of jobs created) and the power sector (43% of additional jobs). Educational efforts, including renewable energy degrees and the establishment of the Oman Hydrogen Center by the German University of Technology, are aligning with the Oman Vision 2040 to prepare the existing skilled workforce for the future. Other universities, such as the Muscat university, have developed Renewable energy specializations.
Technology	If research and development funds today are still assigned to the oil and gas industry, Oman is increasing its green hydrogen research capabilities. Energy Development Oman (EDO) signed a Research and Development MoU with Siemens Energy, a leading global energy technology company. The Oman Hydrogen Centre (OHC) was founded in 2019 by the German University of Technology (GUtech) to support the country in transitioning to renewable hydrogen and energy more broadly. The national research institution Sultan Qaboos University is to engage in developing the hydrogen economy. According to the IEA, two projects in Oman are currently undergoing trials for the implementation of Direct Air Capture technologies.[1] Interestingly, the country has also set its sights on producing green steel, with further details on the technologies to be used expected to be announced in the future.
Cost	The IEA estimates the 2030 levelized cost of renewable hydrogen could be as low as $1.6 /kg and renewable ammonia $400 /t (or $440-520 /t if accounting for shipping).[1] The National Strategy for an Orderly Transition to Net Zero estimates the required investment to unleash the hydrogen export economy at around $230 bn. It is suggested that the private sector could potentially fund 70-80% of the global energy transition by 2050. Private funding is key to building the hydrogen economy in the country and relies on project finance; which the renewables energy arm of the Oman Investment Authority can, in certain cases, fund projects. According to the IEA, the total investment in the country required by 2030 is estimated to be approximately $33 bn. This includes $20 bn for renewable power specifically dedicated to hydrogen production, and $13 bn for electrolysis and ammonia conversion.[1]

Sources: IEA[1]

WORLD ECONOMIC FORUM

In collaboration with ***Accenture***

The UAE | Current market

Main Agreements and MoUs

Countries:

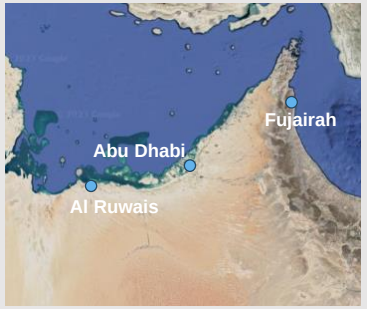
Companies: Siemens Energy, bp, Engie, Fertiglobe, OCI, Petronas, John Cockerill

Hosting COP28, the UAE strategically develops a hydrogen economy for domestic and international trade. Collaboration involves key players like ADNOC (blue hydrogen) and Masdar (green hydrogen). Mubadala contributes to the hydrogen ecosystem, while ADQ explores low-carbon steel via Emirates Steel Arkan. The plan involves scale up hydrogen applications in hard-to-abate sectors both domestically and in regional markets, whilst in parallel driving global trade to key maturing markets in Europe, Korea and Japan.

Facts and Figures

Population (2022)	**9.44 mn**
GDP (2022)	**$507.5 bn**
GDP per capita (2022)	**$53,800**
CO_2 emissions (2022)	**295.11 Mton CO_2eq**
Inst. Renewable Capacity (2022)	**3,058 MW**
Crude oil production (2021)	**3.67 Mbpd**
Natural gas production (2021)	**57 bn m³**
Low-carbon hydrogen aim	Produce **1.4 Mtpa** by 2031, **7.5 Mtpa** by 2040, **15 Mtpa** by 2050

Infrastructure



Ports

Sectoral Overview

Strong and diverse state-backed companies are to put into action the Hydrogen Strategy and Roadmap of the country.

Key players

- UAE Ministry of Energy and Infrastructure (MOEI), UAE Ministry of Climate Change and Environment (MOCCAE), UAE Ministry of Finance (MOF), Abu Dhabi Department of Energy, Abu Dhabi Investment Office (ADIO)
- The Abu Dhabi National Oil Company (ADNOC), Mubadala, TAQA, Masdar (with its shareholders Mubadala, ADNOC, TAQA), Dubai Electricity and Water Authority (DEWA), Emirates Water and Electricity Company (EWEC), Emirates Steel
- Siemens Energy

LCOH (current)	Blue: $3.09 /kg Green: Alkaline: $4.50 /kg, PEM: $5.38 /kg[1]
Policies	UAE National Hydrogen Strategy (2023) Abu Dhabi low-carbon Hydrogen Policy (2023) UAE Energy Strategy 2050 (2023) UAE Net Zero by 2050 Strategic Initiative (2021) Sustainable Aviation Fuel 2050 Roadmap (2022)
Current hydrogen usage	**1.4 Mtpa** signed offtake agreements in place[2]
Technology	AEL (Cockerill), PEM (Siemens Energy), SMR + CCUS (ADNOC)

Sectoral Maturity

A mature energy sector, derivative (such as chemical sector), low-cost, high potential renewable capacity and strong financial resources will support the hydrogen industry

O&G Sector Maturity	Mature oil and gas assets and transportation system, 7th largest natural gas reserves globally, top 10 oil exporters.
Current Funding Model	Substantial financial resources: high credit rating, stable currency, low interest and ability to raise 3rd party financing. Established business hub, strong geopolitical relationships. The UAE has pledged $54 bn in renewables so far and $4.5 bn in clean energy projects in Africa.[2]
Workforce	Various developments to increase jobs through golden visas, increase talent through curriculum developments, collaborations with universities to foster innovation.
Domestic Market	Domestic demand for hydrogen comes from the steel, chemicals e.g. synthetic fuels (SAF), ammonia and methanol industries.
Infrastructure	Ports in place require to be adapted and expanded to the hydrogen economy. Some production infrastructure such as CCUS facilities in place. Advantageous location for renewables: high land availability for renewables and low-cost solar PV.
Energy Independence	Fully independent on O&G and supporting other regions such as Japan, India, China, Singapore, Thailand and Europe, particularly Germany with LNG and Diesel.

National Ministries and agencies · National companies · International partners

Maturity: Developing · Emerging · Mature · Highly mature

Sources: Platts[1], UAE National Hydrogen Strategy[2]

The UAE | Hydrogen progress in view

The current status per barrier has been assessed against the defined 2050 objectives and the current United Arab Emirates policy landscape.

Barriers	Status on the barriers (as of December 2023)
Low-carbon hydrogen acceleration	Low-carbon hydrogen is a key lever for economic growth and economic diversification in the UAE, complementing the country's current energy mix. The country is accelerating ahead of its peers leveraging natural gas resources, CCUS potential, domestic demand (removing reliance upon other countries), abundant sunshine (3,500 hours /year), wind (recent wind program developed) and her strategic location between Europe, Asia and Africa. Importantly the regulatory framework is becoming increasingly mature with the recent release of the Emirate-specific Abu Dhabi low-carbon Hydrogen Policy and the recently updated UAE National Hydrogen Strategy. The National Hydrogen Strategy outlines specific steps, ten enablers for hydrogen acceleration (global collaboration, resources and assets, climate, safety and social drivers, enabling infrastructure, research and innovation, policy, regulation and standards, finance and investments, industry development and demand activation, sustainable commercial and economic models, and skills and education), as well as the creation of hydrogen oases, policy development, regional collaboration, and research investments, to cater for a comprehensive and coherent hydrogen policy framework in the country.
Standards and Certification	The UAE is meeting with countries and first movers on aligning hydrogen with CBAM with the EU, supporting industry through electricity tariffs, land allocation and permissions facilitation. At COP28, they signed the Intergovernmental Declaration of Intent on Mutual Recognition of Certification Schemes for Hydrogen and Hydrogen Derivatives. Currently, policy is set by a proposed collaboration model to bring together working groups (companies) and ministries, outlined in the UAE National Hydrogen Strategy. The UAE is a member of the IPHE and Mission Innovation bodies contributing to standards and certification. EWEC in Abu Dhabi continues its auction for Clean Energy Certificates (CECs), introduced by the Abu Dhabi DoE (issued in units of 1 MWh) to serve as accredited instruments in Abu Dhabi, certifies the electricity consumed originates from a clean energy source. ADNOC's Ruwais refinery has received ISCC certification for SAF production, and the company is also developing a blockchain-based low CO_2 certification system with Siemens Energy. Within transport, the Emirates Authority for Standardization and Metrology (ESMA) has established the first domestic regulations in Dubai for hydrogen vehicles and fuel cells.
Demand	Currently the UAE's hydrogen demand is 0.5 Mtpa[1], primarily produced through steam methane reforming (SMR). The UAE aims to capture 25% of the global low-carbon hydrogen market by 2030 with the sectoral demand expected to grow fivefold between 2031 and 2050[1], diversifying demand from direct hydrogen and ammonia and increasing product value through derivatives such as carbon-based hydrogen products (e-methanol, SAF, polyolefins) and low-carbon steel. Low-carbon hydrogen will first leverage demand in the domestic industry, addressing sectors such as heavy industry, long-haul transport, aviation and shipping, then international trade when the global export market is developed. As well as several UAE has several bilateral agreements / partnerships to drive export demand, the UAE government are part of the International Hydrogen Trade Forum (IHTF) and Hydrogen Council partnership for cross-border trade; a platform for dialogue between exporters and importers of hydrogen and its derivatives, coordinated by UNIDO. Trade options to increase demand are being explored through the Arab League and Africa and a potential India-Middle East-Europe corridor between India, KSA, the UAE, Israel, France, Germany, Italy and the US. The UAE Energy Strategy 2050 published in 2023 envisages UAE production at 1.4 Mtpa of low-carbon hydrogen by 2031 (0.5 Mtpa green produced in the UAE, 0.5 Mtpa abroad, 0.4 Mtpa blue, 0.0075 Mtpa pink), 7.5 Mtpa by 2040 (3.37 Mtpa green, 3.37 Mtpa blue, 0.37 Mtpa pink) and 15 Mtpa by 2050 (7.07 Mtpa green, 7.07 Mtpa blue, 0.74 Mtpa pink). Given the 2031 total demand forecasts (2.7 Mtpa) are 1.3 Mtpa higher than current targets (1.4 Mtpa), there is opportunity for additional production. Targets include: 2.1 Mtpa 2031 forecasted domestic demands (with an additional 0.6-1.8 Mtpa export demand potential)[1]: • Aviation & shipping: 0.55 Mtpa • Iron and Steel: 0.6 Mtpa • Fertilizers and Chemicals: 0.28 Mtpa • Transport: 0.02 Mtpa • Refineries: 0.2 Mtpa • Aluminum: 0.37 Mtpa 5 Mtpa 2040 forecasted domestic demands (with an additional 2.5-5.5 Mtpa export demand potential)[1]: • Aviation & shipping: 2.3 Mtpa • Iron and Steel: 0.9 Mtpa • Fertilizers and Chemicals: 0.5 Mtpa • Transport: 0.1 Mtpa • Refineries: 0.3 Mtpa • Aluminum: 0.8 Mtpa 10.1 Mtpa 2050 forecasted domestic demands (with an additional 4.8-9.6 Mtpa export demand potential)[1]: • Aviation & shipping: 4.9 Mtpa • Iron and Steel: 1 Mtpa • Fertilizers and Chemicals: 0.9 Mtpa • Transport: 1 Mtpa • Refineries: 0.3 Mtpa • Aluminum: 1.7 Mtpa • Grid Flexibility: 0.29 Mtpa

For further information on policies, partnerships and projects, please refer to the deep dive section

Sources: UAE National Hydrogen Strategy[1]

The UAE | Hydrogen progress in view

The current status per barrier has been assessed against the defined 2050 objectives and the current United Arab Emirates policy landscape.

Barriers	Status on the barriers (as of December 2023)
Infrastructure	There is a mature low-cost O&G system in place with abundant natural gas reserves and potential for CCUS (already 1 facility for iron and steel industry in operation housed in Al Reyadah, 1 facility under development). Existing pipelines have the option to be repurposed for hydrogen and a developed industry infrastructure that can shift to using hydrogen derivatives such as steel, ammonia and other fuel. As well as establishing trade corridors, trial runs for transporting hydrogen are underway such as the testing with Hamburg shipped as clean ammonia. Within domestic transport, several hydrogen filling stations are in operation: Al Futtaim Motors and Air Liquide's at Dubai Festival City (a second station due to finish in 2023 in Masdar City)[1], also ADNOC's H2GO and ENOC's in Expo City Dubai. The 2023 UAE National Hydrogen Strategy outlines the ongoing more than twenty low-carbon hydrogen projects, and the development of hydrogen oases "hubs"; two by 2031 and an additional 3 by 2050. All 5 oases are co-locating production and end-use to remove network barriers: nearby refineries, fertilizer plants, industrial plants, airports and ports, all pivoting to use low-carbon hydrogen. In alignment with the Global Ports Hydrogen Coalition, these oases have assigned key ports to be retrofitted to export hydrogen and derivatives, including Fujairah, Abu Dhabi, Ruwais and Khalifa. To achieve 2031 targets of 0.5 Mtpa green hydrogen, the UAE will require 8.7 GW electrolysis powered by 15.3 GW of PV, requiring 94 km^2 of land. An additional 0.4 Mtpa of blue hydrogen translates to around 54,594.3 MMscf natural gas and 5.1 Mtpa of CO_2 captured by CCUS. To achieve 2050 targets, 83 GW electrolysis, 208 GW electricity generation with 1322 km^2 land, and 936,633 MMscf natural gas is required.[1] The UAE Energy Strategy 2050 targets to triple 2023 clean energy (incl. nuclear) capacity to reach 14 GW by 2030: 32% by 2030, 38% by 2035, and 44% by 2050. With high wind and solar potential (71,000 km^2 of land area averaging 6.3 kWh /m^2 per day) and existing nuclear assets, trends predict production of clean energy to reach 14.21 GW by 2031, up from 2.4 GW in 2020. Solar farms are scaling rapidly such as Al Dhafra (2.2 GW, 2023 with the world record low cost solar at 1.35 USD cents kW /hr), Noor Abu Dhabi (1.2 GW, 2019), Mohammed bin Rashid Al Maktoum (1 GW, 2021), with announced further Al Aljan Solar PV (1.5 GW), Sir Bani Yas Island (14 MW) and Umm Al Quwain (500 MW). The UAE wind program launched with Masdar in 2023 is a 103.5 MW project across four locations; a 45 MW wind farm on Sir Bani Yas Island, Delma Island (27 MW), Al Sila in Abu Dhabi (27 MW) and Al Halah in Fujairah (4.5 MW). Masdar and RWE have also announced a 3 GW offshore wind Dogger Bank South farm. Also, DEWA is exploring grid flexibility as an off-take option at its green hydrogen plant. Other developments include the nuclear Barakah nuclear plant, producing 1 Mtpa of pink hydrogen if at full capacity from three 1.4 GW units. The region's first pumped storage hydroelectric plant (250 MW) has commission scheduled for 2024, Abu Dhabi's virtual battery plant (108 MW) is expanding to add 300 MW in 2026, and Dubai's molten storage system will have 700 MW by 2024.[1] Masdar is also advancing a 10 GW growth plan across 6 Sub-Saharan nations to support the renewable energy transition, as well as a collaboration with Bee'ah and SEWA for MENA's first landfill to solar project. In addition, at COP28 the UAE signed the Global Renewables and Energy Efficiency Pledge.
Pace of Development	The UAE is accelerating ahead of competition through leveraging hydrogen domestic demand, decreasing reliance on other countries. More support is required faster from the EU - EPSA projects; today project approvals take 1.5-2 years. The UAE is using demonstrations to guarantee scale up, including low-carbon ammonia pilot shipments and pilots for SAF and green steel. Ahead of SAF scale up, the UAE is forming decarbonized air corridors such as with the UK. The pace of rolling out electrolyzers will be overcome by installing manufacturing plants near production, such as the Electrolyzer manufacturing factory from ADNOC, Strata and John Cockerill. Strategic alliances have been formed to accelerate deployment; the MOEI leading a collaboration model: the Federal Hydrogen Committee, the Hydrogen Strategy Advisory Council, the Working Groups, and the Coordination Office. In addition, state-backed companies' roles in hydrogen are focused to streamline development: ADNOC oversees blue hydrogen and derivatives, Masdar green hydrogen and derivatives, ADQ via Emirates Steel Arcan is to produce low-carbon steel, and Mubadala is leading the creation of the hydrogen ecosystem creation (equipment, services and applications). There is the Hydrogen Alliance: a partnership involving ADNOC, bp, Masdar and Mubadala and NWTN Inc. and CMEC have a strategic partnership to further develop hydrogen plants, carriers, and other clean technology. Masdar has also joined the Hydrogen Council. Abu Dhabi Department of Economic Development are leading a Low-carbon Hydrogen Support Committee, for permitting, regulatory and financial support. Further accelerations include the Masdar and VERBUND production and exporting MoU, Masdar and Hassan Utilities production MoU, Masdar and Engie's hydrogen hub agreement, ADNOC's partnerships with Japan, Malaysia and the Republic of Korea to explore further opportunities, and Abu Dhabi's DoE and Japan's Marubeni MoU to research hydrogen technology. The UAE is also in the G20 Sustainable Finance Working Group aiming to improve sustainable finance by enhancing disclosure, governance and communication.

For further information on policies, partnerships and projects, please refer to the deep dive section

Sources: UAE National Hydrogen Strategy[1]

The UAE | Hydrogen progress in view

The current status per barrier has been assessed against the defined 2050 objectives and the current United Arab Emirates policy landscape.

Barriers	Status on the barriers (as of December 2023)
Technology	The UAE has a top ranking in the 2021 Global Innovation Index within the Middle East and North African region, and joined Mission Innovation with the objective to double clean energy research and development (R&D) back in 2015, but still requires further support and investment for technology improvements. For green hydrogen, technology improvements are to make cheaper, more efficient and longer lifetime electrolyzers and more land for solar development. For blue hydrogen, higher efficiency of methane reforming (only at 65-75%)[1] and lowering the price of CCUS will be needed. With pink, further research is required to improve technology readiness such as optimizing thermochemical reactors to improve economics. Turquoise is also very early development with further research needed into the catalyst deactivation speeds. For waste-gasification hydrogen, higher efficiencies of the biogas reactor is required with feedstock stress-testing to prove large-scale readiness. There are needs to increase effective techniques for safe and economical hydrogen transportation (especially across long distances) and for pioneering new applications such as in SAFs. To help this, the UAE is directly embedding innovation into the hydrogen oases themselves, investing in R&D to improve efficiency and cost-effectiveness of hydrogen, providing commercial opportunities to test and validate technologies. The aim is to establish a hydrogen R&D center by 2031 and establish a globally recognized innovation center for hydrogen by 2050. Centres such as at Khalifah University and CSEM UAE are working in developing green technologies further such as pyrolysis technology. Air Liquide undertook a study in collaboration with Al Futtaim Toyota and Khalifa University to distribute Toyota's hydrogen-powered fuel cell electric vehicle. DEWA and Emirates National Oil Company (ENOC) have signed an MoU to cooperate in a feasibility study to establish, develop and operate a joint integrated pilot project for the use of hydrogen in mobility. Research into further applications, such as at the Jebel Ali and Al Taweelah faciltities for hydrogen improving emissions reduction in natural gas-fired turbines, is under way. ADNOC and bp are collaborating to develop Smart Decision Centres to decarbonize Abu Dhabi's oil and gas operations. Further efforts to address technology challenges include collaboration between Dubai Future Foundation, the Ministry of Climate Change and Environment, the Ministry of Energy and Infrastructure and DEWA launching a report in 2021 to develop integrated strategies to produce, store, and use hydrogen energy. ENEC and EDF have signed an MoU to collaborate on research and development for low-carbon hydrogen production via carbon-free nuclear energy to accelerate nuclear-powered development. In terms of the talent required, the UAE National Hydrogen Strategy outlines the hard ambition to create a thriving talent pool to ensure dynamic talent can power the acceleration of the hydrogen economy and support the technology changes, aiming to create 184,000 jobs by 2031 and 500,000 jobs by 2050. The MOEI, the Ministry for the Environment and Climate Change and the Ministry for Education are collaborating to address the skill gap looking through various campaigns to increase social acceptance, development of curriculums and golden visas.
Cost	According to Platts, the current cost of blue hydrogen is $2.71 /kg, alkaline hydrogen $5.15 /kg and PEM hydrogen $6.1 /kg. Financing clean energy projects began over 15 years ago with $43 bn from 11 projects in the UAE in 2022 and another $50 bn in 40 other countries. The total spend is projected to be another $50 bn over the next decade in 70 countries, $163 bn by 2050. There are several private and public fundings in place; government fundings include the $54 bn pledged for clean energy and hydrogen and $4.5 bn pledged (and catalyse a further $12.5 bn) for African clean energy projects. Private Emirate level fundings include the Dubai Green Fund (DGF), Abu Dhabi Fund for Development, and Ras Al Khaimah RAKBANK Green Financing Solutions as well as the financial hubs Dubai Sustainable Finance Working Group and Abu Dhabi Global Market (ADGM), both with sustainable frameworks. Private and public works are closely tied by state-backed companies such as ADNOC, wholly owned by the Abu Dhabi Government, and ADNOC, TAQA and Mubadala joint shareholders across Masdar. Masdar is looking to raise between $500- $700 mn in green bond sales, to help fund an effort to boost renewable energy generation capacity five-fold by the end of the decade. FAB, TAQA, ACX, and Masdar have also setup a UAE Carbon Alliance aiming to advance decarbonization efforts and developing a carbon market ecosystem. Further private fundings include green bond finance frameworks from Masdar and TAQA, an AED100 mn solar finance program from the Emirates Development Bank and the National Bank of Fujairah, and $250 mn pipeline and hydrogen investments from Snam. Masdar has also collaborated with Mubalada and their partners and taken a leadership role, co-leading the One Planet Sovereign Wealth Funds (OPSWF) network's "Clean Hydrogen Working Group" alongside Mubadala, Ardidan and the Public Investment Fund (PIF). Mubadala has recently unveiled a £270 mn investment in battery developer Zenobē. In 2022 Abu Dhabi launched a Carbon Credit Trading Exchange and Carbon Clearing framework; the world's first trading exchange and clearing house regulator to support carbon as a commodity for trading. There are also several public-private funding initiatives globally such as the UAE-UK Sovereign Investment Partnership, Dubai Green Fund and the Abu Dhabi Fund for Development.

For further information on policies, partnerships and projects, please refer to the deep dive section

Sources: National Hydrogen Strategy and Roadmap[1]

WORLD ECONOMIC FORUM

In collaboration with ***Accenture***

The KSA | Current market

Main Agreements and MoUs

Countries:

Companies: Air Products, ThyssenKrupp, Air Liquide, Haldor Topsoe, InterContinental Energy, Samsung C&T, Engie, Alstom, Marubeni, Posco, DEME

The second largest country in the MENA region, the Kingdom of Saudi Arabia (KSA) has high ambitions in green and blue hydrogen enabled by its renewables and CCUS potential and its geographic position close to the Suez Canal. If the country does not yet have an official hydrogen strategy, it has nonetheless developed multiple projects, the most notable project being the NEOM Green Hydrogen Company having reached FID stage.

Facts and Figures

Population (2022)	**36.4 mn**
GDP (2022)	**$1,108 bn**
GDP per capita (2022)	**$30,400**
CO_2 emissions (2022)	**810.51 Mton CO_2eq**
Inst. Renewable Capacity (2022)	**443 MW**
Crude oil production (2021)	**11 Mbpd**
Natural gas production (2021)	**117 bn m³**
Low-carbon hydrogen aim	Produce **2.9 Mtpa** by 2030

Infrastructure

- **Ports with potential in hydrogen trade**
- **Free trade zone**
- **NEOM**

Sectoral Overview

With strong state-backed companies and its sovereign wealth fund, the PIF, the country is developing ambitious projects with technology partners.

Key players

- Ministry of Energy and Infrastructure, Public Investment Fund (PIF), National Development Fund, National Infrastructure Fund Saudi Industrial Development Fund, NEOM Investment Fund
- Saudi Aramco, ACWA Power, SABIC, ENOWA
- Air Products, Thyssenkrupp, Air Liquide, POSCO, Samsung C&T, DEME

LCOH (current)	Blue: $2.99 /kg Green: Alkaline $3.22 /kg, PEM $3.98 /kg[1]
Policies	Saudi Vision 2030 (2016) Saudi Green Initiative (2021) Integrated Energy Strategy (2020) Liquid Displacement Program (2021) National Renewable Energy Program (2017) Circular Carbon Economy National Program (2021)
Current hydrogen usage	**2.5 Mt** total: refineries (1.1 Mt), steel (0.1 Mt), ammonia (0.3 Mt), methanol (1 Mt)[2]
Technology	SMR and CCUS, alkaline electrolyzer (Thyssenkrupp)

Sectoral Maturity

KSA has large fossil fuel resources, with 6tcm of provden natural gas resources, and high renewable energy capacity, with a record low PV bid at $0.0104 /kWh[3] , strengthening its potential for green and blue hydrogen production.

O&G Sector Maturity	KSA is the third largest oil producer and top oil exporter in the world[4]
Current Funding Model	Consortiums between public funds, state-backed companies and foreign companies successful in funding NEOM Green Hydrogen Company. State-backed companies include Saudi Aramco and ACWA Power. High levels of capital available.
Workforce	Trained workforce in oil and gas, global challenge of expertise in low-carbon hydrogen, Saudization program ongoing.
Domestic Market	Domestic hydrogen used for refinery, chemical (ammonia, urea, methanol) and steel industries.
Infrastructure	Export infrastructure to be adapted to the hydrogen economy (two free trade zones / industrial hubs, ten ports existing, highly developed oil and gas network) and production infrastructure available (CCUS capacities) and under construction (NEOM Green Hydrogen Company).
Energy Independence	KSA is self-sufficient and top world exporter of energy.

National Ministries and agencies · National companies · International partners

Maturity: Developing · Emerging · Mature · Highly mature

Sources: Platts[1], Ministry of Foreign Affairs of the Netherlands[2], PV Magazine[3] , BP[4]

The KSA | Hydrogen progress in view

The current status per barrier has been assessed against the defined 2050 objectives and the current Kingdom of Saudi Arabia policy landscape.

Barriers	Status on the barriers (as of December 2023)
Low-carbon hydrogen acceleration	To improve the business case of low-carbon hydrogen projects, the country is leveraging on CCUS operational assets, as demonstrated by the CO_2-to-EOR Uthmaniyah and CO_2-to-chemicals Jubail project. The business case of certain low-carbon hydrogen projects are strong, such as the NEOM Green Hydrogen Company (NGHC) project that has reached FID stage with $6.1 bn non-recourse financing from 23 local, regional and international banks and financial institutions. There is however still a need for further market incentives, as for example a certain level of secure aggregated demand is still to develop, increasing uncertainty for investors in the expected level of return for first movers.
Standards and Certification	Currently, there are no specific Standards and Certification in KSA on low-carbon hydrogen. Blue hydrogen projects, more specifically SABIC AN and SASREF in Jubail, have been certified in the past by TÜV Rheinland. On standards, a regulation taskforce has been created by the government to develop the response to the CBAM regulation and match the markets on standards. Certification schemes must be established to guarantee the carbon content of hydrogen and ensure the implementation of appropriate technologies and projects.
Demand	The country ambitions to focus first on export markets. NEOM Green Hydrogen Company project will produce 1.2 Mtpa of ammonia to be exported by Air Products to Asia and Europe. In 2020, Aramco and SABIC exported 40 t of blue ammonia to Japan, and Saudi Aramco has signed a Memorandum with Hyuandai OilBank to ship gas to Korea for blue hydrogen production and to transport the CO_2 generated to be stored in KSA. The National Transportation and Logistics Strategy has the objective to develop KSA as a global export hub, contributing to the development of ports to support demand of hydrogen. Although there are already partnerships in place and the Saudi government has announced low-carbon hydrogen production targets, the uncertainty on the size of the global market is slowing the signature of long-term agreements. The CEO of Saudi Aramco Amin H. Nasser announced in May 2023 that Aramco is struggling to find offtakers in Europe for blue hydrogen, pressing the need for longer term agreements to enable targets to be hit. The company suspended its plans to develop blue hydrogen at the Jafurah sour-gas field due to the absence of offtakers. In contrast, the KSA domestic demand for hydrogen is currently of 2.5 Mtpa, consisting of refineries (1.1 Mtpa), steel (0.1 Mtpa), ammonia (0.3 Mt) and methanol (1 Mtpa). In addition, the NEOM Green Hydrogen Company project aims to produce green hydrogen to decarbonize the maritime sector and fuel buses and trucks. Saudi Arabia Railways has partnered in October 2023 with Alstom to introduce hydrogen-powered passenger train in the country.
Infrastructure	KSA has the potential to develop both blue and green hydrogen. The carbon capture and storage (CCS) infrastructure will primarily be situated in the eastern region of the country due to the presence of oil fields. Concurrently, renewable energy capacities will predominantly be developed in the western part of the country, where favorable conditions prevail. On blue hydrogen development, the country has a CO_2 storage capacity potential of 16.7 Gt. Some CCS assets are already in place (SABIC AN and SASREF in Jubail) and hydrogen pipelines developed by Air Liquide Saudi Arabia have been in operation in Yanbu since 2020. On green hydrogen, the NEOM Green Hydrogen Company ammonia project is under construction and is to be operational by 2026, recently winning the second phase of port transformation with DEME and Saudi Archirodon.[1] ENOWA has also recently unveiled a high voltage smart grid for NEOM. With the 2021 lowest levelized lost of electricity bid in the world (the solar PV Sakaka plant), Saudi Arabia plans on attaining 50% of total power generation from renewables by 2030 and, although the 2023 renewables power capacity target of 27.3 GW was missed, the country still maintains the aim to develop a renewables power capacity of 58.7 GW by 2030. The National Champions such as TAQA and ENOWA are in charge of developing renewable energy in the country, but incentives on a state-level require shifting, as they are currently still geared towards fossil-fuels infrastructure and lowering the cost for fossil fuels. In addition, there is a need today for clearer regulation on renewables and a reform on domestic prices for energy. On export infrastructure, ten ports are already in operation in the country, including the Jeddah, Dammam, Yanbu, Jubail, Ras Al Khair and Dhiba ports. The Jubail Industrial Port has already exported ammonia. With the National Transportation and logistics strategy, the country is furthering the development of its port infrastructure to become a global logistics export hub, supported notably by the existing two free-trade zones (Al Khumra, King Abdullah). With the strategy, the country aims to achieve a share of GDP of 10% for the transport and logistics sector by 2030, vs 6% today.

For further information on policies, partnerships and projects, please refer to the deep dive section

Sources: Dredging Today[1]

The KSA | Hydrogen progress in view

The current status per barrier has been assessed against the defined 2050 objectives and the current Kingdom of Saudi Arabia policy landscape.

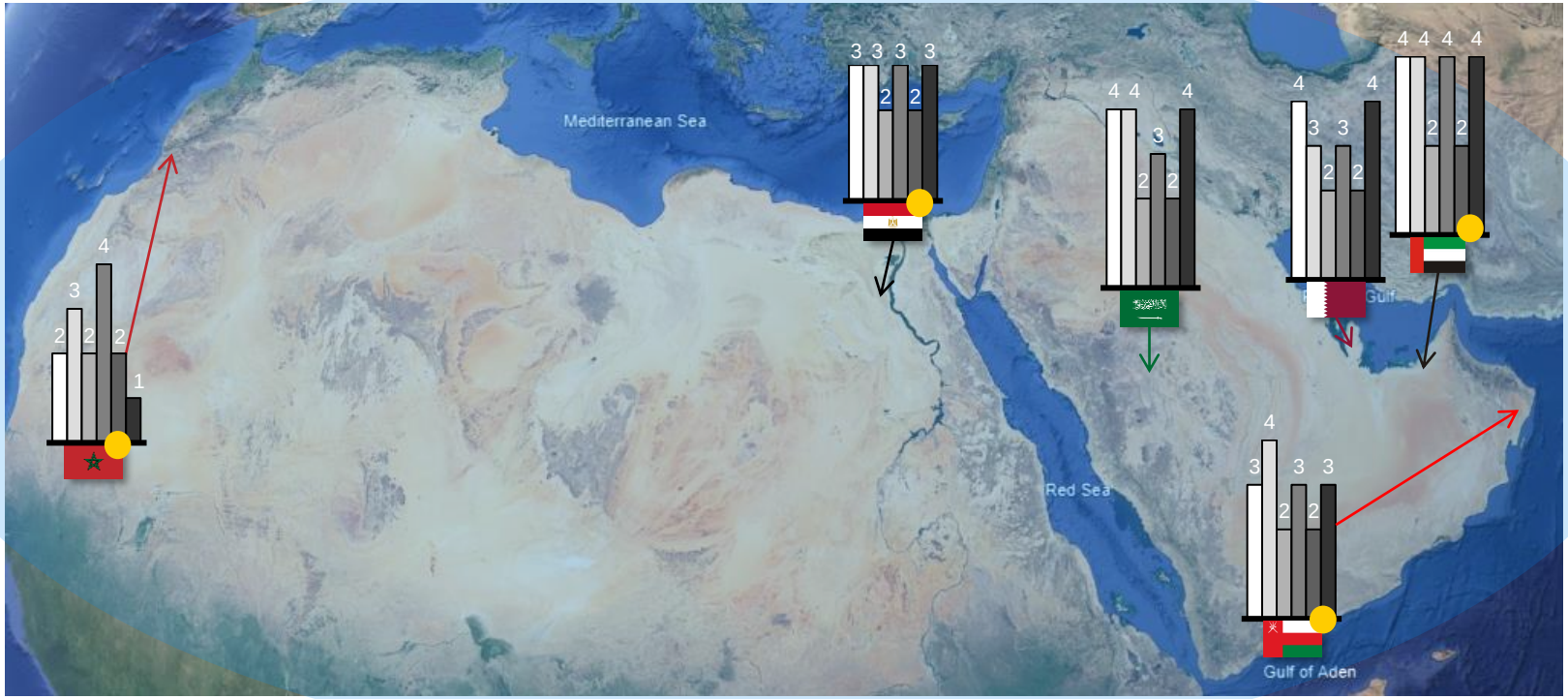
Barriers	Status on the barriers (as of December 2023)
Pace of Development	A distinctive feature of the gulf region is that these National Champions receive state backing, instilling a high level of trust for collaborative efforts and enabling a fast pace of development of hydrogen projects and capabilities. This is applicable to KSA, with multiple blue hydrogen projects in operation and the NEOM Green Hydrogen Company project reached FID stage. Saudi Aramco aims produce 11 Mtpa of blue ammonia by 2030 and to achieve net-zero for Scope 1 and 2 emissions across its wholly-owned operated assets by 2050. In 2020, the company demonstrated its ability to export ammonia by shipping 40 t of blue ammonia to Japan. The supply chain of electrolyzers has been identified as a potential bottleneck and the importance of diversifying the supply chain has been highlighted. The country has already taken steps to alleviate this with signature of a MoU with India to secure reliable and resilient supply chains for materials used in the green/low-carbon hydrogen and renewable energy sector.
Technology	The Kingdom of Saudi Arabia has already put in place the necessary technologies for low-carbon hydrogen projects. The National Champions are key to the development of technology and R&D in this sector. For instance, Aramco is developing a CCUS hub in the Jubail Industrial City, with the objective to capture 9 Mtpa of CO_2 starting in 2027 and 44 Mtpa by 2035. More than four blue hydrogen projects with SMR and CCUS technologies are operational, including the Al Jubail Blue and SASREF facilities recognized by TÜV Rheinland. The NEOM Green Hydrogen Company has chosen thyssenkrupp to engineer, procure and build its alkaline electrolyzer plant. On R&D, the Clean Combustion Research Center (CCRC), part of the King Abdullah University of Science and Technology (KAUST) has been set up to accelerate technology development and commercialization in the combustion sector. The CCRC has recently developed the Cryogenic Carbon Capture technology. Aramco and ENOWA have signed a joint agreement on the establishment of an e-fuel demonstration plant to be located in ENOWA's Hydrogen Innovation and Development Center. Saudi Arabia also has plans to develop technologies abroad, as demonstrated by the agreement signed between Saudi Aramco and Pertamina to develop hydrogen capacities in Indonesia. The global shortage in workforce with the necessary skills for the low-carbon hydrogen technologies also exists in the country. The government has put in place the Saudization program to boost employment opportunities for Saudi nationals and reduce reliance on foreign workers in the private sector, notably in the energy sector. The King Fahd University of Petroleum and Minerals has developed an Interdisciplinary Research Centre for Hydrogen and Energy Storage, and the King Abdullah University of Science and Technology (KAUST) has various courses and conferences on hydrogen and alternative energies.
Cost	According to KAPSARC, the cost of blue hydrogen could fall to $1.13 /kg by 2030 from $1.34 /kg today and the cost of green hydrogen to $1.48 /kg by 2030 from $2.16 /kg today. These cost assumptions are contingent upon a decrease in the cost of renewable power, electrolyzer and CCS technologies. Numerous projects are financed today through the country's sovereign fund, the Public Investment Fund (PIF), with the latter investing heavily in state-backed companies to decarbonize energy assets and in the NEOM Green Hydrogen Company project. State-backed companies are crucial in providing funds to project-financed low-carbon hydrogen projects. Policy incentives and regulatory frameworks could be more detailed to attract more private investments. Although without an official national hydrogen strategy, low-carbon production targets of 2.9 Mtpa by 2030 and 4 Mtpa by 2035 have been announced.

For further information on policies, partnerships and projects, please refer to the deep dive section

All six countries present varying sectoral readiness and maturity

All six countries possess advantageous current conditions for the development of low-carbon hydrogen, including **some level of existing infrastructure to build upon**, and an **emerging workforce**. **KSA, Qatar and the UAE all exhibit a strong O&G sector and energy independence**, exporting much of the existing production. This puts them in a **strong position for scaling up blue hydrogen**. KSA also has a strong funding model in place seen for example in NEOM, and Oman seen with Hydrom. However, **domestic markets are currently strongest in Morocco and the UAE**, such as OCP fertilizer in Morocco and the steel and chemical industries in the UAE.

Current sectoral maturity across the six MENA regions show various levels of readiness for low-carbon hydrogen



Cross-comparison of sectoral maturity[1]

Google Earth[2]

KEY:

Maturity level score:
1 Developing
2 Emerging
3 Mature
4 Highly mature

Area:
O&G Sector Maturity
Current Funding Model
Workforce
Domestic Market
Infrastructure
Energy Independence

Countries with hydrogen strategy

See appendix for detail[1]. Sources: Google Earth[2]

All six countries present varying characteristics associated with low-carbon hydrogen

To facilitate cross-comparison across the six countries in view, below table highlights different characteristics related to low-carbon hydrogen readiness. What stands-out is that the countries with the clearest focus on hydrogen plays, evidenced by the presence of dedicated published hydrogen policies (Morocco, Egypt, Oman and the UAE), also signed the **COP28 Intergovernmental Declaration of Intent**[1] on mutual recognition of certification schemes for hydrogen and hydrogen derivates. Moreover, Morocco, the UAE and Oman, the countries with highest installed renewables capacities, also signed the **Global Renewables and Energy Efficiency Pledge**, signaling a further commitment to renewable hydrogen plays. **Though Qatar and the KSA did not sign the declaration of intent nor the renewables and energy efficiency pledge,** both countries do **still exhibit competitive traits for low-carbon hydrogen plays.**

Morocco, Egypt, Oman and the UAE have strategies, while Qatar and KSA have low hydrogen prices

	Morocco	Egypt	Qatar	Oman	UAE	KSA
GDP, bn (2022)	$134.20	$476.70	$237.30	$114.70	$507.50	$1,108.00
Inst. Renewable Capacity, MW (2022)	3,725	6,322	824	688	3,058	443
Crude oil production, Mbpd (2021)	0	0.6	1.75	0.97	3.67	11
Natural gas production, bn m³ (2021)	0.11	67.8	177	41.8	57	117
Presence of dedicated published hydrogen policy	Yes	Yes	No	Yes	Yes	No
Declaration of Intent signed[1]	Yes	Yes	No	Yes	Yes	No
Low-carbon hydrogen production aim	Up to 0.9 Mtpa by 2030	10 Mtpa by 2040	N.A	Up to 1.15 Mtpa by 2030	1.4 Mtpa by 2031, 7.5 Mtpa by 2040, 15 Mtpa by 2050	2.9 Mtpa by 2030
Green LCOH (current)	$4.64–5.79 /kg	$2.57-6.69 /kg	Alkaline $2.61 /kg; PEM: $3.31 /kg	Alkaline: $3.56 /kg, PEM: $4.35 /kg	Alkaline: $4.50 /kg, PEM: $5.38 /kg	Alkaline: $3.22 /kg, PEM: $3.98 /kg
Blue LCOH (current)	N/A	$1.65 /kg	$2.96 /kg	$3.04 /kg	$3.09 /kg	$2.99 /kg

Cross-comparison of the six MENA countries

Sources: The Intergovernmental Declaration of Intent on Mutual Recognition of Certification Schemes for Hydrogen and Hydrogen Derivatives was signed during COP28[1]

Contents

The UAE and KSA Deep-Dive regions have been further assessed in a 4-step approach

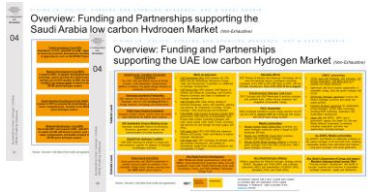
After a high-level hydrogen readiness assessment against the barriers, the objective of the deep-dives is four-fold:

1 Summarize the current policies

- Highlights of relevant **underlying policies** based on their ambitions as stated in official documents (e.g., national hydrogen strategies)

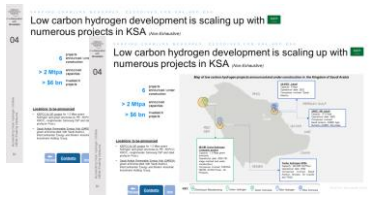
2 Capture the key fundings and partnerships

- Key public and private **fundings, partnerships and company initiatives** supporting low-carbon hydrogen.



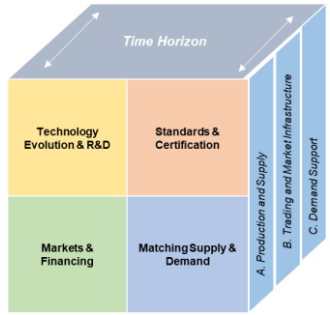
3 Show an overview of notable projects

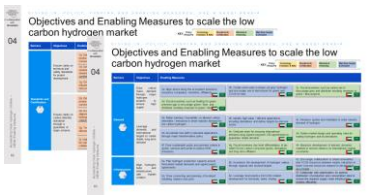
- Notable **operational and proposed projects** and volumes as well as key derivative projects



4 Define the Enabling Measures against the Barriers

- **Top supporting enabling measures** to scale the low-carbon hydrogen market, grouped by the barrier to market development





In view: Navigating policy frameworks, financial mechanisms and key projects in the UAE *(Non-Exhaustive)*

With a detailed Roadmap, the UAE is ready to drive its hydrogen economy

Capitalizing on a mature oil and gas ecosystem, substantial renewable energy potential and domestic industries, the United Arab Emirates (UAE) is well-positioned to play a key role in the low-carbon hydrogen economy.

Host of COP28, the UAE has recently released a detailed **Hydrogen Strategy and Roadmap** with proposed **new policy mechanisms, incentives and financing, implemented by a variety of stakeholders**, including Federal Ministries and agencies, Emirates governments, Municipalities, and the industry. COP28 also saw the UAE launch the world's largest private investment vehicle for climate change action, ALTÉRRA, pledging $30 bn and aiming to mobilize $250 bn globally by 2030.

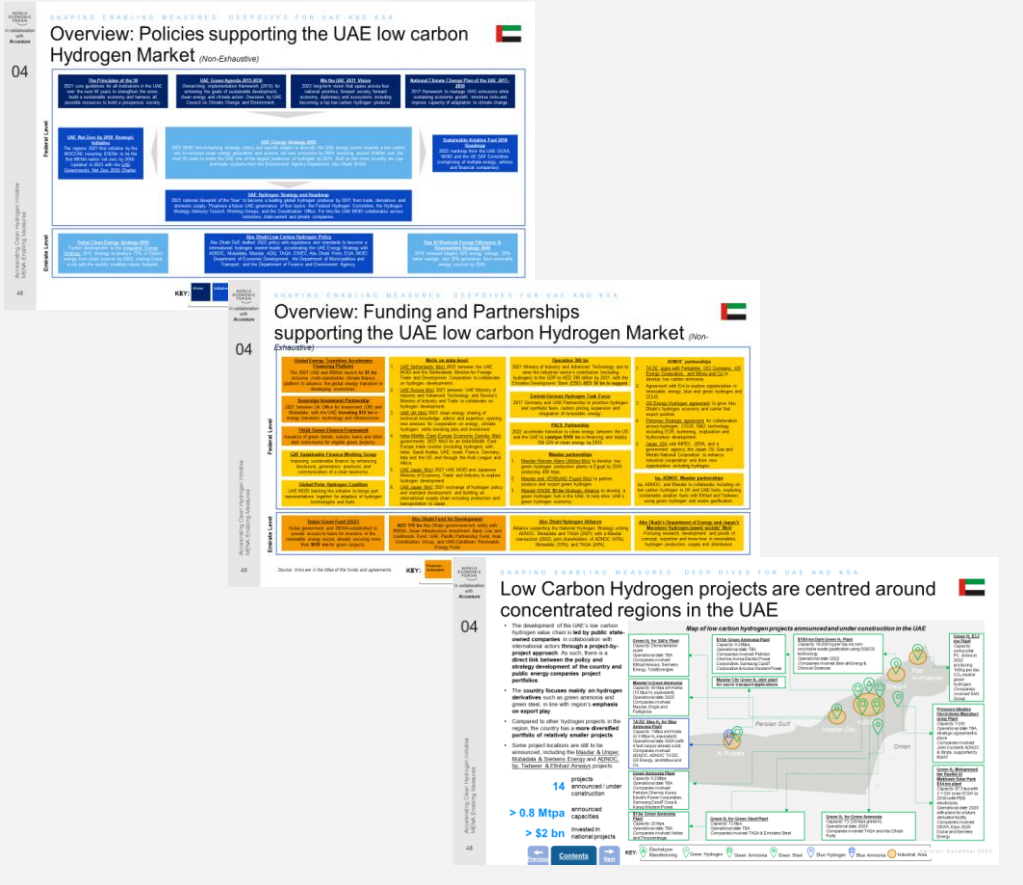
In the UAE, there are **multiple layers of government and company-led visions, strategic partnerships, MoUs and initiatives at the federal and Emirate levels** to develop hydrogen within and outside of the country.

National Champions, such as TAQA, ADNOC and MASDAR, **drive low-carbon hydrogen projects** in collaboration with the ministries and sovereign wealth funds to attain the **objective of producing 1.4 Mtpa of low-carbon hydrogen by 2031**.

The country's companies are also planning on **developing significant hydrogen projects abroad**, including in Mauritania, Egypt, Spain and the United Kingdom.

The next slides provide a non-exhaustive overview of the main policy developments, funding and initiatives related to low-carbon hydrogen.

Overviews on policies, funding, partnerships and projects in the UAE



WORLD ECONOMIC FORUM

In collaboration with ***Accenture***

Policies supporting low-carbon hydrogen in the UAE

(Non-Exhaustive)

Key policies in place in the United Arab Emirates

Federal Level

The Principles of the 50
2021 core guidelines for all institutions in the UAE over the next 50 years to strengthen the union, build a sustainable economy and harness all possible resources to build a prosperous society.

UAE Green Agenda 2015-2030
Overarching implementation framework (2015) for achieving the goals of sustainable development, clean energy and climate action. Overseen by UAE Council on Climate Change and Environment.

We the UAE 2031 Vision
2023 long-term vision that spans across four national priorities; forward society, forward economy, diplomacy and ecosystem, including becoming a top low-carbon hydrogen producer.

National Climate Change Plan of the UAE 2017–2050
2017 framework to manage GHG emissions while sustaining economic growth, minimize risks and improve capacity of adaptation to climate change.

UAE Net Zero by 2050 Strategic Initiative
The regions 2021 first initiative by the MOCCAE investing $163bn to be the first MENA nation net zero by 2050. Updated in 2023 with the UAE Governments Net Zero 2050 Charter.

UAE Energy Strategy 2050
2023 MOEI benchmarking strategy, policy and specific targets to diversify the UAE energy sector towards a low-carbon mix, to increase clean energy generation and achieve net zero emissions by 2050. Investing around $160bn over the next 30 years to make the UAE one of the largest producers of hydrogen by 2031. Built on this more recently are cap-and-trade systems from the Environment Agency Department Abu Dhabi (EAD).

Sustainable Aviation Fuel 2050 Roadmap
2022 Roadmap from the UAE GCAA, MOEI and the UE SAF Committee (comprising of multiple energy, airlines and financial companies).

UAE National Hydrogen Strategy
2023 national blueprint of the "how" to become a leading global hydrogen producer by 2031 from trade, derivatives and domestic supply. Proposes a future UAE governance of four layers: the Federal Hydrogen Committee, the Hydrogen Strategy Advisory Council, Working Groups, and the Coordination Office. For this the UAE MOEI collaborates across ministries, state-owned and private companies.

The Intergovernmental Declaration of Intent on Mutual Recognition of Certification Schemes for Hydrogen and Hydrogen Derivatives
Signed by 39 countries including the UAE during COP28 to cover 80% of future global trade, and the global ISO methodology for Greenhouse Gas (GHG) emissions assessment of ow-carbon hydrogen.

Emirate Level

Dubai Clean Energy Strategy 2050
Further development to the Integrated Energy Strategy, 2015 strategy to produce 75% of Dubai's energy from clean sources by 2050, making Dubai a city with the world's smallest carbon footprint.

Abu Dhabi low-carbon Hydrogen Policy
Abu Dhabi DoE 2023 policy with regulations and standards to become a international hydrogen market leader, accelerating the UAE Energy Strategy with ADNOC, Mubadala, Masdar, ADQ, TAQA, EWEC, Abu Dhabi Ports, EGA, MOEI, Department of Economic Development, the Department of Municipalities and Transport, and the Department of Finance and Environment Agency.

Ras Al Khaimah Energy Efficiency & Renewables Strategy 2040
2018 released targets 30% energy savings, 20% water savings, and 20% generation from renewable energy sources by 2040.

KEY: Vision | Initiative | Program | Strategy

Sources: links are in the titles of the policies.

WORLD ECONOMIC FORUM

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04

Funding and partnerships supporting low-carbon hydrogen in the UAE *(Non-Exhaustive)*

Key funding and partnerships in place in the United Arab Emirates

Federal Level

Global ETAF Platform
The 2021 UAE and IRENA launch for **$1 bn** inclusive, multi-stakeholder climate finance platform to advance the global energy transition in developing economies.

ALTÉRRA Fund
COP28 UAE launched the world's largest private investment vehicle for climate change action, pledging **$30 bn** and aiming to mobilize **$250 bn** globally by 2030.

Sovereign Investment Partnership
2021 UK OfI and Mubadala, with the UAE **investing $12 bn** in energy transition, technology and infrastructure.

TAQA Green Finance Framework
Issuance of green bonds, sukuks, loans and other debt instruments for eligible green projects.

Global Ports Hydrogen Coalition
UAE MOEI backing the initiative to brings port representatives together for adaption of hydrogen technologies and fuels.

Partnerships on state-level:

1. UAE Netherlands MoU 2022 between the UAE MOEI and the Netherlands to collaborate on hydrogen developments.
2. UAE Russia MoU 2021 between UAE Ministry of Industry and Advanced Technology and Russia to collaborate on hydrogen development.
3. UAE UK MoU 2023 clean energy sharing of technical knowledge, advice and expertise, opening new avenues for cooperation on energy, climate, hydrogen, while boosting jobs and investment.
4. India–Middle East–Europe Economic Corridor MoU governments 2023 MoU for India-Middle East-Europe trade corridor (including hydrogen) with India, KSA, UAE, Israel, France, Germany, Italy and the US, and through the Arab League and Africa.
5. UAE Japan MoU 2021 UAE MOEI and Japan to explore hydrogen development.
6. UAE Japan MoC 2021 exchange of hydrogen policy, development and international supply chain including production and transportation to Japan.
7. UAE Morocco bilateral cooperation for investment partnerships, energy and sustainable development.
8. UAE Austria MoU for a collaborative hydrogen alliance.

Operation 300 bn
2021 Ministry of Industry and Advanced Technology aim to raise the industrial sector's contribution (including hydrogen) to the GDP to AED 300 billion by 2031, with the Emirates Development Bank (EBD) **AED 30 bn in support**.

Emirati-German Hydrogen Task Force
2017 Germany and UAE Partnership to prioritize hydrogen and synthetic fuels, carbon pricing, expansion and integration of renewable energy.

PACE Partnership
2022 accelerate transition to clean energy between the US and the UAE to **catalyse $100 bn** in financing and deploy 100 GW of clean energy by 2035.

Masdar partnerships
Masdar has multiple projects, agreements and MoUs, such as the Masdar Hassan Allam Utilities MoU to develop two green hydrogen production plants in Egypt by 2030 producing 480 ktpa. The Masdar and VERBUND Export MoU to partner, produce and export green hydrogen. The Masdar ENGIE **$5 bn** Strategic Alliance is to develop a green hydrogen hub in the UAE, to help drive UAE's green hydrogen economy. There are further agreements with AD Ports and with OMV.

ADNOC partnerships

1. TA'ZIZ signs with Fertiglobe, OCI Company, GS Energy Corporation, and Mitsui and Co to develop low-carbon ammonia.
2. Agreement with Eni to explore opportunities in renewable energy, blue and green hydrogen and CCUS.
3. GS Energy Hydrogen agreement to grow Abu Dhabi's hydrogen economy and carrier fuel export position.
4. Petronas Strategic agreement for collaboration across hydrogen, CCUS, R&D, technology including EOR, bunkering, exploration and hydrocarbon development.
5. Japan JSA with INPEX, JERA, and a government agency, the Japan Oil, Gas and Metals National Corporation to enhance industrial cooperation and drive new opportunities including hydrogen.

bp, ADNOC Masdar partnerships
bp, ADNOC, and Masdar to collaborate including on low-carbon hydrogen in UK and UAE hubs, exploring sustainable aviation fuels with Etihad and Tadweer, using green hydrogen and waste gasification.

Emirate Level

Dubai Green Fund (DGF)
Dubai government and DEWA established to provide access to loans for investors in the renewable energy sector, already securing more than **$650 mn** for green projects.

Abu Dhabi Fund for Development
AED 119 bn Abu Dhabi government-led entity with IRENA, Asian Infrastructure Investment Bank, Live and Livelihoods Fund, UAE, Pacific Partnership Fund, Arab Coordination Group, and UAE-Caribbean Renewable Energy Fund

Abu Dhabi Hydrogen Alliance
Alliance supporting the National Hydrogen Strategy uniting ADNOC, Mubadala and TAQA (2021) with a Masdar transaction (2022) joint shareholders of ADNOC (43%), Mubadala (33%), and TAQA (24%).

Abu Dhabi's Department of Energy and Japan's Marubeni 'hydrogen-based society' MoU
Pursuing research, development and proofs of concept, expertise and know-how in renewables, hydrogen production, supply and distribution.

Sources: links are in the titles of the funds and agreements.

KEY: Financial instrument | Partnerships

WORLD ECONOMIC FORUM

In collaboration with ***Accenture***

Low-carbon hydrogen projects are centred around concentrated regions in the UAE *(Non-Exhaustive)*

04

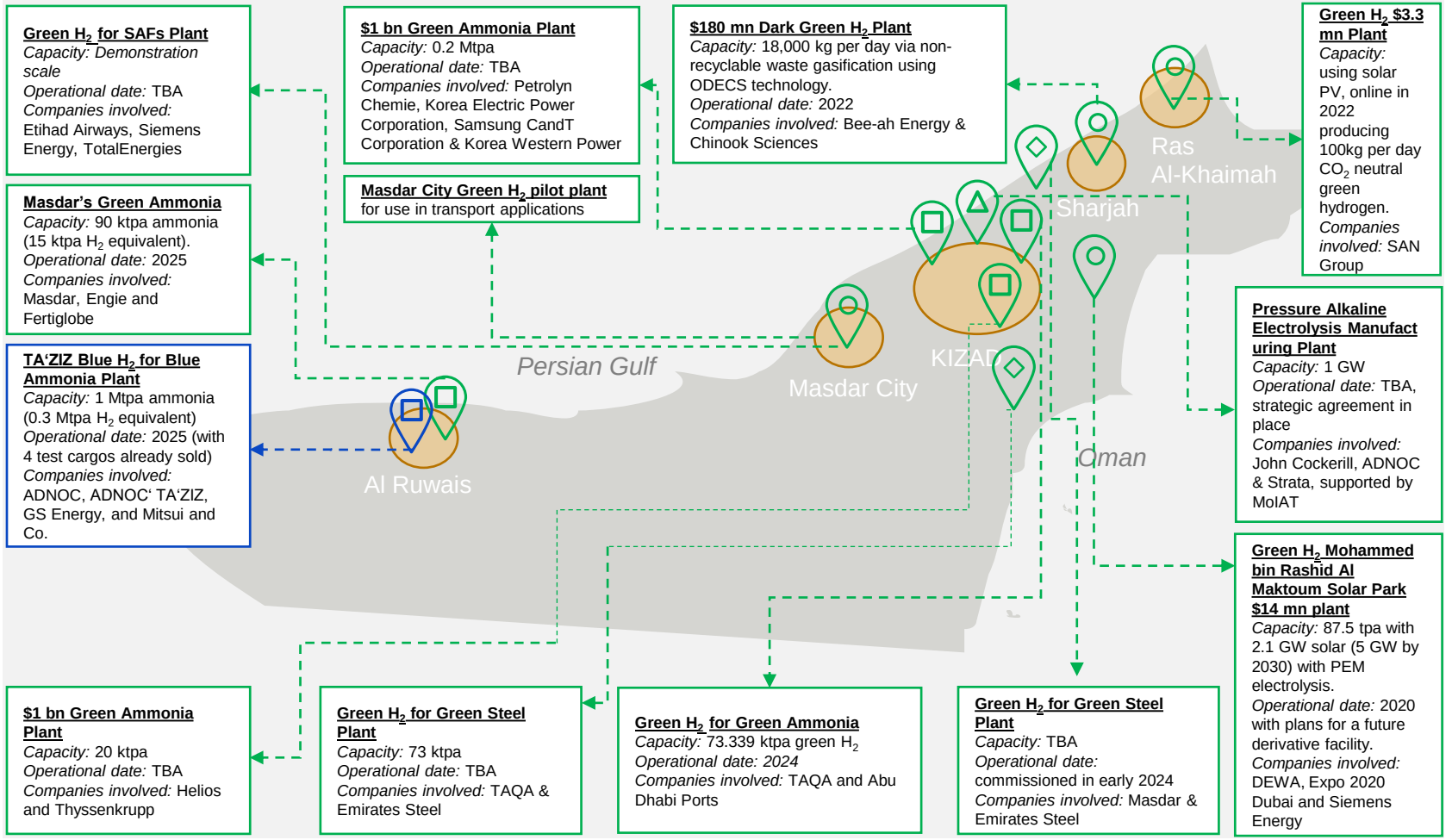
- The development of the UAE's low-carbon hydrogen value chain is **led by public state-owned companies** in collaboration with international actors **through a project-by-project approach**. As such, there is a **direct link between the policy and strategy development of the country and public energy companies project portfolios**.
- The **country focuses mainly on hydrogen derivatives** such as green ammonia and green steel, in line with region's **emphasis on export play**.
- Compared to other hydrogen projects in the region, the country has a **more diversified portfolio of relatively smaller projects**.
- Some project locations & details are still to be announced, including the KEZAD Masdar & AD Ports Group, Masdar & Uniper, Mubadala & Siemens Energy and ADNOC, bp, Tadweer & Ethihad Airways projects.

14 projects announced / under construction

> 0.8 Mtpa announced capacities

> $2 bn invested in national projects

Map of low-carbon hydrogen projects announced and under construction in the United Arab Emirates



Version: December 20th 2023

In view: Navigating policy frameworks, financial mechanisms and key projects in the KSA

KSA has low-carbon hydrogen projects well under way, despite not having a low-carbon hydrogen Roadmap

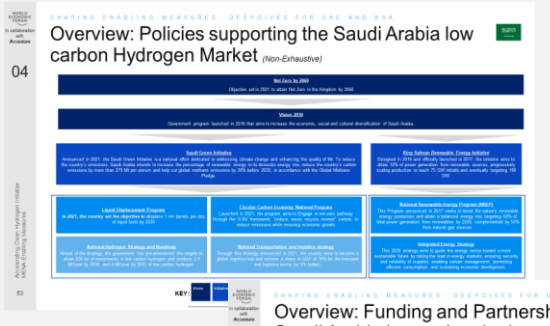
In the Kingdom of Saudi Arabia, there is a **spectrum of government visions, initiatives, programs and strategies** to support the energy transition of the country.

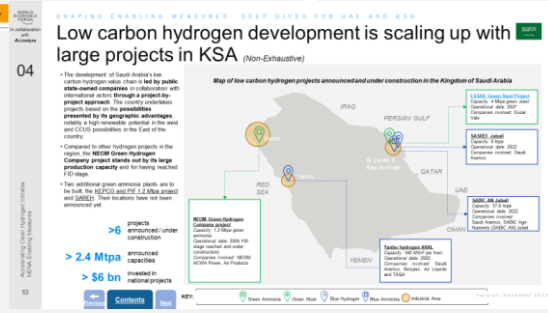
The KSA has a number of policies supporting the energy transition but has **not yet released a detailed hydrogen strategy**. However, the government has already announced **low-carbon hydrogen production targets of 2.9 Mtpa of low-carbon hydrogen by 2030 and 4 Mtpa by 2035**.

Numerous partnerships, MoUs and large government-backed funds are active in developing low-carbon hydrogen projects. Clear highlights include the **1.2 Mtpa NEOM Green Hydrogen Company Project** which has already reached FID, and the Northern blue hydrogen and ammonia projects from Saudi Aramco, which leverage key existing ports including Yanbu and Jubail.

The next slides provide a non-exhaustive overview of the main policy developments, funding and initiatives related to low-carbon hydrogen.

Overviews on policies, funding, partnerships and projects in KSA





WORLD ECONOMIC FORUM

In collaboration with ***Accenture***

Policies supporting low-carbon hydrogen in the KSA

(Non-Exhaustive)

Key policies in place in the Kingdom of Saudi Arabia

Net Zero by 2060

Objective set in 2021 to attain Net Zero in the Kingdom by 2060

Vision 2030

Government program launched in 2016 that aims to increase the economic, social and cultural diversification of KSA.

Saudi Green Initiative

Announced in 2021, the Saudi Green Initiative is a national effort dedicated to addressing climate change and enhancing the quality of life. To reduce the country's emissions, KSA intends to increase the percentage of renewable energy in its domestic energy mix, reduce the country's carbon emissions by more than 279 Mt per annum and help cut global methane emissions by 30% before 2030, in accordance with the Global Methane Pledge.

King Salman Renewable Energy Initiative

Designed in 2016 and officially launched in 2017, the initiative aims to attain 10% of power generation from renewable sources, progressively scaling production to reach 75 GW initially and eventually targeting 100 GW.

Liquid Displacement Program

In 2021, the country set the objective to displace 1 mn barrels per day of liquid fuels by 2030

Circular Carbon Economy National Program

Launched in 2021, the program aims to Engage in net-zero pathway through the “4 Rs” framework: “reduce, reuse, recycle, remove” carbon, to reduce emissions while ensuring economic growth

National Renewable Energy Program (NREP)

This Program announced in 2017 seeks to boost the nation's renewable energy production and attain a balanced energy mix, targeting 50% of total power generation from renewables by 2030, complemented by 50% from natural gas sources.

National Hydrogen Announced Targets

Ahead of the strategy, the government has pre-announced the targets to attain $36 bn of investments in low-carbon hydrogen and produce 2.9 Mt/year by 2030, and 4 Mt/year by 2035 of low-carbon hydrogen.

National Transportation and Logistics Strategy

Through this strategy announced in 2021, the country aims to become a global logistics hub and achieve a share of GDP of 10% for the transport and logistics sector (vs 6% today).

Integrated Energy Strategy

This 2020 strategy aims to guide the energy sector toward a more sustainable future by taking the lead in energy markets, ensuring security and reliability of supplies, enabling carbon management, promoting efficient consumption, and sustaining economic development.

KEY: Vision | Initiative | Program | Strategy

Sources: links are in the titles of the policies.

WORLD ECONOMIC FORUM

In collaboration with ***Accenture***

Funding and partnerships supporting low-carbon hydrogen in the KSA *(Non-Exhaustive)*

Key funding and partnerships in place in the Kingdom of Saudi Arabia

Public Investment Fund (PIF)
Established in 1971, with **$700 bn** AuM , objective to lead local economic development. Investments in giga projects, such as the NEOM Project.

National Development Fund (NDF)
Created in 2001, to support development funds and banks, goal to diversify the Saudi economy and fuel non-oil GDP growth. In 2020, the fund had **$93.3 bn of total capital**. Invested in the NEOM green hydrogen project.

Saudi Industrial Development Fund (SIDF)
Created in 1974 to promote the local industry and boost competitiveness. Invested in the NEOM green hydrogen project, dispersing over **145 bn SAR**.

National Infrastructure Fund (NIF)
Part of the NDF and created in 2021, with **$53 bn** of capital, the NIF will invest in sectors such as water, transportation and health. Invested in NEOM green hydrogen project.

State-level MoUs

1. **Japan:** cooperation with Japanese Industry and Trade Ministry on clean hydrogen, production of ammonia and derivatives and recycles carbon fuels.
2. **Netherlands:** cooperation on green energy and hydrogen, with the Netherlands as a potential destination for KSA's green hydrogen.
3. **China:** development of green hydrogen and promotion of direct investments in both countries.
4. **Germany:** cooperation on the production, processing, use and transport of low-carbon hydrogen.
5. **United States:** creation of intercontinental green transit corridors across KSA, connecting Asia and Europe. The objective is to streamline the transportation of renewable electricity and clean hydrogen through transmission cables, pipelines, and the development of rail linkages.
6. **India:** co-development of projects and establishment of supply chains for clean hydrogen and renewable energy projects.
7. **Korea:** Korea-Saudi Hydrogen Oasis Cooperation Initiative, for collaboration on clean hydrogen, from production to distribution.

Saudi Aramco partnerships

1. **Yanbu Aramco Sinopec refining company (YASREF) project**: Steam Methane Reforming (SMR) facility under operation, built with Air Liquide Arabia. Air Liquide's technology enables to capture 90% of CO_2 emitted during the hydrogen production process.
2. **Hyundai OilBank partnership**: on blue hydrogen trade route. KSA planning to ship gas to South Korea to produce hydrogen and to bring back the carbon dioxide emitted during the process.
3. **MoU with SLB & Linde**: creation of a hub for carbon capture and storage. This hub has the potential to securely store up to 9 Mt of CO_2 annually by 2027.
4. **MoU with InterContinental Energy, Modern Industrial Investment Holding Group**: development of a green ammonia plant, KSA Renewable Energy Hub (SAREH).
5. **MoU with Korea Electric Power Corporation (KEPCO), POSCO and Lotte Chem**: to develop a blue ammonia project in Ras Al-Khair, with a value of $15.5 bn.

Saudi Arabia Railways
MoU with Alstom on passenger hydrogen trains.

PIF partnerships

1. **MoU with Marubeni**: feasability study to produce clean hydrogen in KSA for local and export markets.
2. **MoU with Engie**: development of green hydrogen and derivatives projects.

Saudi Public Transport Company (SAPTCO) MoU
MoU with Air Products Qudra (APQ), Hyundai Motor Company and Korea Automotive Technology Institute (KATECH) to develop hydrogen mobility in KSA.

ACWA Power partnerships

1. **NEOM Green Hydrogen Company (NGHC) joint venture**: with Air Products, Thyssenkrupp and ACWA power in the NEOM Green Hydrogen project, valued at $8.4 bn
2. **MoUs with five Italian companies**: with Eni, A2A, Rina, Industrie de Nora and Italmatch Chemicals on green hydrogen and renewable energy projects, R&D on sustainable technologies and the use of green hydrogen and derivatives for shipping.
3. **MoUs with five Chinese firms**: with State power Investment Corporation, Bank of China, Power China Group, Energy China Group, Jinko Solar on green hydrogen and water desalination projects.

Sources: links are in the titles of the funds and agreements.

KEY: Financial instrument | Partnerships

WORLD ECONOMIC FORUM

In collaboration with ***Accenture***

Low-carbon hydrogen development is scaling up with large projects in the KSA *(Non-Exhaustive)*

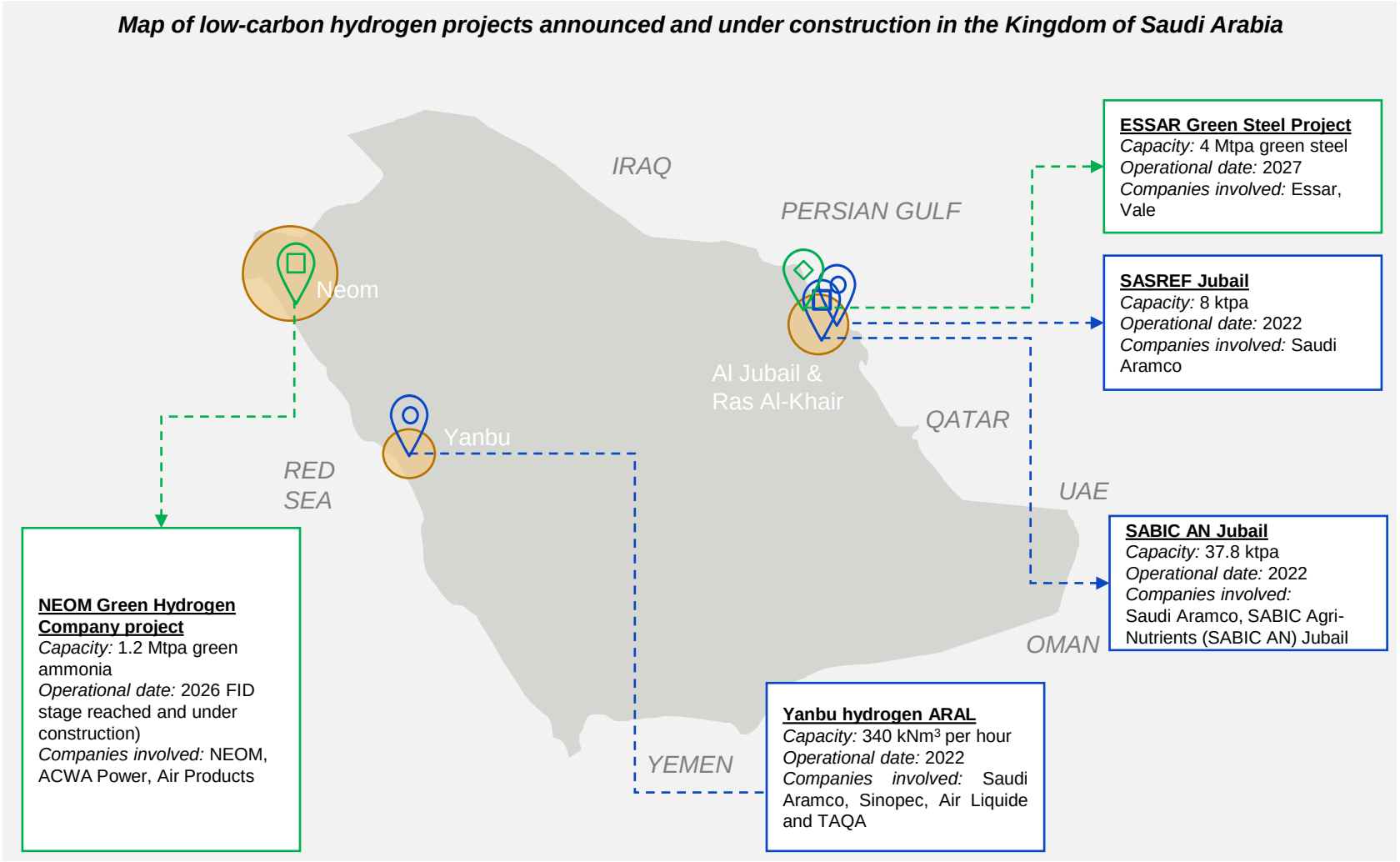
- The development of Saudi Arabia's low-carbon hydrogen value chain is **led by public state-owned companies** in collaboration with international actors **through a project-by-project approach**. The country undertakes projects based on the **possibilities presented by its geographic advantages**, notably a high renewable potential in the west and CCUS possibilities in the East of the country.
- Compared to other hydrogen projects in the region, the **NEOM Green Hydrogen Company project stands out by its large production capacity** and for having reached FID stage.
- Two additional green ammonia plants are to be built, the KEPCO and PIF 1.2 Mtpa project and SAREH. Their locations have not been announced yet.

>6 projects announced / under construction

> 2.4 Mtpa announced capacities

> $6 bn invested in national projects

Map of low-carbon hydrogen projects announced and under construction in the Kingdom of Saudi Arabia



Version: December 20th 2023

WORLD ECONOMIC FORUM

In collaboration with ***Accenture***

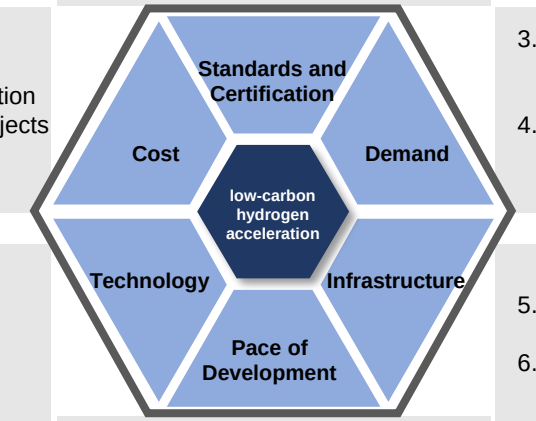
The Enabling Measures focus on removing Barriers through collaboration and policy

For each objective within the Barriers, enabling measures are identified, pertaining to technology evolution & R&D, standards & certification, markets & financing and matching supply & demand.

From the low-carbon hydrogen Barriers…

1. Ensure clarity on technical and safety standards and certifications for project development
2. Ensure clarity on carbon intensity standards and certifications through a guarantee of origin scheme

10. Remove critical cost and regulatory barriers for production
11. Support the bankability of projects for investors



3. Drive critical mass demand through major hydrogen projects to ensure high supply
4. Leverage domestic and international targets to create stable, long-term demand

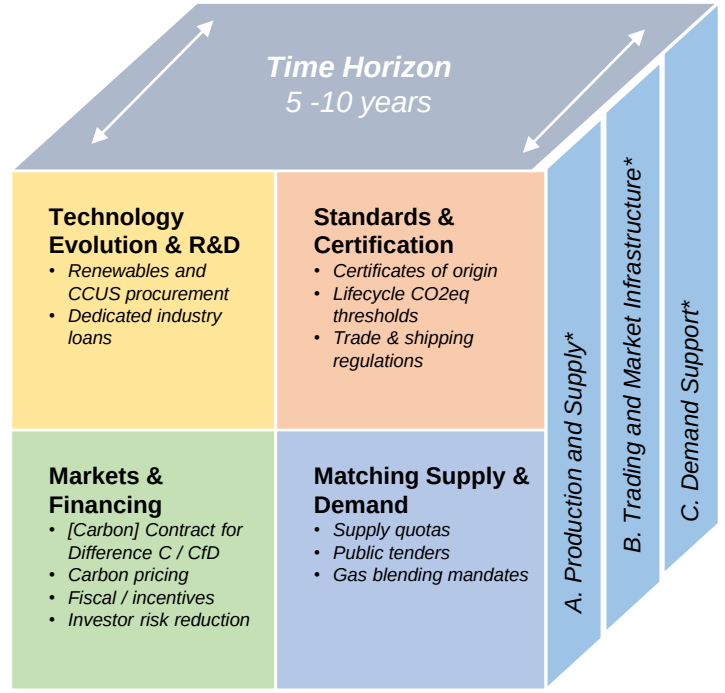
9. Focus innovation and R&D to enable technology scale up

5. Align hydrogen hubs and infrastructure with market creation
6. Ensure first ramp up of *'no regret'* infrastructure

7. Accelerate slow pace of hydrogen scale-up and development to drive economies of scale
8. Coordinate ecosystem

KEY: Barrier | Objectives

… to the Enabling Measures



*Indicative

Version: December 20th 2023

Objectives and Enabling Measures to scale the low-carbon hydrogen market

KEY: *Action Required* | Technology Evolution & R&D | Standards & Certification | Markets & Financing | Matching Supply & Demand

Barriers	Objectives	Enabling Measures
Standards and Certification	Ensure clarity on technical and safety standards- and certifications for project development	1a. Define **technical standards** for the **hydrogen production value chain** (transportation, storage, conversion) 1b. Define **technical standards for upstream** (e.g. renewables, desalination plants, CCUS) and **downstream hydrogen derivatives** (e.g. ammonia, synthetic fuels) 1c. Develop **safety standards** for the hydrogen **production value chain** (transportation, storage, conversion) 1d. Develop **safety standards for upstream** (such as renewables, desalination plants and CCUS) and **downstream hydrogen derivatives** (e.g. ammonia, synthetic fuels) 1e. Release **certifications** defining **low-carbon hydrogen technical and safety standards** 1f. **Test success of technical and safety standards** in pilot / demonstration projects 1g. **Drive technical and safety standards across all industries** and **embed metrics** in policy making and new project requirements 1h. **Unify technical and safety standards and project permitting** across all Emirates for ministries and companies using the proposed collaboration model
	Ensure clarity on carbon intensity standards and certifications through a guarantee of origin scheme	2a. Define **carbon intensity metrics for the hydrogen production value chain** (transportation, storage, conversion) in line with the IPHE / ISO methodology[1] 2b. Define **carbon intensity metrics for upstream** (such as renewables, desalination plants and CCUS) and **downstream hydrogen derivatives** (e.g. ammonia, synthetic fuels) 2c. Introduce **environmental externalities** (water, land, etc) in the certification process 2d. Ensure **national- and global-level alignment on the methodology and scope** for carbon intensity along the hydrogen value chain, in line with the COP28 Intergovernmental Declaration of Intent[2] 2e. Release **certifications** and **guarantee of origin schemes** defining low-carbon hydrogen (& derivatives) carbon intensity metrics pursuant to the COP28 Intergovernmental Declarations of Intent[2] 2f. Ensure **carbon intensity traceability across the low-carbon hydrogen value chain**, upstream and downstream 2g. **Test success of carbon intensity metrics** in pilot / demonstration projects 2h. **Drive carbon intensity metrics across all industries** and **embed metrics** in policy making and new project requirements 2i. Ensure certifications **are internationally recognized and compatible for global trade**, in line with the Intergovernmental Declaration of Intent on Mutual Recognition of Certification Schemes[2] 2j. **Unify carbon intensity metrics** across all Emirates for ministries and companies using the proposed collaboration model 2k. Define **standards and certification on carbon sources**, in alignment with international regulations

Sources: The International Standards Organization launched its technical specification for determining greenhouse gas emissions associated with hydrogen pathways, on a life-cycle analysis and in line with IPHE guidelines, during COP28[1]; The Intergovernmental Declaration of Intent on Mutual Recognition of Certification Schemes for Hydrogen and Hydrogen Derivatives was signed during COP28[2]

WORLD ECONOMIC FORUM
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Objectives and Enabling Measures to scale the low-carbon hydrogen market

KEY: *Action Required* — Technology Evolution & R&D | Standards & Certification | Markets & Financing | Matching Supply & Demand

Barriers	Objectives	Enabling Measures		
Demand	Drive critical mass demand through major hydrogen projects to ensure high supply	3a. **Align actors along the ecosystem** (investors, insurance companies, ministries, offtakers)	3b. Create **action plan to phase out grey hydrogen** and encourage use of electrolysis for green and CCUS for blue	3c. Create **fiscal incentives** such as carbon **tax to discourage grey** and distribute resulting revenues to green / blue projects
		3d. Develop **fiscal incentives** such as **funding for green premium gap to encourage green / blue**	3e. Conceive **subsidies tailored to green / blue hydrogen** projects and **eliminate subsidies to the O&G sector**, in line with the International Coalition to phase out fossil fuel subsidies[1]	
	Leverage domestic and international targets to create stable, long-term demand	4a. Enable **better tracking / traceability** on **allowed carbon intensities / emissions** to drive industry demand for low-carbon hydrogen	4b. Identify **high-value / efficient applications** including derivatives and **define targets by end-use sector**	4c. Introduce **quotas and mandates** to order industry demand of hydrogen
		4d. Accelerate **fuel shift in industrial applications** through **major transformation policy**	4e. **Dedicate team for ensuring international demand** using signed **long-term CfD agreements** to guarantee stable demand	4f. **Define market design and operating rules** for trading hydrogen and its derivatives
		4g. **Drive sustainable public procurement criteria** in goods, services and works to reduce GHG emissions	4h. Establish **fiscal incentives** (tax level differentiation & tax relief) for **low-carbon consumer goods**, derivatives and long term offtakers	4i. **Maximize development of domestic markets** to remove reliance on international market uncertainty
Infrastructure	Align hydrogen hubs and infrastructure with market creation	5a. **Plan hydrogen production capacity around forecasted market demands** and signed export agreements	5b. **Incentivize the development of hydrogen valleys** through regional and sectoral targets	5c. Encourage **collaboration to share renewables and CCUS resources between nearby industries** to lower cost and resources required to decarbonize as a cluster
		5d. Drive **connecting and planning of localized refuelling stations and ports**	5e. **Leverage best practice from LNG market development** for terminals, tanks, trading	5f. **Collaborate with stakeholders for optimal distribution of production and consumption** sites to ensure the required supply chain infrastructure evolves efficiently

Sources: The International Coalition to phase out fossil fuel subsidies was signed by 12 countries during COP28[1]

Objectives and Enabling Measures to scale the low-carbon hydrogen market

KEY: *Action Required* — Technology Evolution & R&D | Standards & Certification | Markets & Financing | Matching Supply & Demand

Barriers	Objectives	Enabling Measures		
Infrastructure	Ensure first ramp up of *'no regret'* infrastructure	6a. Ensure **required capacity of renewables and CCUS** is in place **to maximize produced hydrogen demand**	6b. **Clarify regulation on renewables** and reform domestic prices for energy to encourage renewables	6c. Drive **public tenders to promote renewable energy** and **CCUS capacity** / infrastructure
		6d. Develop a **national plan for resilient / seasonal hydrogen storage** and investigate existing potential capacities	6e. **Incentivize the ramp up building of** green and blue **hydrogen infrastructure** with funding and capacity payments	6f. **Disincentivize new developments of O&G infrastructure** with taxing and supply quotas
		6g. **Specify interoperable quality standards and definitions** to enable integration with existing infrastructures	6h. **Plan for retrofitting existing O&G infrastructure** (incl. NH_3 terminals) with required hydrogen infrastructure (pipelines, storage, and usage)	
Pace of Development	Accelerate pace of hydrogen scale-up and development to drive economies of scale	7a. Set specific, **long-term national targets** for **electrolyzer and CCUS component quality improvements**	7b. Drive **automation of electrolyzer and CCUS manufacturing** and increase raw material efficiency	7c. Target **funding to pilot and demonstration scale projects** to allow ramp up and testing of new technologies
	Coordinate ecosystem	8a. Develop and publicize a **dedicated hydrogen strategy**	8b. Create **one-stop-shop for deploying hydrogen projects**	8c. **Streamline process for project grant approvals** to speed up time to FID and online
		8d. **Enforce the proposed collaboration model** to remove bottlenecks and create consistencies across Emirates and working groups	8e. **Assign specific land for blue and green developments**, including CCUS and renewables	8f. **Co-develop, integrate and align long-term infrastructure internationally** and promote knowledge exchange e.g. ports and ships
		8g. **Ensure size of required labor is present to build and run major hydrogen projects**, and develop strategy to ensure availability of qualified workforce	8h. **Standardize construction process** of groundworks and foundations and capital project builds across companies **for smooth scaleup**	8i. Ensure **sector-specific production, infrastructure and end-use targets are aligned** and contribute to value chain acceleration

Objectives and Enabling Measures to scale the low-carbon hydrogen market

KEY: *Action Required* | Technology Evolution & R&D | Standards & Certification | Markets & Financing | Matching Supply & Demand

Barriers	Objectives	Enabling Measures		
Technology	Focus innovation and R&D to enable technology scale up	10a. Identify **critical skills** and **develop strategy to ensure highly qualified workforce** is **available**	10b. **Identify possible long term supply chain bottle necks** by value chain components	10c. **Shift R&D budgets from the oil and gas sector to low-carbon hydrogen** development
		10d. **Colocate research centers with relevant large scale production** to ensure streamline scaleup from new technology to mass implementation	10e. Continue **developing R&D facilities for required maximum yields / efficiencies**, electrolyzer lifetimes, and reducing energy consumption of ammonia cracking	10f. Identify **opportunities to couple power generation with ammonia cracking**
		10g. Ensure inclusive, affordable, robust and large scale training programs to skill workforce and for research into improve technology performance		
Cost	Remove critical cost and regulatory barriers for production	11a. **Ease additionality rules for first movers**	11b. **Decrease investment costs for renewables, electrolyzers and CCUS** with dedicated support (e.g. grants/loans)	11c. **Decrease high electricity prices** with dedicated support
		11d. **Unify multiple funds available as a one-stop-shop** nationally to ensure funding is easily accessible and implemented into required projects		
	Support the bankability of projects for investors	12a. Tackle the **high capital cost through financial structuring and innovation, auctions, subsidies**	12b. Ensure **research** is in place to **drive down the cost of low-carbon infrastructure**, including CCUS and renewables (as well as long term PPA agreements)	11c. **Implement Carbon Contracts for Difference** (CfD)
		11d. **Fund activities** in line with international **development finance**		

Outcomes per Barrier for the MENA region

Indicative outcomes if enabling measures are implemented and objectives achieved.

Barriers	Outcomes 2024-2026	Outcomes 2027-2030
Low-carbon hydrogen acceleration	Clear actions are specifically in place for developing low-carbon hydrogen projects and for the required value chain infrastructure to match production and export targets. Adequate funding is available and accessible to ensure projects are not held back or prevented from reaching FID. A clear method of intent / working is in place for global trade.	Low-carbon hydrogen projects and required value chain infrastructure are rapidly developing and are in construction phase with some in operation. Trade agreements for export / importing are in place with sufficient agreements in place for offtake to ensure demand, using agreed method and certifications.
Standards and Certification	Technical, safety and carbon intensity standards and certifications for hydrogen production value chain and hydrogen derivatives are defined and under testing phase on national and international levels. Environmental externalities have been identified and guarantee of origin schemes are under deployment.	Standards and certification for the entire hydrogen value chain (transportation, storage, and derivatives) are established and aligned between industry and governing authorities, in line with first-launched projects. Internationally-agreed standard and guarantees of origin scheme being used for first few commercial projects.
Demand	Policy instruments to promote hydrogen uptake, such as fiscal incentives, have been identified by sector with legislation in place. Actors in the hydrogen ecosystem have determined an action plan to phase out grey hydrogen and encourage the use of low-carbon hydrogen.	All projects either in operation, construction, planning or agreed upon to meet capacity required for production targets. Export / offtake agreements signed to meet demand targets. low-carbon hydrogen is replacing grey hydrogen in industrial applications and is rapidly increasing across new applications, in domestic and international markets.
Infrastructure	An action plan is in place to secure supply chains to ensure ramp up of renewables, electrolyzers, CCUS and desalination plants. Incentives are continuing to encourage the construction of key shared infrastructure. O&G infrastructure to be retrofitted has been determined. Hydrogen valleys have been identified with associated regional and sectoral hydrogen production targets encouraging industry collaboration.	All infrastructure either in operation, construction, planning or agreed upon to meet capacity required for hydrogen production targets. Some first hydrogen valleys are starting to function on low-carbon hydrogen and benefit from economies of scale from co-location of production. Supply chains are secured and key infrastructure construction and retrofitting is continuing to ramp-up and is on track to produce low-carbon hydrogen at a large scale, for domestic and international use.
Pace of Development	Detailed hydrogen strategy and policies, with specific targets for each sector and assigned funding, have been elaborated and are in application. A one-stop-shop to deploy hydrogen projects has been created to lead the application of the hydrogen strategy, to streamline project grant approvals, coordinate required parties, standardize construction, and push R&D to enable economies of scale.	Multiple projects have reached FID stage through the streamlined hydrogen policy, one-stop-shop and aligned ecosystem. Construction processes are standardized and without bottlenecks for permissions, planning or builds. Required manpower is available to ensure projects are adequately staffed.
Technology	R&D budgets have been shifted away from O&G towards low-carbon hydrogen. Critical skills for the ramp-up of R&D have been identified and training programs adjustments are ongoing.	R&D centers are in place and colocated with universities and industries to ensure maximum yields and efficiencies. All required training programs are in place to ensure skills required for transitioning and developing the newer technologies.
Cost	The one-stop-shops created include fiscal incentives, funds to ease additionality rules for first movers and to cover the cost gap of low-carbon hydrogen production. Banks are incentivized to the level required to support projects to some level of subsidy / part-loan.	Domestic and international demand growth has spurred cost decrease, making low-carbon hydrogen the most attractive for new facilities across industry and long-haul transport. Banks are incentivized to fully loan / support projects to the level required.

Contents

Alphabetical list of acronyms

Acronym	Description
ASU	Air Separation Unit
BAU	Business-As-Usual
bn	Billion
CCS / CCUS	Carbon capture, utilization and storage / carbon capture and storage
CO_2 / CO_2e	Carbon dioxide / Carbon dioxide equivalent
FID	Final Investment Decision
GCC	Gulf Coast Countries
GHG	Greenhouse Gas
GO	Guarantee of Origin
H_2	Hydrogen
JSA	Joint Study Agreement
KSA	Kingdom of Saudi Arabia
ktph	Thousand tons per hour
ktpa	Thousand tons per annum
LCOH	Levelized Cost of Hydrogen
LNG	Liquefied Natural Gas

Acronym	Description
MoU	Memoranda of understanding
MMscf	Mn standard cubic feet
mn	Million
Mtpa	Million tons per annum
O&G	Oil & gas
PPA	Power Purchase Agreement
R&D	Research and Development
RE	Renewable Energy
SAF	Sustainable Aviation Fuel
SMR	Steam Methane Reforming
SRM	Strategic Raw Materials
TBD	To Be Defined
tcf	Trillion cubic feet
tcm	Trillion cubic meters
trn	Trillion
UAE	United Arab Emirates

Appendix - The Roadmap focuses on 6 key MENA countries, with two frontrunners

Methodology for the Country Selection

To identify **key barriers** that are hindering the scaling of a future hydrogen economy and formulate **enabling measures** that accelerate the production of low-carbon hydrogen, the **hydrogen market readiness** of the **six most advanced countries** has been assessed as representation for the entire MENA region.

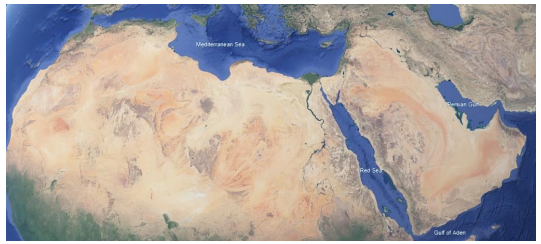
The selection of countries for the hydrogen readiness analysis captured three high-level components that are considered prerequisites for the ramp-up of a future hydrogen economy, scoring from 1 (low score) to 3 (high score):

1. **Hydrogen policy maturity & ambition** – strategy and targets clearly defined, scope / years of coverage, level of instruments (including infrastructure readiness to favour the hydrogen landscape).
2. **Hydrogen projects –** Number and amplitude of low-carbon current projects operational, launched or in design.
3. **Financial resources -** Potential to finance the hydrogen landscape based on the economy, domestic financing capabilities and GDP per capita.

Country	Hydrogen policy, maturity and ambition	Hydrogen projects	Financial resources	Prioritization Score
UAE	2.50	2.50	3.00	2.7
KSA	1.50	3.00	3.00	2.5
Oman	2.50	2.50	2.00	2.3
Morocco	2.33	2.00	2.00	2.1
Qatar	1.00	2.00	3.00	2.0
Egypt	2.00	2.00	2.00	2.0

The six leading hydrogen countries are **the UAE, the KSA, Oman, Morocco, Egypt and Qatar** with two standing out; the UAE for its extensive policy ambitions and agenda and the KSA where the largest hydrogen projects are both announced and under construction. Both these countries also have extensive financial resources and national champions. For these countries additional analyses have been performed to capture insights in policy and funding schemes.

Countries in the MENA region



Google Earth[1]

Longlist of 6 countries for the market analysis and global context

Morocco, Egypt, the KSA, the UAE, Oman, Qatar

Deep Dive on 2 countries for policies, funding schemes, projects and enabling measures

The UAE, the KSA

Sources: Google Earth[1]

Appendix – Out of 16 MENA countries best equipped for low-carbon hydrogen plays, six top-scoring countries were selected for analysis and two for deep-dives

Overview of the countries in the MENA region

Google Earth[1]

Country	Hydrogen policy, maturity and ambition	Hydrogen projects	Financial resources	Prioritization Score
UAE	**2.50**	**2.50**	**3.00**	**2.7**
KSA	**1.50**	**3.00**	**3.00**	**2.5**
Oman	**2.50**	**2.50**	**2.00**	**2.3**
Morocco	**2.33**	**2.00**	**2.00**	**2.1**
Qatar	**1.00**	**2.00**	**3.00**	**2.0**
Egypt	**2.00**	**2.00**	**2.00**	**2.0**
Israel	1.67	1.00	3.00	1.9
Kuwait	1.00	1.00	3.00	1.7
Bahrain	1.00	1.00	3.00	1.7
Jordan	1.00	2.00	2.00	1.7
Algeria	1.67	1.00	2.00	1.6
Iran	1.00	1.00	2.00	1.3
Tunisia	1.00	1.00	1.00	1.0
Libya	0.00	0.00	2.00	0.7
Lebanon	0.00	0.00	2.00	0.7
Iraq	0.00	0.00	1.00	0.3

Sources: Google Earth[1]

Appendix - Breakdown of barriers

Six barriers have been assessed to evaluate the impediments to a hydrogen economy.

Barriers	Definition	Examples
Low-carbon hydrogen acceleration	Lack of benefits, feasibility, motivation and interest in projects, resulting in the absence of level playing field with grey hydrogen	▪ Lack of regulatory barriers for production ▪ No mechanisms to accelerate supply and demand through policy frameworks
Standards and Certification	On standards, lack of guidelines on quality, compatibility, safety, or environment characteristics of hydrogen. On certification, absence of guarantees that the produced hydrogen respects one or more standards.	▪ No standard for production, transport, offtakes, or kg CO_2 per kg hydrogen ▪ No certification of low-carbon hydrogen ▪ No certification of hydrogen derivatives ▪ Cross-border incompatibility and lack of shared vision on certification schemes ▪ Lack of clarity on environmental impact beyond GHG
Demand	Uncertain, unpredictable market demand	▪ Uncertain hydrogen offtake ▪ Lack of critical mass in offtake ▪ Absence of demand incentives such as offtake obligations ▪ Lack of protection for globally competing industries, such as CBAM in Europe ▪ Unavailability of supply guarantees ▪ Uncertainty in the size of demand for low-carbon hydrogen derivatives (at green premium price)
Infrastructure	Absence of available infrastructure to facilitate hydrogen industry development	▪ Lack of infrastructure for hydrogen development (clean electricity availability, ports, roads, carbon capture and storage facilities, desalination plants,...)
Pace of Development	Misalignment of value chain and ecosystem leading to shackles in pace and constraints hindering the rapid advancement of low-carbon hydrogen.	▪ Lack of ecosystem collaboration ▪ Slow / limited capacity component manufacturing and renewable deployment, unclear additionality ▪ Uncertain industrial assets lifetime
Technology	Unavailable large-scale and reliable technology and required supporting talent	▪ High cost of new technology equipment materials, manufacturing and construction ▪ High risks of new industrial applications and integrated PtX pathways ▪ Performance limitations of electrolyzer and fuel cells (efficiency, power density etc.) ▪ Limited compatibility of the existing gas grid ▪ Lack of specialized talent, education and training programs ▪ Technology limitations blocking project bankability
Cost	Uncertain financing structure and ecosystem, including funds, financing instruments, insurance and risk evaluation	▪ Insufficient availability of dedicated hydrogen funding ▪ Incompatibility with project finance or non-recourse financing instruments ▪ Difficulties in insuring risks of large-scale hydrogen projects ▪ Difficulties in assessing and underwriting risks of large-scale hydrogen projects

Appendix - Sectoral Maturity

Six factors have been assessed to evaluate the current state of play

Maturity	Developing	Emerging	Mature	Highly mature
O&G Sector Maturity	▪ Non-existent oil and gas production	▪ Little (but some) oil and gas production ▪ Ambitions to increase levels of production	▪ Newly-established ▪ Projects in planning / commissioning / build phase ▪ LNG terminals / infrastructure in place	▪ Mature, long-standing oil and gas production ▪ High exporter of oil and gas
Current Funding Model	▪ No established funding mechanisms ▪ No capital for financing	▪ Proposed (but not launched) funding mechanisms but insufficient capital available	▪ Some funding and finance available, newly established	▪ Large spread of proven funding mechanisms, exhibited in successful projects ▪ High levels of capital available
Workforce	▪ Unskilled low available workforce ▪ Education not tailored to renewables or hydrogen economy	▪ Domestic available workforce needing further training and reliance on international workforce ▪ Workforce are skilled for oil and gas era ▪ Education to be tailored for renewables and hydrogen economy	▪ Workforce are skilled for oil and gas era ▪ Education tailored for renewables and hydrogen economy ▪ Programs to decrease reliance on international workforce	▪ Highly available, advanced workforce of the future ▪ Education tailored for renewables and hydrogen economy ▪ Collaboration with universities for research and innovation
Domestic Market	▪ Reliance on export markets as demand for hydrogen	▪ One domestic industry using hydrogen in its processes	▪ More than one domestic industry using hydrogen in its processes	▪ Existing domestic companies leading the way for local demand for low-carbon hydrogen
Infrastructure	▪ Low-carbon hydrogen production infrastructure is developing (renewables, electrolyzer manufacturing, CCUS capacities,...) ▪ Low-carbon hydrogen export infrastructure is developing (ports, existing LNG terminals, special economic zones, existing fertilizer exports,...)	▪ Low-carbon hydrogen production infrastructure is emerging (renewables, electrolyzer manufacturing, CCUS capacities,...) ▪ Low-carbon hydrogen export infrastructure is emerging (ports, existing LNG terminals, special economic zones, existing fertilizer exports,...)	▪ Low-carbon hydrogen production infrastructure is mature (renewables, electrolyzer manufacturing, CCUS capacities,...) ▪ Low-carbon hydrogen export infrastructure is mature (ports, existing LNG terminals, special economic zones, existing fertilizer exports,...)	▪ Low-carbon hydrogen production infrastructure is highly mature (renewables, electrolyzer manufacturing, CCUS capacities,...) ▪ Low-carbon hydrogen export infrastructure is highly mature (ports, existing LNG terminals, special economic zones, existing fertilizer exports,...)
Energy Independence	▪ Imports more than 60% of its energy needs	▪ Imports up to 60% of its energy needs	▪ Fully energy independent, no exports to other countries	▪ Fully energy independent ▪ Additionally support other countries in their energy supply

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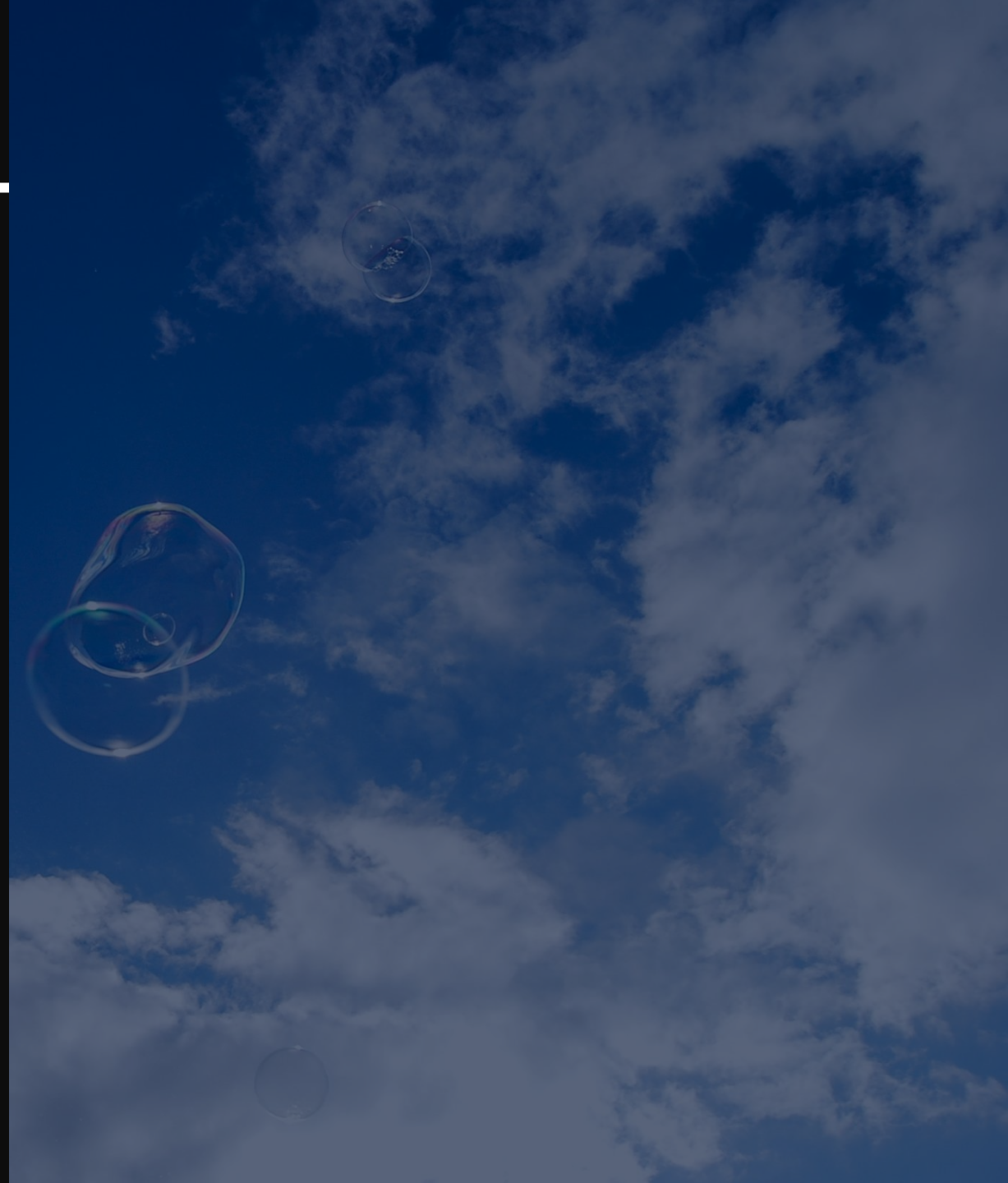

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