UNITED ARAB EMIRATES
MINISTRY OF ENERGY & INFRASTRUCTURE

National Hydrogen Strategy

United Arab Emirates

July 2023

Ministry of Energy and Infrastructure (MoEI)

Foreword from His Excellency, the Minister for Energy and Infrastructure

As the Minister of Energy and Infrastructure for the United Arab Emirates (UAE), I am pleased to present the UAE's National Hydrogen Strategy. This strategy outlines the key steps the UAE will take to position the nation as a top global producer of low carbon hydrogen by 2031 and support the UAE's commitment to achieving net-zero by 2050.

The deployment of low carbon hydrogen will ensure prosperity for the nation despite the rising challenges of climate change. The UAE has determined that clean energy is the solution to decarbonizing the economy. Energy stakeholders across the country have successfully laid the groundwork for a sustainable energy sector and a low carbon future.

Low carbon hydrogen will play a prominent role in decarbonizing the UAE's hard-to-abate sectors, such as heavy industry, long-haul transport, aviation, and shipping. Together with sector coupling, low carbon hydrogen production and demand generation is crucial for the UAE to reach its carbon emission reduction targets agreed upon under the Paris Agreement.

Low carbon hydrogen represents a significant economic opportunity to maintain the UAE's position as a strategic energy producer, exporter, and leader in the global energy market as the world undertakes the transition to a decarbonised energy system. Our natural gas resources, combined with our Carbon Capture, Utilisation, and Storage (CCUS) capacity, complement our abundant sunshine and strategic location at the crossroads of Europe, Asia, and Africa. These conditions position the UAE to develop and deploy low carbon hydrogen production technologies and to play a leading role in the global hydrogen economy.

The UAE National Hydrogen Strategy outlines the key steps the UAE will take to accelerate the growth of our hydrogen economy and become a top global producer of low carbon hydrogen. In the context of the UAE's Net Zero by 2050 ambition, the primary use for hydrogen will be to support the decarbonisation of the UAE's domestic industry whilst the global export market develops. The UAE is committed to the creation of hydrogen oases to activate the domestic hydrogen sector, the development of policy frameworks to support the growth of the hydrogen industry, collaboration with other countries in the region to activate a thriving regional hydrogen market, and investment in Research and Development (R&D) to improve the efficiency and cost-effectiveness of implementing hydrogen.

A clear and consistent strategic framework is required to instil investor confidence, support businesses in establishing hydrogen supply chains, and accelerate community confidence in hydrogen as a fundamental component of the energy mix. The strategic framework will inform the UAE's actions over the coming decades, ensuring that a seamless hydrogen value chain is supported to scale in parallel to meet the anticipated demand.

This strategy precedes the publication of the UAE's Low Carbon Hydrogen policy which will provide clarity on the market mechanisms that will drive the UAE's progress towards a global top low carbon hydrogen producer.

The UAE has been at the forefront of the global energy transition, and through our commitment to developing a hydrogen sector we ensure we maintain our leading position whilst futureproofing our economy.

The UAE invites partners to join us as we re-shape the global energy landscape to be sustainable for all of humanity.

H.E. Suhail Mohamed Al Mazrouei, Minister of Energy and Infrastructure

Acknowledgments

The Ministry of Energy and Infrastructure (MoEI) would like to express gratitude to all stakeholders who participated in the engagement process. The input and insights provided by all stakeholders have been invaluable in developing this National Hydrogen Strategy. Their participation has been crucial in ensuring that this strategy is well-rounded, harmonized, and implementable. Their contributions have shaped this strategy's direction and helped bring the vision of a hydrogen-powered future closer to reality in the UAE.

The Ministry recognises each stakeholder's time and effort to make this strategy successful. The support provided has been key in making this strategy a reality, and the Ministry appreciates the support and values each stakeholder's role. The Ministry is confident that this strategy will catalyse the growth of the UAE's hydrogen industry through attracting investment, manufacturing, services and industrial off-takers to the UAE and help position the UAE as a leader in this field. The Ministry is committed to working closely with all stakeholders to ensure the successful implementation of this strategy and to bring the benefits of hydrogen to the people of the UAE. It is envisioned that this strategy will be refreshed and updated as new developments in the hydrogen industry and the UAE come to bear. The Ministry looks forward to fruitful engagements with key stakeholders as the UAE's hydrogen outlook continues to evolve.

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Important Notice: All numbers and forecasts provided in this strategy are based on publicly available data sources and early-stage forecasts from a selection of key stakeholders. Due to the nascent hydrogen market and rapidly evolving technology and economic landscape, these forecasts and figures will likely require frequent review to maintain relevance and accuracy. All stakeholder data is still under development; therefore, the numbers presented in this document should be considered a baseline to build upon.

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Acronyms

ADGM	Abu Dhabi Global Market
ADNOC	Abu Dhabi National Oil Company
AED	Emirati Dirham
ATR	Auto Thermal Reforming
CCUS	Carbon Capture, Utilisation and Storage
CDM	Clean Development Mechanism
CeCaS	Center for Catalysis and Separations
CEO	Chief Executive Officer
CfD	Contracts for Difference
CO2	Carbon Dioxide
CO2e	Carbon Dioxide Equivalent
COP	Conference of the Parties
DED	Department of Economic Development
DEME	Dredging, Environmental and Marine Engineering
DEWA	Dubai Electricity and Water Authority
DGF	Dubai Green Fund
DoE	Department of Energy
DRI	Direct Reduced Iron
EDF	Electricitie De France
EGA	Emirates Global Aluminium
ENEC	Emirates Nuclear Energy Corporation
EOR	Enhanced Oil Recovery
ESMA	Emirates Authority for Standardisation and Metrology
EU	European Union
FCEVs	Fuel Cell Electric Vehicles
FEED	Front-End Engineering and Design
FERTIL	Ruwais Fertiliser Industries
FID	Final Investment Decision
g	grams
GCC	Gulf Cooperation Council
GCCIA	GCC Interconnection Authority
GDP	Gross Domestic Product
GE	General Electric
GHG	Green House Gas
GW	Gigawatts
H2	Hydrogen
H20	Water
H2S	Hydrogen Sulphide
HDS	hydrodesulphurisation
HHLA	Hamburger Hafen & Logistik
HPA	Hydrogen Purchase Agreements
ICV	In-Country Value
JOGMEC	Japan Organisation for Metals and Energy Security
JSA	Joint Study Agreements
kg	Kilogram
KIZAD	Khalifa Industrial Zone Abu Dhabi
KU	Khalifa University
kWh	Kilo watt hour
LNG	liquefied natural gas
LOCH	levelised cost of hydrogen
LOHC	liquid organic hydrogen carrier
Masdar	Abu Dhabi Future Energy Company PJSC
MBR Solar Park	Mohammed bin Rashid Al Maktoum Solar Park
MENA	Middle East and North Africa
MJ	mega-joule
MMBtu	Metric Million British Thermal Unit
MMscf	Million standard cubic feet
MoC	Memorandums of Cooperation
MoEI	Ministry of Energy and Infrastructure
MoIAT	Ministry of Industry and Advanced Technology
MOU	memorandum of understanding
mtpa	million tonnes per annum
PEM	Proton Exchange Membrane
PPA	Power Purchase Agreements
PtX	Power-to-X
PV	Photovoltaic
R&D	Research and Development
RAB	Regulated Asset Base
RD&I	Research, Development, and Innovation
RES	Renewable energy sources
RICH	Research and Innovation Center on CO2 and H2
SAF	Sustainable aviation fuel
SDG’s	Sustainable Development Goals
SFWG	Sustainable Finance Working Group
SME’s	Small and Medium Enterprises
SMR	Steam methane reformation
TAQA	Abu Dhabi National Energy Company PJSC
UAE	United Arab Emirates
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
USD	United States Dollar

Executive Summary

The UAE is well-positioned to develop a low carbon hydrogen supply chain and hasten its transition to clean energy.

The UAE's mission is to leverage its plentiful natural gas reserves, high solar radiance, and a wide range of 'engineered' advantages. These advantages include the UAE's established status as an energy and international business hub, substantial financial resources, and a high credit rating. As a stable and business-friendly location, the UAE will become a low-carbon hydrogen powerhouse.

The UAE aims to become a leading global producer of low-carbon hydrogen by its 60th anniversary in 2031.

To become a leading global producer by 2031, the Strategy departs from a ten-element framework. The ten elements underpinning this framework are the enablers the UAE stakeholders, including government, industry, and academia, will collaborate around to build the hydrogen value chain. The framework details the key enablers required to drive the hydrogen economy and achieve the UAE's ambition. Each enabler in the framework has a corresponding action plan and timeline of activities till 2031. A well-defined governance structure will strengthen the control and track implementation of strategic goals and actions outlined in the UAE's National Hydrogen Strategy.

By 2031, the UAE targets a production capacity of 1.4 million tonnes per annum (mtpa) of low-carbon hydrogen positions the UAE as a top global producer.

Under the right market conditions, sectoral demand within the UAE could reach 2.1 mtpa with an additional 0.6 mtpa of export potential by 2031. Beyond 2031, and in the Diversify Scenario of the UAE's 2050 Net Zero strategy, the UAE's forecasted production target, including a low export potential is 14.9 mtpa.

The UAE's national champions and businesses are already active across the end-to-end value chain for hydrogen.

They are well-positioned to support and participate in the emerging hydrogen economy. Oil and gas, renewables, chemicals, petrochemicals, steel, and aluminium are established sectors with a wealth of skills and capacity.

Hydrogen sectoral demand in the UAE could potentially grow ×5 between 2031 and 2050, i.e., from 2.1 mtpa to around 10.1 mtpa.

The forecasts are based on stakeholder input and global industry benchmarking, representing a technically feasible figure reliant on market and pricing conditions. Significant growth could be achieved in the right market environment where necessary incentives and supporting policies are implemented.

Substantial domestic demand for low-carbon hydrogen means that the UAE can accelerate ahead of the competition in developing projects as it does not rely on other countries to generate a market for its product.

The primary use for low-carbon hydrogen should be to support the decarbonisation of the UAE's domestic industry, while the export of hydrogen derivatives is considered in parallel once the domestic demand is met. Thus, the UAE will focus on stimulating local demand in the following sectors:

- Iron and steel
- Chemical and fertilizer
- Transport
- Aviation
- Aluminum
- Refining
- Shipping
- Grid flexibility

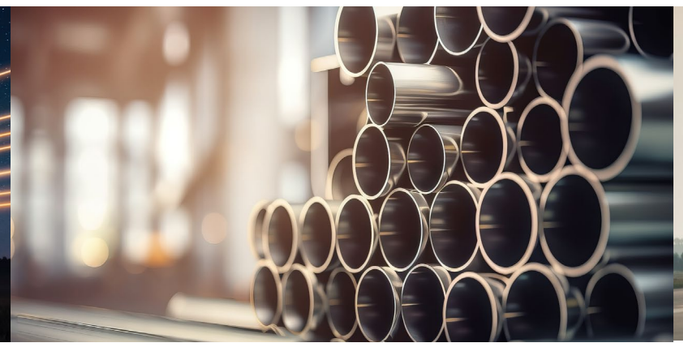
The UAE will establish clean energy precincts and hydrogen oases as a practical approach to accelerating industry adoption of low-carbon hydrogen, cultivating a supply chain, and enabling infrastructure.

The oases will support demand generation and optimisation of development costs through co-locating production and end-use applications in clusters, removing network barriers, and providing commercial opportunities to test and validate technologies.

The UAE is well positioned to become a significant global exporter, leveraging its robust infrastructure, existing export facilities and ports and vital geographic location to supply to European and Asian markets.

Up until 2031 the UAE's low-carbon hydrogen export market is expected to be in the form of derivatives and green products such as ammonia, synthetic fuels, and green steel. The UAE's export potential is presented as a range between low and high export forecasts.

The low hydrogen export potential reflects hydrogen demand only from certain hard-to-abate applications, mainly in industry and transport. The high export forecast corresponds to the latest published National Strategies, roadmaps and commitments announced by focus countries and encompasses a broader range of sectors where hydrogen can be introduced.

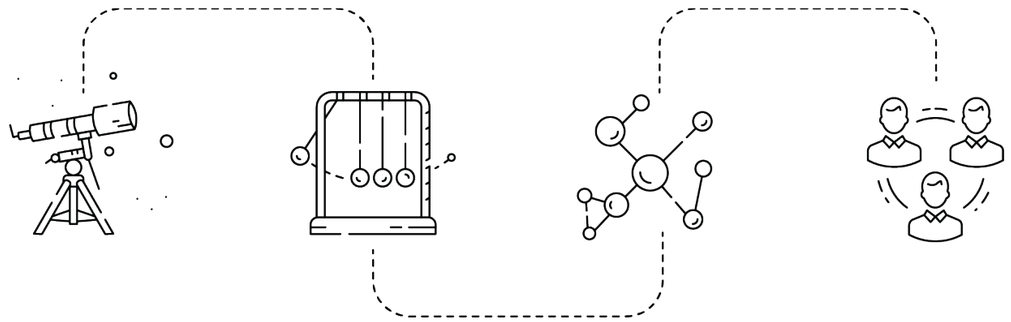
The role of low carbon hydrogen in the UAE

The UAE aims to reduce its carbon footprint through deliberate and responsible actions to meet the commitments outlined in the Sustainable Development Goals (SDGs) and the Paris Agreement. This National Hydrogen Strategy will support and build on the foundations laid through the Centennial 2071 plan, UAE's National Energy Strategy, We the UAE 2031, and the Net Zero 2050 Strategic Initiative.

The UAE Centennial 2071 rests on four primary pillars aimed at strengthening the government's long-term efforts to foster the development of future generations and position the UAE as the world's leading country. The UAE's National Hydrogen Strategy adds to this ambition and aligns with these four pillars. The strategy will identify the barriers and challenges to establishing a hydrogen economy in the UAE. The objective is to increase the nation's energy security, promote sustainable and resilient living, and grow the national talent pool.

The UAE is making an accelerated effort to decouple its economic growth from environmental impact, to chart the Nation's new development path and present its united ambition and determination. *We the UAE 2031* vision was launched with the goal of enhancing the UAE's position as a global collaborator, economic hub, and attractive partner for the world. This vision seeks to showcase the various opportunities that the UAE has to offer to international partners. One of the key national targets of We the UAE 2031 is to position the UAE as a top low carbon hydrogen producer.

The execution of the UAE's National Hydrogen strategy will ensure that the pathway towards a UAE hydrogen economy adds value across the following four key pillars.



Pillar 1

Future focused government

A government with a long-term vision that seeks to achieve social prosperity and to spread a positive message to the world, as well as provide new and diverse sources of sustainable government non-oil revenues and investment capabilities.

Pillar 2

Excellent education

Advancing our education across science and technology, space science, engineering, and health sciences. This also extends to educational measures and fostering innovation.

Pillar 3

A diversified knowledge economy

Increasing productivity of our national economy, support for national companies, investment in scientific research and focus on innovation, entrepreneurship, and advanced industries.

Pillar 4

A happy and cohesive society

Establishing a secure, tolerant, cohesive, and ethical society that embraces happiness, a positive lifestyle, and a high quality of life.

The Green Economy for Sustainable Development initiative, launched in 2012, outlined the UAE's commitment to improving the sustainability and competitiveness of its development. This initiative will secure the nation's resilience against the adverse effects of climate change during the transition to a cleaner and greener environment.

The UAE sees transitioning to a climate-resilient green economy as an opportunity for economic diversification while positioning the country as a global leader in renewable energy and green innovation. The National Climate Change Plan 2050, adopted by the UAE Cabinet in June 2017, consolidated the UAE's climate actions under one framework and outlined the strategic priorities for mitigation and adaptation.

The UAE National Energy Strategy 2050 outlines a clear plan to increase the proportion of clean energy generation in the UAE to 32% by 2031, ultimately aiming for Net Zero emissions by 2050. To achieve these goals, the UAE Energy Strategy 2050 has revised its objectives and will invest a significant amount, ranging from Dh150 billion to Dh200 billion by 2030, to meet the country's energy demand and support its economic growth.

Furthermore, the strategy will prioritize enhancing both individual and institutional energy consumption efficiency rates to effectively reduce carbon emissions and promote environmental sustainability. These efforts are expected to result in substantial financial savings of Dh100 billion and the creation of 50,000 new green jobs by 2030.

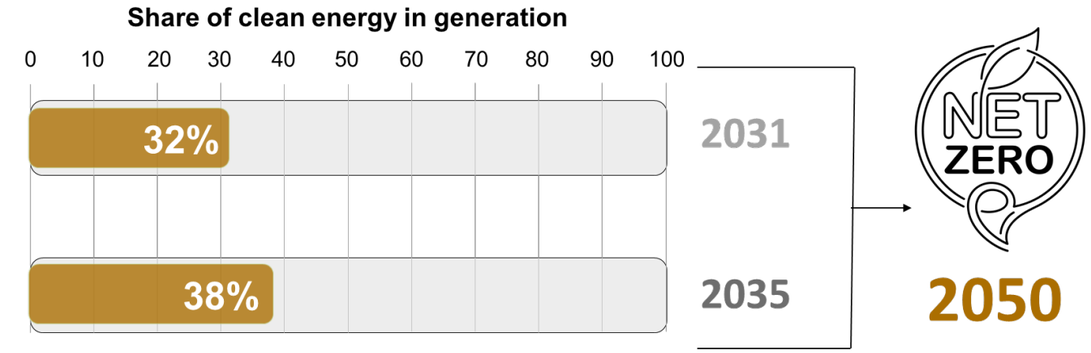


Figure 1 UAE National Energy Strategy targets

In line with the ambition to reshape the country's energy profile, the National Hydrogen Strategy will advance the National Energy Strategy 2050 by accelerating access to low carbon hydrogen.

The UAE's energy sector accounts for over 85% of the country's carbon emissions. Low carbon hydrogen will be integrated into the market as a major energy carrier to support decarbonising key economic sectors.

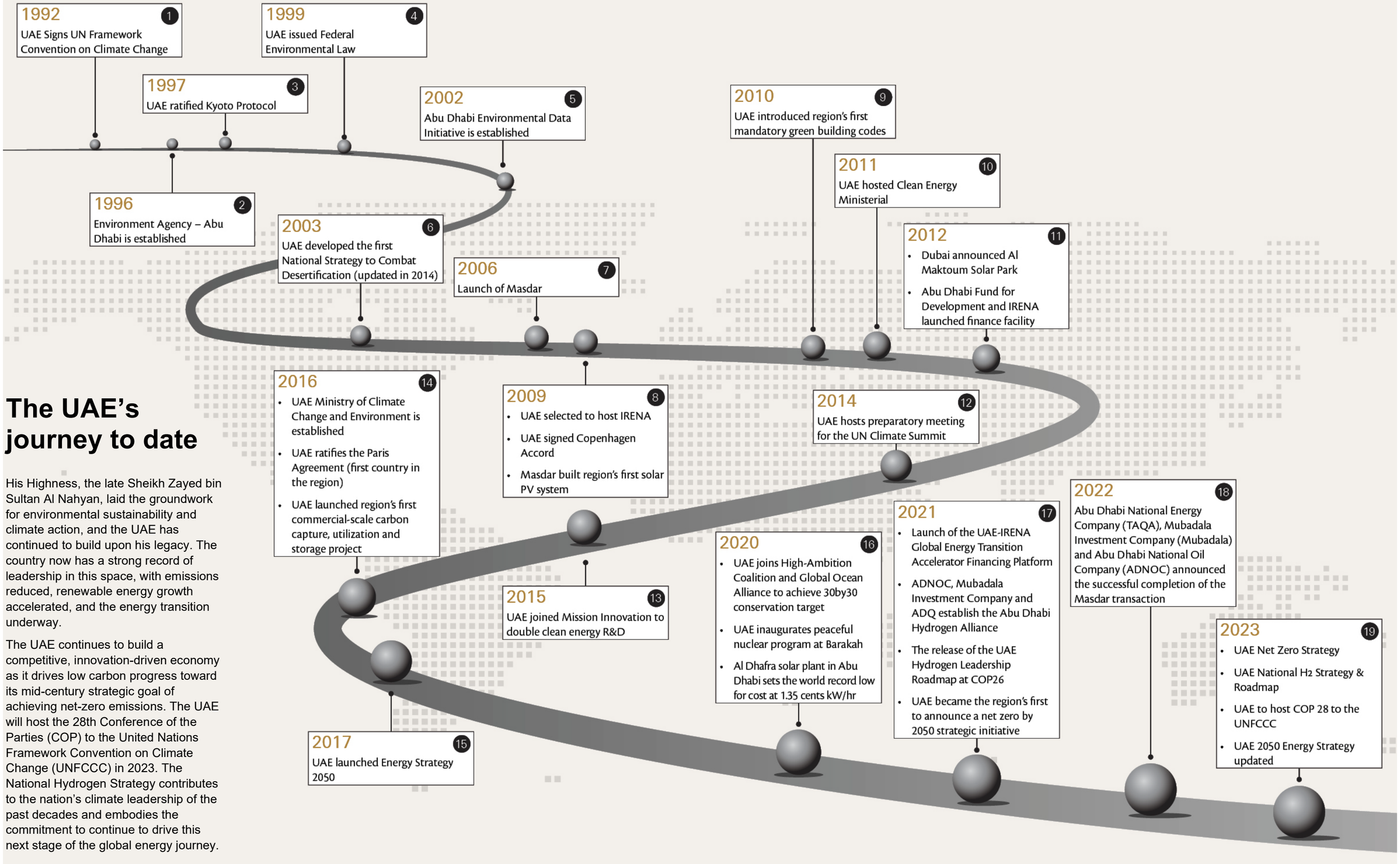
In October 2021, the UAE announced its Net Zero 2050 Strategic Initiative, with plans to invest AED 600 billion in clean and renewable energy sources (RES) over the next thirty years. Low carbon hydrogen will play a key role in achieving the UAE Net Zero 2050 Strategic Initiative, specifically focusing on decarbonising hard-to-abate sectors. Hydrogen has a role in industries that are challenging to electrify and thus decarbonise.

The UAE, with its unique geography, natural resources, and infrastructure, has the potential to be a leader in producing low carbon hydrogen and become a world-leading hub for innovation and excellence in this nascent global market.

The UAE's journey to date

His Highness, the late Sheikh Zayed bin Sultan Al Nahyan, laid the groundwork for environmental sustainability and climate action, and the UAE has continued to build upon his legacy. The country now has a strong record of leadership in this space, with emissions reduced, renewable energy growth accelerated, and the energy transition underway.

The UAE continues to build a competitive, innovation-driven economy as it drives low carbon progress toward its mid-century strategic goal of achieving net-zero emissions. The UAE will host the 28th Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) in 2023. The National Hydrogen Strategy contributes to the nation's climate leadership of the past decades and embodies the commitment to continue to drive this next stage of the global energy journey.

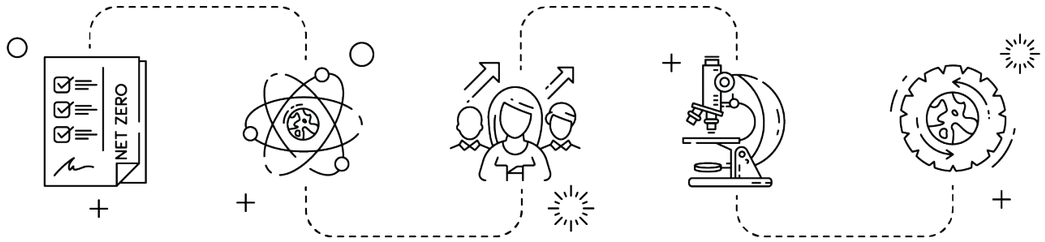


The UAE's hydrogen vision

The UAE's vision is to be amongst the **top global producers of low carbon hydrogen**, continuing the pioneering efforts in driving the global energy transition and fostering environmental stewardship while contributing to a prosperous future for all.

The mission

By leveraging both engineered and natural advantages, the UAE will become a top global producer of low carbon hydrogen by:



Creating a clear policy and regulatory environment, one that that projects confidence in the business community, stimulates demand and contributes to our Net Zero targets	Fostering global collaboration to enable hydrogen market growth and drive foreign direct investment	Accelerating the shift toward a circular carbon economy	Creating a thriving talent pool to ensure the UAE is equipped with the dynamic talent to power the acceleration of the hydrogen economy	Catalysing research, technology, and innovation across the value chain

The strategic objectives

The UAE has identified five strategic objectives that will facilitate the activation of the hydrogen market in the region:

Create a robust hydrogen economy in the UAE to support the national decarbonisation efforts	Drive the hydrogen economy resulting in foreign direct investment, job creation and workforce upskilling	Embed innovation in the UAE's industrial clusters	Establish the UAE as a leading global producer and exporter of low carbon hydrogen	Develop a resilient hydrogen supply chain to support domestic industry growth

What success looks like?

As a nation committed to advancing its economy, hydrogen is considered one of the low carbon solutions to unlocking value for the UAE and driving sustainable outcomes across industries and communities.

Diversification of the UAE's economy is essential to accelerate industry, provide local job opportunities, and bring a wealth of investment into the region. The UAE's ambitions are driven by its committed national targets and ability to continue serving as a global energy market leader. With the current market climate, countries including the United States and Germany are setting ambitious hydrogen production targets to decarbonise their own hard to abate sectors. The UAE has set the bold target of establishing itself as a top global producer of low carbon hydrogen by 2031.

To understand what a top global producer by 2031 looks like, a benchmarking assessment [1] was conducted drawing on existing global data on announced projects, ambitions, and resources of different countries. As a 2031 target, estimations suggest the UAE needs to exceed a production capacity of 1.4 million tonnes per annum (mtpa) of low carbon hydrogen to be considered a top producer globally. Given the rapidly changing and expanding nature of the hydrogen industry, the UAE acknowledges the need for continuous assessment of the situation. Therefore, the UAE will proactively monitor industry forecasts and adjust its targets accordingly.

Paving the way for a low carbon hydrogen future, ADNOC and TAQA have joined Mubadala Investment Company as shareholders in Abu Dhabi Future Energy Company PJSC (Masdar), consolidating their renewable energy and green hydrogen portfolios into the company and leveraging its strong international legacy and brand identity. Combined, the group is targeting a low carbon hydrogen production capacity of 1.4 mtpa by 2031, slightly above the benchmarked target.

Under the right market conditions, the demand from export and regional industry in the UAE could outstrip forecasted production capacities. Sectoral demand within the UAE could reach 2.1 mtpa with an additional 0.6 mtpa of export potential. These numbers rely on the appropriate technology being available as well as the market mechanisms to catalyse both production and uptake of low carbon hydrogen. This gap, as outlined in the figure below, highlights the opportunity for the UAE to ramp up plans for hydrogen production.

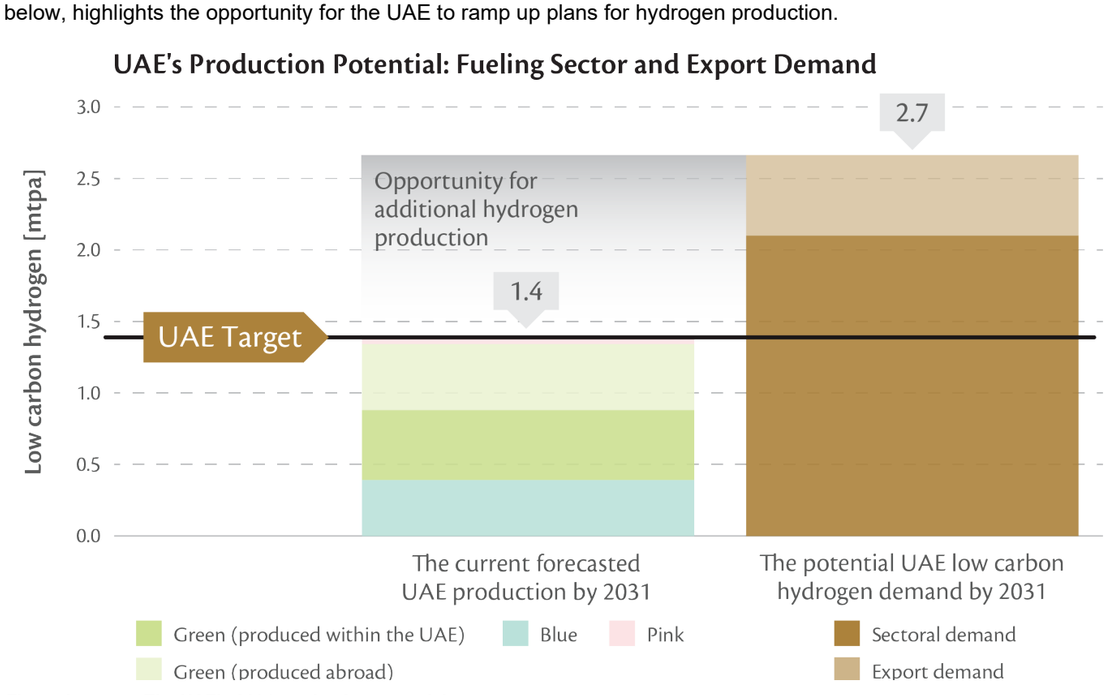


Figure 2 ***The UAE's 2031 production potential***

The strategic framework below summarises the UAE's ambitions and targets until 2050 and the KPIs that will monitor progress throughout implementation.

Vision

To be amongst the top global producers of low carbon hydrogen, continuing the pioneering efforts in driving the global energy transition and fostering environmental stewardship while contributing to a prosperous future for all.

Mission

By leveraging both engineered and natural advantages, the UAE will become a global top ten producer by:

- Creating a clear policy and regulatory environment that projects confidence for the business community, stimulates demand, and contributes to our Net Zero targets.
- Fostering global collaboration to enable hydrogen market growth and drive foreign direct investment.
- Creating a thriving talent pool to ensure the UAE is equipped with dynamic talent to power the acceleration of the hydrogen economy.
- Catalysing research, technology, and innovation across the value chain.
- Accelerating the shift towards a circular carbon economy.

Objectives

- Create a robust hydrogen economy in the UAE to support the national decarbonisation efforts.
- Drive the hydrogen economy through attracting foreign direct investment, job creation and workforce upskilling.
- Embed innovation in the UAE's industrial clusters through pioneering R&D.
- Establish the UAE as a leading global producer and exporter of low carbon hydrogen.
- Develop a resilient hydrogen supply chain to support domestic industry growth.

Targets

2031	25% emission reduction in hard-to-abate sectors	184,000 new jobs created	R&D hydrogen center established	Production of 1.4 mtpa of hydrogen	Establishment of two hydrogen oasis in the UAE
2050	100% reduction in hard-to-abate sectors	500,000 new jobs created	Globally recognized innovation hub for hydrogen	Production of 14.9 mtpa of hydrogen	Establishment of five hydrogen oasis in the UAE

10 Elements

- Policy, Regulation and Standards
- Finance and Investments
- Global Collaboration
- Industry Development and Demand Activation
- Resources and Assets
- Enabling Infrastructure
- Climate, Safety and Social Drivers
- Sustainable Commercial and Economic Models
- Skills and Education
- Research and Innovation

The UAE's hydrogen framework

Globally, the hydrogen value chain development is in its infancy. A system-level approach is needed to coordinate the supply chain development and ensure the connection between production and end use is central to all government policies. The UAE recognises the challenge of delivering low carbon hydrogen as a competitive fuel and a globally traded commodity.

The framework below details the key enablers required to drive the hydrogen economy and achieve the UAE's ambition. Through the development of this strategy a broad range of stakeholders have been consulted relevant to each element to ensure the strategy captures activities throughout the hydrogen value chain. By design, the elements within the framework are inherently interrelated, reflecting the complex nature of the hydrogen economy. While interrelated, this framework is designed to encompass all critical activities through which the UAE will develop its hydrogen economy.

Each enabler in the framework has a corresponding implementation plan and timeline of activities till 2031 to ensure the UAE remains on track to reach its targets.

Global Collaboration

Building international partnerships and creating investment opportunities to drive the global transition to a hydrogen economy.

Resources and Assets

Leveraging natural resources and existing assets to competitively lead future energy markets.

Climate, Safety and Social Drivers

Guiding society to embrace hydrogen and unlocking the common good as a result of global carbon mitigation.

Enabling Infrastructure

Creating the infrastructure necessary to link production with demand, accelerating hydrogen availability and utilisation.

Research and Innovation

Incubating and accelerating next generation hydrogen technology developments across the value chain.

Policy, Regulation and Standards

Establishing the legislative mechanisms to support the low-carbon hydrogen transition, including hydrogen certification and guarantees of origin.

Finance and Investments

Creating an attractive investment environment to support the hydrogen transition, as well as developing green finance mechanisms domestically.

Industry Development and Demand Activation

Providing the certainty, predictability and confidence industry needs to transition to hydrogen.

Sustainable Commercial and Economic Models

Achieving and maintaining globally competitive hydrogen pricing through a long-term market driven support mechanism.

Skills and Education

Nurturing and growing a highly skilled workforce to drive forward the transition to hydrogen.

Positioned to lead

The UAE is well positioned to develop a hydrogen supply chain and hasten its transition to clean energy due to its plentiful natural resources and the advantages it has gained through its leadership in energy markets.

The UAE's mission to leverage both natural and 'engineered' advantages refers to natural advantages such as gas reserves, solar radiance, geographic location, and others such as infrastructure, export facilities, industrial presence, and global trade agreements.

The existing oil and gas expertise and offtake connections place the UAE in a prime position to capture a significant market share of low carbon hydrogen and its derivatives, thus contributing to the global decarbonisation agenda. Its institutional and technical capabilities will expedite research and development and diminish the levelised cost of low carbon hydrogen, providing the UAE with the means to deliver low carbon hydrogen at a competitive price point on a global scale. By capitalising on these current strengths, the UAE has the potential to position itself as a leading global producer of hydrogen.

Both public and private industries are already active across the end-to-end value chain for hydrogen. They are well-positioned to support and participate in the emerging hydrogen economy. Oil and gas, renewables, chemicals, steel, aluminium, aviation, and maritime are established sectors with a wealth of skills and capacity. Hydrogen represents an appealing diversification opportunity for those sectors as the country continues its energy transition. The UAE starts from a position of strength with 20+ existing low carbon hydrogen projects and developments which are underway in the UAE.

Ample Energy Resources

Abundant, low-cost solar power enabled through 15+ years of research, development, and policy support. The UAE has three of the world's largest solar plants and is building more.

The UAE's installed solar capacity projected to reach 9.2 GW by the end of 2025, and the target is to increase it to 14.21 GW by 2031.This forecasted capacity is for decarbonisation of the country's grid.

Low-cost gas resources and carbon capture and utilisation (CCUS) experience will make the UAE a leading producer of competitively priced low carbon hydrogen.

Strong Existing Industry Presence

Many of the world's major oil and gas corporations have a local presence because of the UAE's established oil and gas sector and its capacity to construct collaborative and internationally competitive supply chains.

The UAE possesses significant aluminium, steel, aviation, and shipping industries.

Several existing hydrogen projects and a robust project pipeline are in existence.

Existing Supply Chain Infrastructure

The UAE has world-class industrial and export facilities that can support the growth of the hydrogen sector.

Geological hydrogen storage is available in salt caverns and depleted natural gas reservoirs.

The UAE has 12 commercial trading ports.

The UAE possesses an extensive scale network of refining and petrochemical facilities.

Access to Markets

The favourable geographic positioning of the UAE is key to future low carbon hydrogen markets in Asia and Europe.

The UAE has partnerships with major importers across Asia and Europe. Agreements are in place with key off-takers, infrastructure players, and technology leaders. The UAE government is dedicated to progressing global relationships.

A Strong Renewable Investment Portfolio

The UAE and the United States agreed to spend USD 100 billion on clean energy projects to add 100 GW globally by 2035.

The UAE invested USD 50+ billion in clean energy projects across 40 countries, including 27 climate-vulnerable island nations, and will commit to a further USD 50 billion over the next 10 years.

$15 billion earmarked for landmark decarbonisation projects by 2030 including carbon capture, electrification, new CO2 absorption technology and enhanced investments in hydrogen and renewables.

Skilled and Innovative Workforce

The UAE leads the Arab World in the World Talent Ranking and is ranked 21st globally.

The UAE is the number one environment for innovation in the Arab World, a distinction it has held for five straight years.

The UAE has a highly trained and growing workforce with knowledge and skills across the energy sector in a world-class ecosystem of universities and research institutions.

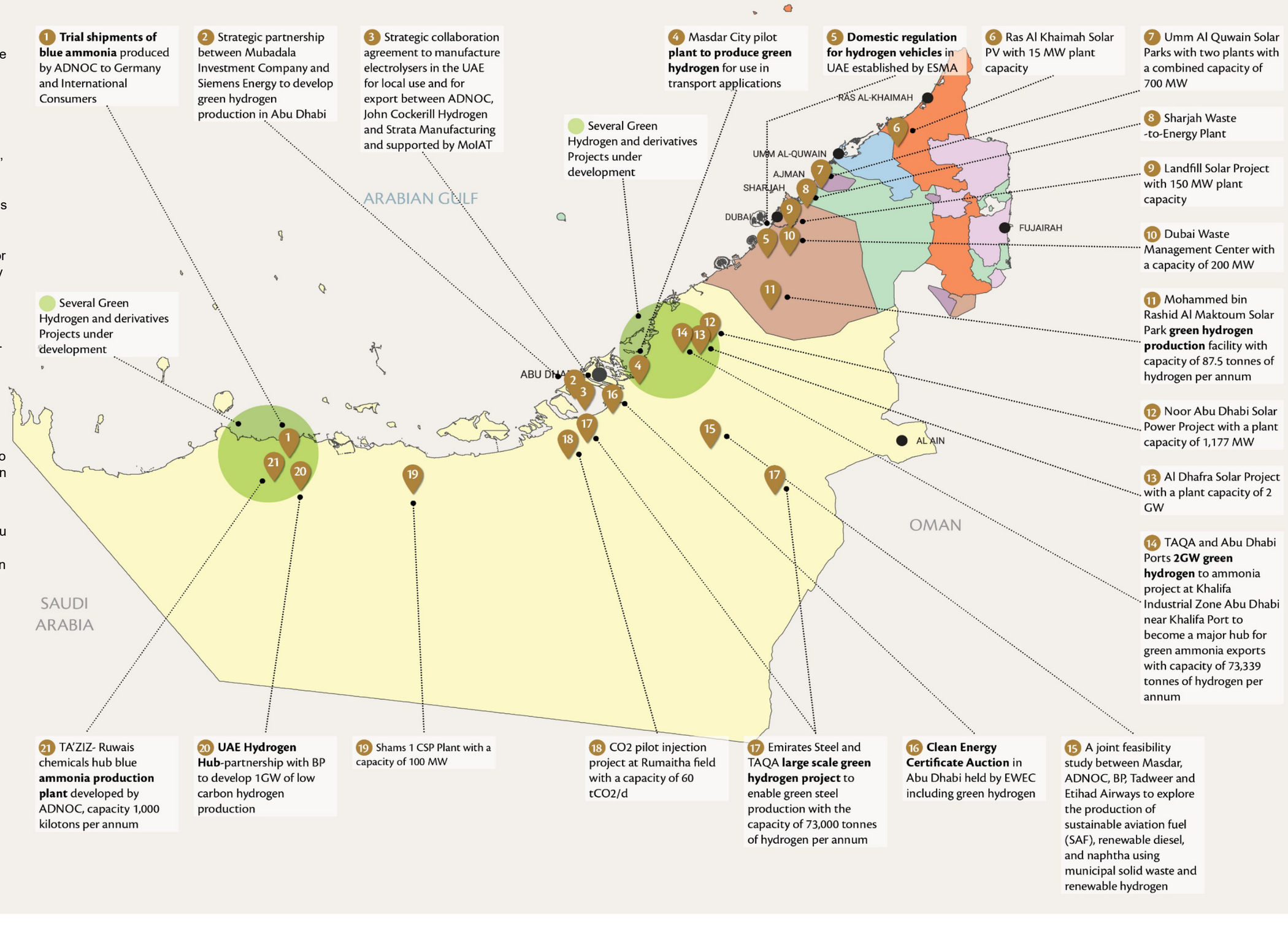
UAE's current clean energy landscape

The UAE's national champions and businesses are already active across the end-to-end value chain for hydrogen. They are well-positioned to support and participate in the emerging hydrogen economy. Oil and gas, renewables, chemicals, petrochemicals, steel, and aluminium are established sectors with a wealth of skills and capacity. Hydrogen represents an appealing diversification opportunity for those sectors as the country continues its energy transition.

The UAE starts from a position of strength with 20+ projects and developments on the ground.

Renewable energy source (RES) developments are shown, highlighting the importance of additionality to support electrolytic hydrogen production.

Masdar are the electrolytic hydrogen champions for Abu Dhabi and will be coordinating green hydrogen activities.



ADNOC Blue Ammonia

ADNOC is developing plans for a world-scale blue ammonia production facility in Ruwais, Abu Dhabi, at the TA'ZIZ industrial ecosystem and chemicals hub. In the design phase, the facility's capacity will be 1,000 kilotons of blue ammonia per annum. Design contracts have been awarded for the initial Front-End Engineering and Design (Pre-FEED) work to Wood which will be done alongside a feasibility study undertaken by ADNOC on the supply of blue hydrogen to the project from its Ruwais operations. The start-up is aimed at 2025. With more than 300,000 tonnes per annum of hydrogen produced at Ruwais Industrial Complex, ADNOC is already a significant producer of hydrogen and ammonia [2].

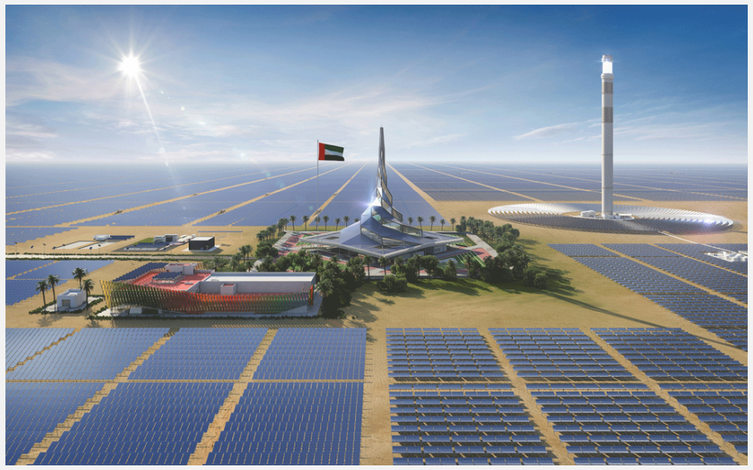
This project will help to accelerate ADNOC and the UAE's leadership in emerging low carbon fuel value chains. In November 2021, Japan's Mitsui & Co. Ltd (Mitsui) and the Republic of Korea's (Korea) GS Energy Corporation (GS Energy) announced their partnership with ADNOC on the project. The partnership demonstrates international investors and the UAE's interest in meeting the needs of global export markets and Japan and South Korea's energy and industry markets [3]. The blue ammonia will be made from nitrogen and blue hydrogen, derived from natural gas feedstocks, with the carbon dioxide by-product from hydrogen production, captured and stored. The project will build on ADNOC's advantaged position as a leader in carbon capture and underground storage with the Middle East's first commercial CCUS facility at Al Reyadah.

Source: Fertiglobe joins ADNOC's blue ammonia facility in Abu Dhabi's Ruwais

Dubai's First Green Hydrogen Plant

Dubai's first green hydrogen plant was commissioned in May 2021. The US$14 million project is a public-private partnership between Dubai Electricity and Water Authority (DEWA), Expo 2020 Dubai and Siemens Germany. The green hydrogen project covers an area of 10,000 square meters at the outdoor testing facility of the DEWA Research and Development Centre, part of the Mohammed bin Rashid Al Maktoum Solar Park [4]. The park's current operational installed capacity is 2,127 MW of photovoltaic (PV), and a total capacity of 5GW is planned by 2030. The green hydrogen plant harnesses the solar photovoltaic-generated electricity from the Phase 1 of the MBR Solar Park to produce hydrogen using Proton Exchange Membrane (PEM) electrolysis during the day. It has the capacity to produce 20 kg of hydrogen per hour [5]. The green hydrogen produced is stored and used to complement DEWA's energy storage capability for energy shifting to meet electricity generation demand.

The project demonstrates the production of green hydrogen from solar power, storage, and re-electrification of hydrogen as the first solar-driven green-hydrogen producing facility in the Middle East and North Africa region. The plant also can house future applications and test platforms for the different use cases of hydrogen, including mobility and industrial uses.



Source: Dubai commissions hydrogen plant

2GW Green Hydrogen to Ammonia Project

A memorandum of understanding was signed in July 2021 between multi-energy and water utility Abu Dhabi National Energy Company PJSC (TAQA) and Abu Dhabi Ports to develop an industrial-scale green hydrogen-to-ammonia project in Abu Dhabi [6]. The project includes turning green hydrogen into liquid ammonia to supply ships that have been converted to use ammonia as bunker fuel, as well as exporting ammonia via specialised gas carriers from Abu Dhabi Ports. The green hydrogen is to be produced via an electrolysis unit connected to a 2-GW solar PV farm, which will be built at the Khalifa Industrial Zone Abu Dhabi (KIZAD), an industrial park near Abu Dhabi Ports- run Khalifa Port [7]. This industrial zone will also accommodate the ammonia production plant with a direct pipeline to the Khalifa Port, which will house a storage facility enabling large volumes of ammonia to be directly delivered to the port.

As an industrial-sized project, this will aid in transforming the Khalifa Port into a major hub for green ammonia exports to international markets such as Europe and East Asia. This project highlights the strength of the UAE's resources and entities to lead the way in green hydrogen production. TAQA is an internationally recognised leader in large-scale, low carbon electricity and desalinated water sectors. With electricity and desalinated water as key inputs for green hydrogen production, TAQA is advantaged in facilitating the project, placing Abu Dhabi at the heart of the emerging market for green hydrogen.

Source: TAQA Group and Abu Dhabi Ports' eye green ammonia bunker-producing project

The UAE's hydrogen supply chain

Hydrogen is a versatile energy vector that can be produced from a range of feedstocks. Hydrogen can be used directly as a clean-burning gas for industrial heat, converted to green ammonia, injected into natural gas grids, to produce decarbonised shipping and aviation fuels, reconverted into electricity, or used as a transportation fuel. Low carbon hydrogen is needed to enable the transition to net zero through:

- **Decarbonising hard-to-abate sectors**: Feedstock for ammonia, methanol, and steel as a direct reducing agent, or through direct combustion or fuel cells for other high-temperature industrial processes in heavy industry, heavy-duty and long-haul transport, aviation, and shipping.
- **Enabling greater energy security in a net-zero world**: Low carbon hydrogen can be generated from fossil and renewable energy resources; many countries can benefit from hydrogen for energy supply diversification.
- **Enabling renewable energy integration and grid flexibility**: Hydrogen can be used for storage enabling better integration of large amounts of variable renewable energy into the national energy system.
- **Enabling clean energy trade**: Hydrogen trade can create a channel between regions with excellent renewable energy potential and regions with high energy demand.

Low-carbon hydrogen's commercial-scale adoption faces several obstacles, such as the immaturity of technologies across the supply chain and uncertainty in off-take. In addition, the absence of dedicated hydrogen infrastructure also presents a significant hurdle that requires attention. The scale has not yet been achieved, which puts pressure on cost and risk. The adoption of hydrogen will depend largely on certainty provided to investors through national policies and international agreements including a regulatory and certification framework.

The UAE will focus on mitigating early mover risks and reducing costs to help accelerate the adoption of low carbon hydrogen use cases.

The colours of hydrogen

Low carbon hydrogen within the UAE is defined as all hydrogen from renewable resources in addition to hydrogen from non-renewable resources with CCUS. For the purposes of this strategy, low carbon hydrogen refers to all the colours referenced in Figure 3, except grey. The UAE understands this definition is subject to change across geographies and international emissions thresholds are likely to be announced.

Hydrogen is differentiated by its colour codes, indicating the production method used. The colour codes are a helpful reference, but the carbon intensity of the hydrogen production process is a more significant factor. The colour nomenclature is used in this strategy to enable greater clarity in the different hydrogen production methods and technologies, and how these are being developed in the UAE. This allows for comparison with other energy sources.

The most common hydrogen colour, grey hydrogen, is produced through methane reformation, including both auto-thermal reforming (ATR) and steam methane forming (SMR), and accounts for 95% of the current supply. However, this method is not suitable for the goal of achieving net-zero emissions [8]. To achieve this goal, low carbon hydrogen must be produced.

Carbon intensity measures the greenhouse gas (GHG) emissions over the entire hydrogen production and "well-to-wheel" lifecycle and is usually expressed in kilograms of carbon dioxide (CO_2) equivalent per kilogram (kg) of hydrogen or grams of CO_2 equivalent per mega-joule of hydrogen. The UAE are exploring certification to track the carbon emission from each process across the hydrogen value chain from renewable energy generation to construction and production, through to distribution.

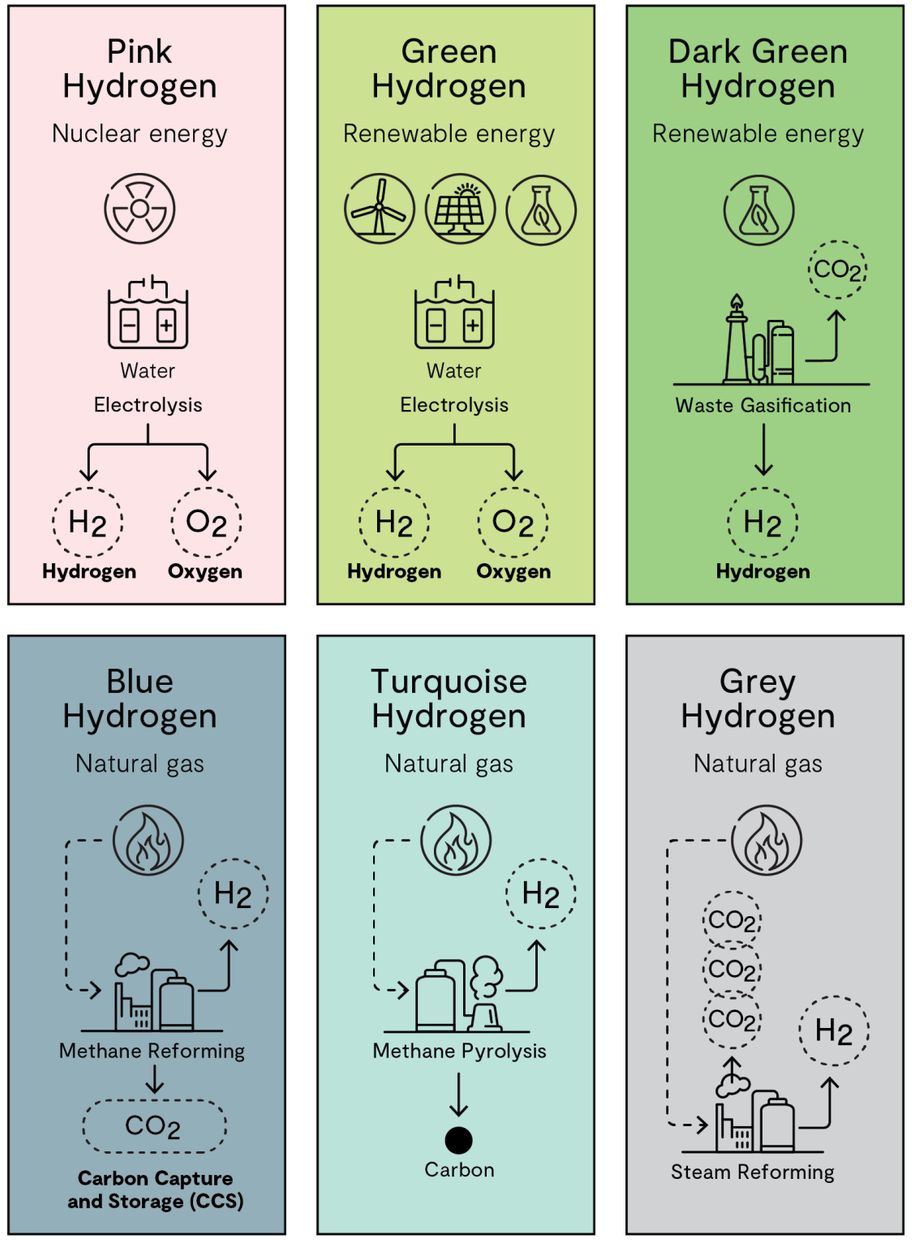


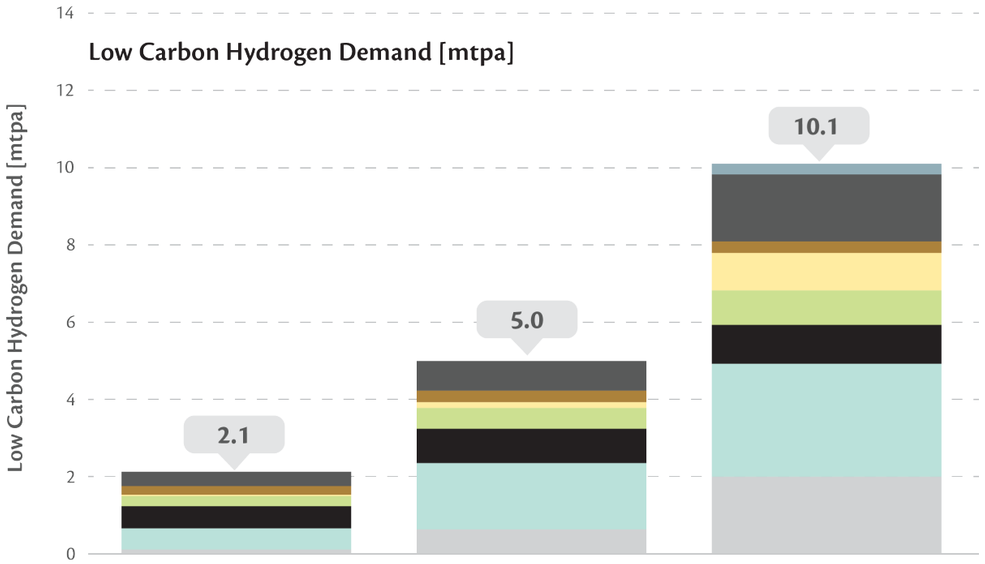
Figure 3 *The different colours of hydrogen relevant to the UAE and how they are produced*

The UAE's hydrogen potential

The UAE will use policy and financial levers to drive the demand for low carbon hydrogen in the region, supporting industry decarbonization and promoting trade in green products.

Currently, the UAE's hydrogen demand is 0.5 mtpa, primarily produced through SMR [9]. Most of the hydrogen in the UAE is used in the refining and chemical industries. With the goal of achieving net zero, there is growing interest in widespread hydrogen adoption, particularly in sectors that are difficult to decarbonise.

Hydrogen sectoral demand in the UAE could potentially grow more than fivefold between 2031 and 2050, amounting to around 10.1 million tonnes by 2050, as demonstrated in Figure 4.



	2031	2040	2050
Total	**2.1**	**5.0**	**10.1**
Grid Flexibility	0.0	0.0	0.3
Aluminium	0.4	0.8	1.7
Refineries	0.2	0.3	0.3
Transport	0.0	0.1	1.0
Fertilizers and chemicals	0.3	0.5	0.9
Iron and Steel	0.6	0.9	1.0
Shipping	0.5	1.7	2.9
Aviation	0.1	0.6	2.0

Figure 4 *UAE Low Carbon Hydrogen Sectoral Demand from 2031 to 2050 in mtpa. Source: Fraunhofer CINES.*

The forecasts in Figure 4 are based on stakeholder input and global industry benchmarking, representing a technically feasible figure reliant on market and pricing conditions. Significant growth could be achieved in the right market environment where necessary incentives and supporting policies are implemented.

While iron and steel, shipping, aviation, and transport will be the long-term driver for demand, in the near term, demand will likely be driven by the more mature markets in industrial feedstock – fertilisers, chemicals and refineries.

Modelling results by sector

Aluminium

The hydrogen potential calculation in the aluminium sector includes different parameters such as production capacity, expected growth rate, hydrogen intake for hydrogen-based boilers and Emirates Global Aluminium's (EGA) projections. Aluminium production is a fast-growing industry in the UAE. The global potential low carbon hydrogen demand for aluminium is estimated to be around 0.37 mtpa in 2031, with a steady increase until 2050. [10]

Grid Flexibility

Hydrogen can play an important role in the power sector by providing grid flexibility as the share of variable renewable electricity increases to fulfil the net-zero plans. Underground hydrogen storage will present an asset for seasonal flexibility, while plants could play a role in the industry by balancing overground tanks with hydrogen-powered regeneration. This use-case, however, is only foreseen in the long term and is expected to constitute around 0.29 mtpa by 2050.

Iron and steel

Hydrogen based steel will replace conventional crude steel production via the direct reduction of iron ore. Emirates Steel aims to expand its production capacities in the long run and unlock the green steel market faster than other leading companies globally. Under the right market conditions, these and other efforts will translate into 0.6 mtpa predicted demand for low carbon hydrogen in 2031 for the sector. [11] In the long term to 2050, they plan to deploy 17.5 mtpa of steel production, which could require 1 mtpa of hydrogen dependent on rates of adoption across different processes.

Chemicals and fertilisers

The MENA region shows the highest growth of the ammonia industry globally. Therefore by 2050, the production capacity is expected to triple compared to 2031 leading to long-term demand growth for hydrogen. Low carbon hydrogen market penetration could reach 0.28 mtpa in 2031, constituting more than half the total hydrogen demand. This trend of increasing demand for low-carbon products is expected until 2050, when grey hydrogen is anticipated to be phased out.

Refineries

ADNOC Refining operates one of the world's largest and most sophisticated refineries, with a demonstrated capacity to process 1 million barrels of oil per day. Currently, 0.2 mtpa of low carbon hydrogen is forecasted for 2031 as shown in Figure 4, although under the right conditions ADNOC Refining has the capability to produce up to 0.46 mtpa with most of that production utilized for self-consumption.

Based on projects in the pipeline, there is potential for excess of approximately 0.1 mtpa of hydrogen with varying carbon intensities to be made available as a stand-alone product. As part of its long-term strategy, ADNOC Refining is developing its overall decarbonisation roadmap aligned with ADNOC and UAE's Net Zero Commitments. Conversion of the existing grey hydrogen production to blue via CCUS is an initiative that is being explored as part of ADNOC's long-term strategy. This conversion is subject to fulfilment of necessary market requirements and alignment to its overall decarbonisation roadmap.

Aviation

Aviation will see moderate demand for low carbon hydrogen over the next few decades, meeting 2 mtpa by 2050. [12] The preliminary demand shown here is based on a range of parameters, including the share of sustainable aviation fuel (SAF) as a percentage of total demand, the energy intensity of kerosene (including SAF and bio-SAF) and hydrogen planes and the kerosene to hydrogen conversion factor (based on the hydrogen content in kerosene).

Shipping

Shipping and maritime are forecasted to reach 0.45 mtpa by 2031, scaling to approximately 3 mtpa by 2050. The methodology for estimating the future hydrogen demand is based on quantitative data from IRENA [13]. Other parameters are conversion factors, such as ammonia-to-hydrogen and methanol-to-hydrogen, energy intensity and shipping demand factor. The estimation shows that the shipping industry must meet various challenges, including suitable and safe locations for fuel storage and bunkering facilities, proper bunkering procedures (including shore-to-ship and truck-to-ship modes), and a framework for supporting national and international regulations [14].

Transport

The estimated low carbon demand in the sector stands at only 0.02 mtpa in 2031 but is expected to ramp up in the long run. Net-zero transport systems will likely require hydrogen as a fuel source for heavy-duty vehicles operated with fuel cells to exploit the technology's operational flexibility by enabling long distances and quick refuelling. As electric trains are expected to have the largest share in the railway sector, hydrogen will play a minor role in routes that cannot be electrified.

Sectoral demand

The demand for hydrogen varies greatly depending on its use and the available alternatives. Factors such as the pace of the energy transition, technology adoption, and policy and financial support also play a role in determining demand. Increasing domestic demand is important to become a top producer of low carbon hydrogen. Thus, the UAE will focus on stimulating local demand across the following sectors.

Sector	The UAE today	The opportunity for the UAE tomorrow	The challenges in getting there	The UAE's journey so far
Aluminium	The UAE has a strong industrial footprint that exports products globally. The UAE is the world's fifth-largest aluminium-producing country, producing around 2.6 million tonnes annually [15]. Low carbon hydrogen can replace many fossil fuel feedstocks and help decarbonise high-temperature industries where electrification is not an option.	There is great potential for hydrogen to play a role in decarbonising the UAE's heat-intensive industries. Gas-fired plants can be retrofitted to run on a blend of low carbon hydrogen or ammonia for heat-intensive industries, including aluminium smelting and cement. Hydrogen can be blended with natural gas up to a certain percentage, depending on the application. System changes and equipment modifications would allow 100% hydrogen fuel in the long term. Hydrogen can also be used to reduce emissions in the cast house, digestion and calcination process. The UAE can benefit significantly from green aluminium export aluminium, which is in high demand globally.	The main barrier to the adoption of hydrogen in aluminium and other similar industrial uses is the high cost compared with conventional production methods and low technology readiness.	EGA signed an agreement with General Electric (GE) to examine how hydrogen could reduce emissions from 33 natural gas-fired turbines, with a combined electricity generation capacity of 5,200 MW, at their Jebel Ali and Al Taweelah facilities. The agreement will also investigate how hydrogen could play a role in new power plants in the future.
Grid Flexibility	In 2021, the UAE power market's cumulative installed capacity was 43.5 GW. Natural gas-based electricity generation had a 95% share in the electricity mix in 2020 and is expected to dominate up to 2030. The UAE has committed to meeting a significant portion of its electricity needs using clean energy by 2050, which will involve an expansion of both renewable and nuclear power generation. This scale-up of renewables will require a new energy storage and transmission infrastructure.	Hydrogen can produce electricity and heat, with high efficiencies and without emissions. Hydrogen applications have the potential for load balancing in the electricity network and leverage short-term and long-term geological storage for seasonal energy variations. The UAE is exploring the application of low carbon hydrogen as energy storage to manage the intermittency of renewable energy from solar PV and as a strategic reserve for buffering during outages. Additionally, seasonal energy exports are forecast to grow to supply countries requiring hydrogen to support seasonal variation in their renewable energy generation. The UAE is well-positioned to capture this opportunity.	Cost is the most significant barrier to the use of green hydrogen in the power sector due to high electrolyser costs and low efficiencies. The feasibility of connecting electrolysers to the electricity network in the UAE is still to be assessed. The market size needs to be established as long-term storage demand may be limited in the UAE. Seasonal variation is currently aligned with renewable generation since cooling needs are met with solar irradiation [16].	ADNOC and GE Gas Power initiated a collaboration to create a decarbonisation roadmap reducing carbon emissions from gas turbines powering ADNOC's downstream and industrial operations. Both companies are also exploring the potential of hydrogen and hydrogen-blended fuels for low carbon power generation ammonia and CCUS for powering gas turbines. DEWA is exploring grid flexibility as an off-take option at its Green Hydrogen pilot.
Iron and steel	The iron and steel industry contributes 7 to 9% of global GHG emissions, equating to 1.9 tCO2 per tonne of steel on average. Alternatives such as the direct reduction (DRI) process using green hydrogen instead of coal must be adopted. The UAE produced 3.5 million metric tons of steel as of 2021 [17]. Emirates Steel, the UAE's largest steel and building materials manufacturer, emits 50% lower GHG emissions per ton of steel produced compared to the global average [18].	The UAE is well-positioned to become a global leader in low carbon steel production due to its existing gas-based DRI processes. By using low-carbon hydrogen to produce "green" steel, the UAE could take advantage of the growing demand for clean products. To maximize the benefits of this opportunity, the UAE will explore the adoption of innovative commercial models that leverage its DRI process. By leveraging its existing infrastructure and strategic location, the UAE has the potential to become a key player in the global green steel market and create value both at home and abroad.	Cost competitiveness with conventional methods is a barrier to using low carbon hydrogen in the iron and steel industry.	Emirates Steel and TAQA announced a partnership in August 2021 to develop a green hydrogen project, enabling the production of the first green steel in the MENA region. This partnership supports the growing demand for low carbon steel on a national and global level, and the project design has expanded to meet the anticipated growth. This project is an essential milestone in reducing the carbon footprint of the construction, industrial and transportation sectors.
Chemical and fertilisers	In the UAE, the current production capacity of ammonia is 1.2 million tonnes and 2.1 million tonnes of urea as of 2019, with the majority produced at the FERTIL ammonia and urea plant at the industrial centre of Ruwais [19]. Ammonia is mainly produced via the Haber-Bosh process, which requires hydrogen and is predominantly used as a base chemical in producing ammonium nitrate for fertilizers. Production of ammonia results in approximately 2.9 t CO_2 per tonne of ammonia. [20]	Low carbon ammonia can also be used as an energy storage and transportation medium. Low carbon ammonia is expected to play a large role as the hydrogen economy develops in the UAE. Using low carbon hydrogen to produce ammonia in fertilisers and other chemical products has great potential in the UAE. The UAE's already established chemicals industry with knowledge in transport of hydrogen derivatives and manufacturing capabilities will serve and scale the UAE hydrogen economy.	Cost competitiveness with feedstock is a barrier to using low carbon hydrogen.	ADNOC is already a major producer of hydrogen and ammonia, with more than 300,000 tonnes per annum produced at Ruwais Industrial Complex. ADNOC has plans for a large-scale blue ammonia production facility at the Ruwais complex. TAQA and Abu Dhabi Ports have partnered to develop an industrial-scale green hydrogen-to-ammonia project in Abu Dhabi, with a production capacity of 73,339 tonnes per year. Masdar and Engie have partnered to study a green hydrogen plant to supply Fertiglobe's ammonia production plant to be operational by 2025. [21]

Sector	The UAE today	The opportunity for the UAE tomorrow	The challenges in getting there	The UAE's journey so far
Refining 	The UAE is one of the global oil-producing countries, with an average output of 3.2 million barrels of petroleum and liquids per day [22]. Hydrogen is used in oil refining, such as hydrodesulphurisation (HDS), removing sulphur and other impurities from petroleum products and natural gas and hydrocracking to produce diesel or petrol in the presence of hydrogen and a catalyst. About one kilogram of hydrogen is needed to refine one barrel of crude oil. None of the hydrogen used in refining is low carbon hydrogen. Growth plans are expected to increase the petrochemical output by more than 150% by 2025 [23].	With the forecasted growth of the oil marked, the opportunity for low carbon hydrogen in the UAE oil refining process is immense. The oil market potential presents an immediate demand source to support the scaling of production capacity while reducing the carbon intensity of the UAE's refined oil products.	The increased cost associated with the addition of CCUS needs to be overcome. Key stakeholders in the sector need collaboration to enable a quick transition to low carbon hydrogen and ensure enough is available to meet the high demand. Policy interventions, incentives, and a low carbon hydrogen standard are needed to encourage the use of low carbon hydrogen over grey hydrogen.	ADNOC has a joint study agreement with two Japanese companies, INPEX and JERA, and a government agency, the Japan Oil, Gas and Metals National Corporation (JOGMEC), to explore blue hydrogen production in the UAE to supply Japanese markets.
Aviation 	The aviation industry is a core pillar of the UAE's economy, contributing to around 13% of the national GDP with six national airports [24]. The UAE's geographic centrality to most of the globe enhances the throughput of travellers and the growth of the industry. In 2021, the industry produced 720 million tonnes of carbon emissions globally.	Hydrogen has the potential to decarbonise the aviation sector, either as hydrogen-derived SAF or in the development of hydrogen-powered aircraft [25]. Replacing as much as 73% of conventional jet fuel with power to liquid-based sustainable aviation fuels would align the national aviation industry with the country's 2050 net-zero ambitions.	The UAE is dedicated to improving performance and growing the sector with high investment in infrastructure. Some SAF production routes are still in early stages of technology development will require significant investments and global R&D efforts over the next decade.	The green hydrogen pilot project in Masdar City will explore the use of hydrogen in aviation fuel development.
Shipping 	The UAE is a key player in the global oil and gas trade, with numerous vessels transporting oil and gas through its territorial waters, home to the port of Fujairah, one of the world's largest bunkering hubs, placing the UAE as a major maritime international hub. The international shipping industry is responsible for around 2% of global energy-related CO_2 emissions due to the use of heavy fuel oil [26]. In 2021, this accounted for 667 million tonnes of carbon emissions.	Hydrogen is a proposed alternative to traditional bunker fuel. It can be used to decarbonise the shipping industry as a fuel in the form of ammonia or hydrogen-based synthetic liquid fuels or fuel cells. The UAE is planning a leading position by adapting to the decarbonisation strategies set by the International Maritime Organisation (IMO) by providing the necessary bunkering infrastructure and corresponding fuels. Consequently, the strategy sees a substantial role in the international bunkering of hydrogen in the UAE's sectoral demand.	Globally, low carbon hydrogen as an alternative to traditional bunkering fuel is still in its infancy. Although the UAE is exploring various pathways, it is still at a low maturity phase. Conflicting views on the superior fuel type (methanol, ammonia, or synthetic liquefied natural gas) have slowed progress.	Masdar and Abu Dhabi Ports' 2GW green hydrogen to ammonia project aims to supply ammonia to the maritime industry to be used as bunker fuel.
Transport 	The UAE has seen a significant increase in public transport usage with the introduction of new metro and tram lines. However, there has also been growth in the number of private vehicles on the roads leading to increased traffic and poor air quality.	The UAE is exploring hydrogen for vehicles that transport goods and services on fixed routes, allowing for a centralised refuelling station system, highlighting where hydrogen will be best placed in the transport sector [27]. Transport accounts for approximately 20% of global emissions. Hydrogen provides an alternative solution to transport sectors that are difficult to electrify, including Heavy Goods Vehicles and long-distance transit. Hydrogen fuel cells offer longer travel distances between refuelling and faster refuelling times compared to electric technologies.	The UAE, to date, has focused on electrification as the pathway to decarbonisation of transport. The main barrier for hydrogen in light-duty vehicles is the significant investment in a network of refuelling stations. Other barriers include the high cost of development, safety considerations for the distribution and storage of hydrogen at refuelling stations and a lack of legislation and policy on hydrogen for use in commercial vehicles.	The Emirates Authority for Standardization and Metrology (ESMA) established the first domestic regulations in Dubai regarding hydrogen vehicles and the use of hydrogen fuel cells in March 2019. Al Futtaim Toyota has partnered with Air Liquide to open the first hydrogen refuelling station at Al Badia, Dubai Festival City. 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. [28]

Export demand

The low carbon hydrogen export market is expected to reach 150 million tonnes per year globally by 2050 [29]. Nations with abundant resources and well-developed infrastructure will take the largest share of the market.

While the UAE has a strong export ambition regarding low carbon hydrogen, there is also a priority consideration for domestic demand for hydrogen. The UAE's low cost of renewable energy could bring about a cost-competitive source of low carbon hydrogen. Low-cost renewables will benefit the export prospects of low carbon hydrogen and the competitiveness of products that contain hydrogen, such as green steel and green ammonia, in terms of their carbon footprint, product diversification and economic value.

The UAE is well positioned to become a major global player, leveraging its strong infrastructure, existing export facilities and ports and a strong geographic location to supply to European and Asian markets. The UAE's low carbon hydrogen export market is expected to be in the form of chemicals and industrial products, such as ammonia, synthetic fuels, and green steel, up to 2031 [30].

The UAE's export potential is presented in Figure 5 as a range between low and high export forecast. The low hydrogen export potential reflects hydrogen demand only from certain hard to abate applications, mainly in industry and transport. The high export forecast corresponds to the latest published National Strategies, roadmaps and commitments announced by focus countries and encompasses a wider range of sectors where hydrogen can be introduced.

For 2031, a production capacity between 0.6 mtpa and 1.8 mtpa will be needed to address import targets for these countries. This has the potential to scale significantly up until 2050.

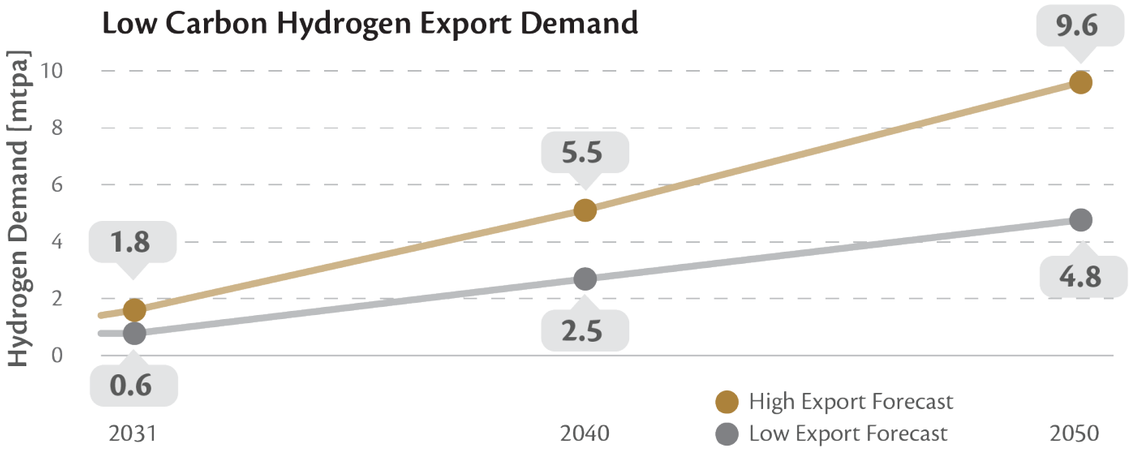


Figure 5 *Low carbon hydrogen export demand (mtpa). Source: Fraunhofer CINES.*

Trial run of Hydrogen supply chain from the UAE to Hamburg

ADNOC and Fertiglobe signed an agreement with Hamburger Hafen & Logistik (HHLA) in March 2022 to test hydrogen transport from the UAE to Germany. The hydrogen supplied by ADNOC was shipped as clean ammonia from Fertiglobe's plant in Abu Dhabi

The first shipment arrived at the Port of Hamburg on October 21, 2022, attended by H.E. Sultan Ahmed Al Jaber, the UAE's Minister of Industry and Advanced Technology, Dr. Peter Tschentscher, Mayor of Hamburg and Michael Hagemann, Senator for Economics. This project represents a milestone in the planned scale-up of blue ammonia production capabilities in Abu Dhabi. The project originated from a memorandum of understanding (MoU) and joint study agreements (JSA) between ADNOC and German companies and shall lay an essential foundation to understand the supply chain for later medium-term imports of blue and green hydrogen derivatives to Germany.

ADNOC is progressing towards its goal of increasing hydrogen and low-carbon ammonia production in Abu Dhabi. This development marks a significant achievement in ADNOC's plans to expand its production capabilities. [31]

Production

To become a top global producer of low carbon hydrogen in alignment with the vision, the UAE's ambition is to produce 1.4 mtpa by 2031.

Although this requires a lower investment than unlocking the full potential of the hydrogen market (2.7 mtpa as mentioned in the *UAE's hydrogen potential*), significant investment will still need to be made. ADNOC and Masdar have demonstrated leadership in the UAE directing efforts towards development of production and networks infrastructure for export whilst the UAE regional sectors transition.

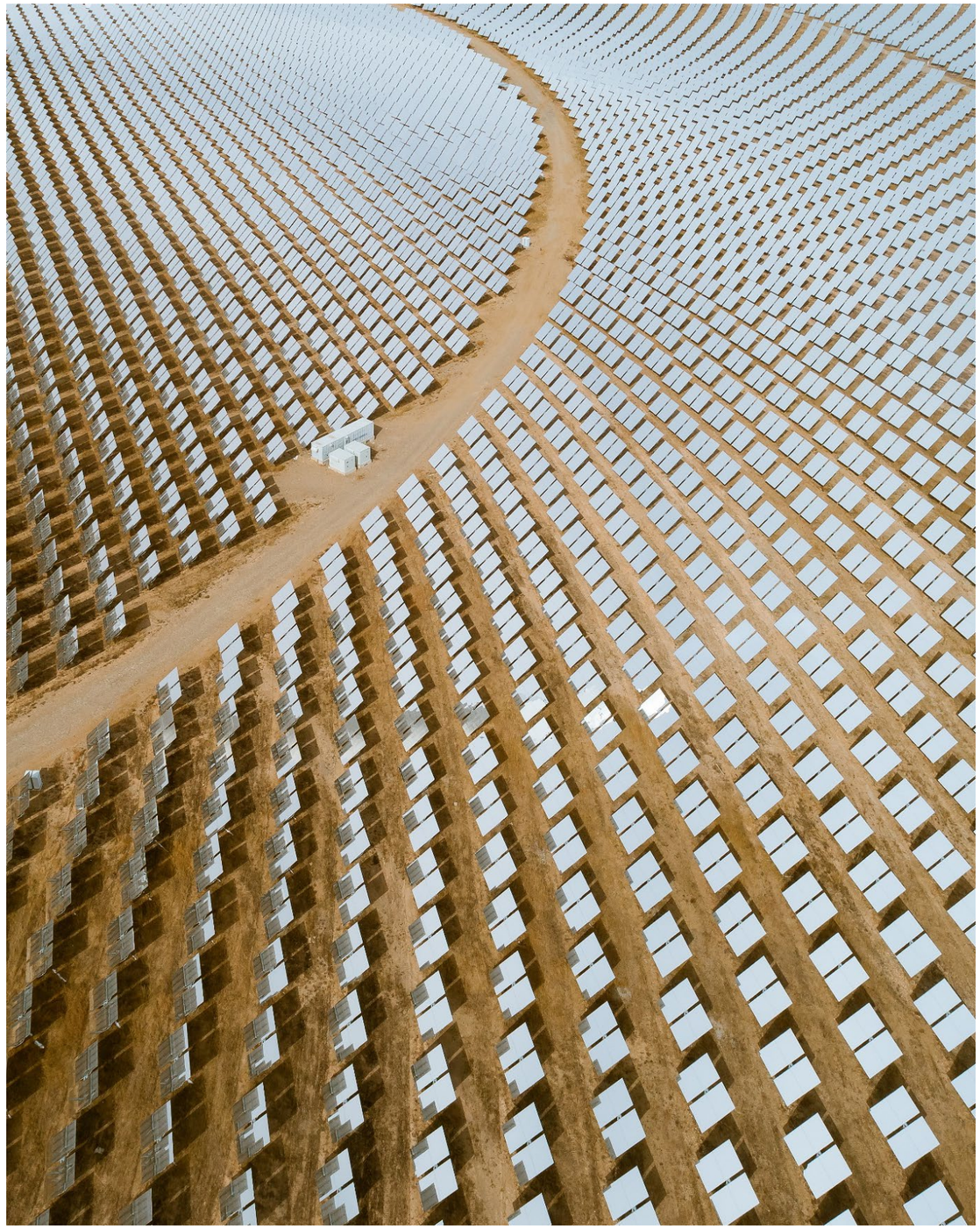
Currently, the UAE has a forecast production capacity of 1.4 mtpa by 2031 spread across different production pathways and regions. This production capacity will position the UAE as a top producer globally.

Electrolytic from renewable energy (Green) *Produced within the UAE*	0.5 mtpa
Electrolytic from renewable energy (Green) *Produced abroad*	0.5 mtpa
Methane reforming with CCUS (Blue)	0.4 mtpa
Electrolytic from nuclear energy (Pink)	0.0075 mtpa

To achieve the production outputs of 0.5 mtpa of green hydrogen, the UAE will require an in-country electrolysis capacity of 8.7 GW_{H2} powered by 15.3 GW of PV plants. In addition, approximately 94 km^2 of land is required for these PV plants. An additional 0.4 mtpa of blue hydrogen is foreseen and translates to 1.98 GW hydrogen of methane reforming fed with around 54,594.3 million standard cubic feet (MMscf) of natural gas, resulting in 5.1 mtpa of CO2 captured by the CCUS facility. Emirates Nuclear Energy Corporation (ENEC) are forecasting production of 7,500 metric tonnes of pink hydrogen by 2031 from 50MW of nuclear energy capacity.

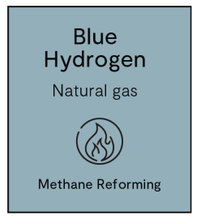
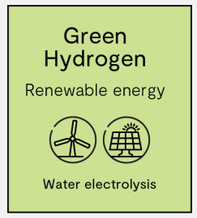
The table below summarises the required inputs to produce hydrogen at the forecasted quantity by 2031.

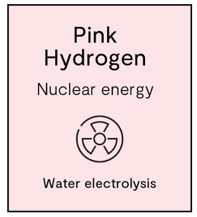
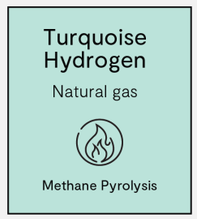
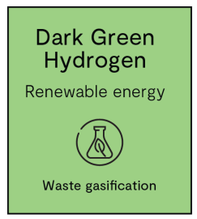
Year	**2031**	
Hydrogen colour	Green *(Produced within the UAE)*	Blue
Hydrogen quantity supplied [mtpa]	0.5	0.4
Hydrogen electrolysis capacity required [GW_{H2}]	8.7	-
Electricity generation capacity [GW_{el}]	15.3	-
Carbon capture (mtpa) [32]	-	5.1
Natural gas required [MMscf]	-	54,594.3 [33]
Land (km^2) [34]	~ 94	-



UAE's production today

The UAE holds the world's seventh-largest natural gas reserves at 215 trillion cubic feet[35], with approximately 30% of its GDP based on oil outputs[36]. The UAE is currently exploring the following low carbon hydrogen production methods at different maturity levels and commercial application stages.

The different colours	How is the hydrogen produced?	What is happening in the UAE today?	What are the biggest challenges facing the UAE?
 **Methane reforming with CCUS**	SMR produces hydrogen, carbon dioxide and carbon monoxide from methane using high-temperature steam under 3-25 bar pressure and a catalyst. Carbon monoxide can undergo a similar process to produce more hydrogen and carbon dioxide. Hydrogen and impurities are then separated, with the carbon dioxide stored underground. ATR combines steam and partial oxidation reactions to produce more hydrogen than partial oxidation alone, with faster start-up and response times than methane reforming and higher emissions recovery at a lower cost.	The UAE is well-positioned to lead the blue hydrogen market due to its low cost, ample supply of hydrocarbons, large-scale ammonia and hydrogen production facilities, and favourable underground formations for carbon dioxide storage. The UAE sees blue as a steppingstone to increase domestic hydrogen use and distribution. Although adding CCUS to hydrogen production from natural gas will increase production costs by 50%, the UAE can still have one of the lowest costs for blue hydrogen production globally. The estimated cost of blue hydrogen production is $1.5/kg[37], competitive with grey hydrogen production in the US and lower than other major markets such as the European Union, China, and India. The UAE has implemented 14 projects to reduce GHG emissions by 1 million tonnes of CO_2 equivalent per year under the Clean Development Mechanism (CDM).	• Production of hydrogen from methane reforming has an efficiency of 65-75%. [38] • Fuel costs make up a large percentage of production costs. • CCUS increases fuel, capital, and operation costs by 50%. • CCUS facilities could become stranded assets if they fail to achieve target capture rates and when green becomes competitive with blue. • Limited commercial-scale projects have captured 90% or more CO_2 in the medium to longer term.
 **Water electrolysis using RES**	Electrolysis converts water into hydrogen and oxygen by applying an electric current. This hydrogen is considered low carbon with zero greenhouse gas emissions if the electricity is produced via renewable sources.	The UAE has substantial potential for green hydrogen production due to its abundant solar energy, with approximately 71,000 square kilometres of land area and an annual average daily solar radiation of 6.3 kWh/m^2 per day [39]. With a goal of 14.21 GW of installed solar PV by 2031, the UAE's installed capacity has dramatically risen from 100 MW in 2015 to 3.1 GW in 2021, making it the most significant relative increase in renewable energy worldwide in the past decade. This, combined with one of the world's lowest solar power costs of 1.35 USD cents per kilowatt hour at the Al Dhafra plant, demonstrates the UAE's ability to produce electrolytic hydrogen efficiently and on a large scale [40]. The UAE are exploring alternative sources of renewable energy such as wind or concentrated solar power to meet decarbonisation objections and supply green hydrogen.	• The overall efficiency of electrolysers and their lifetime need to be improved. • Ability to provide uninterrupted RES generation to electrolysers when reliant primarily on solar PV. • Land available for solar development needs to be identified in the UAE. • Investment is needed to help scale production to meet demand (both domestic and export). • Investment is needed to help catalyse demand. • Electrolyser costs need to reduce to lower overall levelised cost of hydrogen (LCOH)

The different colours	How is the hydrogen produced?	What is happening in the UAE today?	What are the biggest challenges facing the UAE?
 **Hydrogen production using nuclear energy**	Pink hydrogen from nuclear energy can provide efficiencies and lower costs due to increased heat. This additional heat allows a range of electrolysis processes, including cold, low-temperature steam, high-temperature steam, and high-temperature thermochemical production. For direct electrolysis of water, hydrogen production requires a minimum temperature of 2500°C (high-temperature nuclear energy). Lower temperatures are needed for thermochemical processes such as the water-splitting cycle (low-temperature nuclear energy).	ENEC has three operational nuclear units at Barakah each with 1.4 GW capacity. A fourth unit is current under development but once operational, they will provide 25% of the country's power needs and abate 21 million tons of carbon emissions annually. ENEC and Électricité De France (EDF) signed a MoU to collaborate on research and development for low carbon hydrogen production via carbon-free nuclear energy to accelerate nuclear-powered development.	• Low technology readiness level for hydrogen production via nuclear on an industrial scale. • More research is required to understand how existing nuclear reactors need to be optimised for high-temperature thermochemical production. • Need to develop technology at scale. • The current process has low efficiency and poor economics. • Changes needed for commercial viability.
 **Methane pyrolysis**	In a pyrolysis reactor, methane is heated to 1000-1500°C (in the absence of oxygen) and dissociates into solid carbon and hydrogen. Solid carbon has lower greenhouse gas emissions than methane reforming, and hydrogen can be used as fuel in many applications. Hence, it still requires electricity, but several times less than electrolysis, depending on the technology used [41]. Several turquoise hydrogen production methods exist, of which catalytic thermal decomposition is the most used. Recent research states that hydrogen produced by methane pyrolysis via thermal plasma has a low carbon intensity, reaching 0.06 $kgCO_2e/kg$.	Khalifa University is exploring using pyrolysis technology in the UAE to produce hydrogen at a lower cost. The solid carbon produced is an industrial product with a global market of ~15 million tons per year, used for tires and other rubber products, and inks for printers, at prices from $0.5 to $2 per kg [42]. Simultaneously, new carbon applications like carbon-based composite buildings could be considered to expand the existing market [43]. Khalifa University is also exploring the use of carbon-based additives to support the decarbonisation of concrete. .	• The production method is in the early stages of development. • Further investment into research and development is needed for industrial-scale viability. • The application of methane pyrolysis is limited by the requirement of a solid catalyst that deactivates quickly.
 **Waste gasification**	Biomass, a renewable organic resource such as crop residues or organic waste, can be broken down into hydrogen and other products using heat, steam, and oxygen without combustion and is a sustainable alternative to landfill and waste incineration. It is a self-sustainable thermal conversion treatment (gasification and pyrolysis) of waste wood, plastic and municipal solid waste which breaks into a mixture of gases or synthetic gas (syngas) composed of methane, hydrogen, and carbon monoxide. The syngas is collected and used to generate hydrogen and electricity. This production pathway is especially beneficial for hydrogen derivatives such as low carbon fuels. The carbon intensity of the process can be near 0 or negative with CCUS.	ADNOC, bp and Masdar have joined with Abu Dhabi Waste Management Centre (Tadweer) and Etihad Airways to explore production of sustainable aviation fuels, from hydrogen and municipal waste gasification, in the UAE. [44] UAE-based Bee'ah Energy is partnering with UK-based Chinook Sciences to produce up to 18,000 kg of low carbon hydrogen per day from non-recyclable waste [45]. The $180 million waste gasification energy project will use Chinook Sciences' RODECS gasification technology. The planned hydrogen output is expected to lead the transition of the company's fleet of up to 800 waste collection trucks to fuel cell trucks. This cost-competitive method has the potential to be equal to or less than the cost of diesel and gasoline and could fuel 1,000 hydrogen-powered vehicles a day [46].	• Low efficiency of biogas reactor, resulting in lower yields and hydrogen production rates. • Technology readiness level is not yet proven on a large scale. • Production dependent on the availability and uniformity of the feedstock and its cost.

Meeting Net Zero 2050, hydrogen's role beyond 2031

Under the 2050 Net Zero strategy, the "Diversify Scenario" developed outlines a pathway to a decarbonised future. To achieve this vision, the UAE would need to scale low carbon hydrogen production to support hard to abate sectors. The Net Zero 2050 model forecasts an equal share of green and blue hydrogen in the long run.

Figure 6 outlines the balance of low carbon hydrogen production by 2040 and 2050 to meet forecast demand.

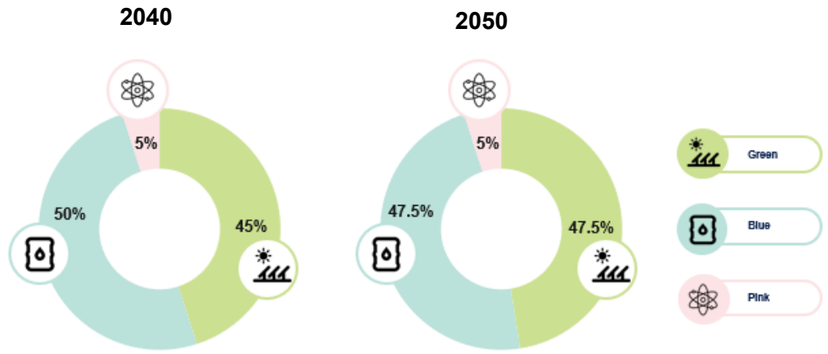
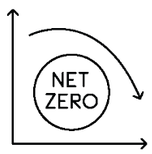


Figure 6 Shares of hydrogen colours in 2040 and 2050

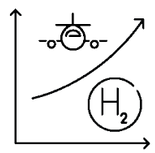
ENEC will also play a key role in developing the electrolytic technology to produce zero-carbon hydrogen through nuclear. The advantage of nuclear energy as an alternative energy source for hydrogen production is its ability to provide a base-load production that could increase energy security for the UAE.

The Diversify Scenario includes:



Aiming to achieve net zero emissions by 2050.

Futureproofing key export sectors, i.e., CCUS ramp-up for petrochemicals, steel, oil and gas, and aluminium and providing early green power for aluminium and petrochemicals



Capturing growth opportunities in new export markets, including low carbon hydrogen and green fuels for shipping and aviation and Direct Air Capture offsets.

Figure 7 presents the UAE's hydrogen production capacities supplying all potential sectoral demands and the export for the lower international demand forecast (see ***The UAE's hydrogen potential***).

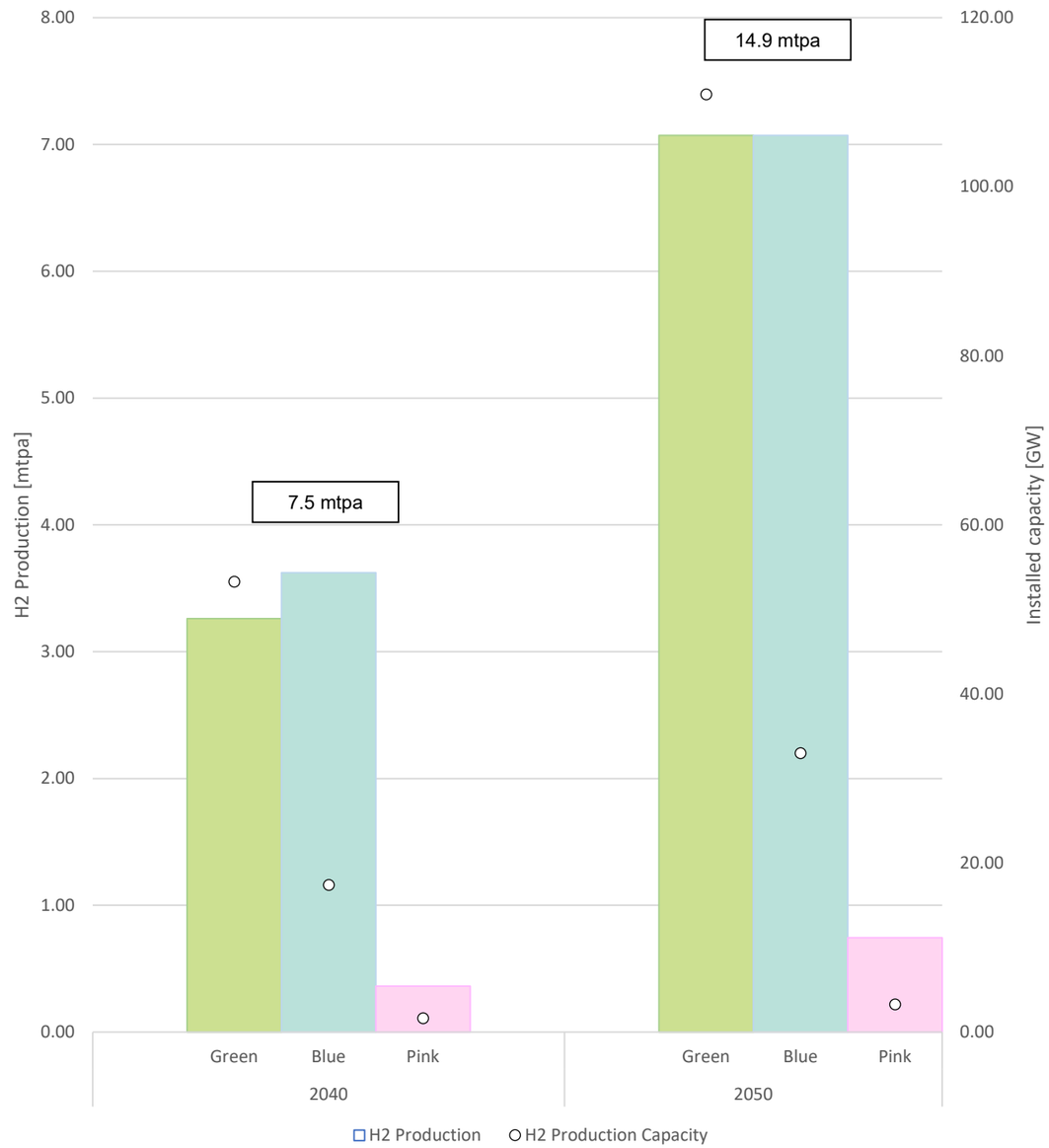


Figure 7 Forecasted UAE production requirement including low export potential. Source: Fraunhofer CINES.

The UAE low carbon hydrogen model assumes a sub-system for green hydrogen production, including utility-scale photovoltaic systems with optimally sized PEM electrolysers. The photovoltaic capacity needs will potentially decrease by coupling these systems with large-scale storage technologies.

For blue hydrogen, ATR is considered because of its higher achievable capture rates at relatively lower costs [47].

ENEC is exploring different technologies for hydrogen generation as nuclear-based energy offers an excellent solution for generating the electricity, heat and steam required for low carbon hydrogen production. The company is interested in demonstration projects focused on coupling nuclear reactors and SOEC. However, the scale-up of such technology requires overcoming various obstacles, such as nuclear regulatory requirements for steam reuse and safety issues and developing SOEC technology to a commercially viable level. A possible alternative for pink hydrogen production is PEM electrolysis powered by nuclear electricity. Such a decision will depend on the maturity level of SOEC over the coming years.

As technologies including small modular reactors are advanced and deployed, the opportunity for distributed nuclear energy generation could also prove valuable for the UAE in pink hydrogen production. Different production approaches will be explored to support the UAE in meeting longer term targets.

It is important to note that the capacity figures outlined below are based on today's technologies. It is anticipated that as the industry develops that hydrogen production efficiencies will improve, and new technologies will emerge.

Year	**2040**			**2050**		
Hydrogen Colour	Green	Blue	Pink	Green	Blue	Pink
Share of hydrogen supplied [%]	45%	50%	5%	47.5%	47.5%	5%
Hydrogen quantity supplied [mtpa]	3.37	3.75	0.37	7.07	7.07	0.74
Hydrogen electrolysis capacity required [GW_{H2}]	55.12	-	1.7	83.2	-	3.0
Electricity generation capacity [GW_{el}]	97.28	-	1.7	208.3	-	3.3
Natural gas required [MMscf]	-	511,548.3	-	-	936,632.9	-
Land (km^2)	~ 633.6			~ 1,322		

Networks

Hydrogen networks are a fundamental component of the hydrogen economy by connecting production centres to storage points and end users. Hydrogen networks consist of the following two elements:

1. Transmission and distribution infrastructure, including pipeline and non-pipeline routes (road, rail, and marine), terminals and refuelling stations.
2. Storage infrastructure, including above-ground (storage tanks) and below-ground (salt caverns, depleted oil, or gas fields).

The UAE has the assets, favourable conditions, and experience to establish low-cost transmission corridors and storage facilities to support export and sectoral demand. The UAE's existing resources (both natural and engineered), including ports, oil and gas reserves, geography, and geology, offer advantages to rapidly developing an expansive network.

Transmission

Pipelines

Pipelines offer the cheapest means for delivering high volumes of hydrogen. The UAE currently has four oil and ten natural gas pipelines used for regional distribution and export to nearby countries, including Qatar and Oman [48]. These pipelines span hundreds of kilometres and highlight the UAE's experience building pipeline infrastructure.

To move hydrogen at scale with minimal capital expenditure, the UAE could repurpose existing gas pipelines to transport hydrogen. Natural gas pipelines can be modified to transport up to 20% blend of hydrogen with minor changes [49]. More substantial retrofits are needed to transport 100% hydrogen in existing pipelines, with the conversion process only taking a few years [50]. Challenges arise with this approach as hydrogen can cause embrittlement which affects the strength of the pipeline material to cause cracks eventually.

The UAE is planning a dedicated hydrogen pipeline to connect production, domestic users and export terminals. The pipeline will connect Jebel Ali, Raz El Karma, Al Ain, and Fujairah. This will require significant investment, clear legislation and network planning to overcome the complexities of pipeline construction and management of multiple fuel types.

Road Transport

Road tankers allow for a flexible means of transporting hydrogen and come in two forms.

1. Horizontal cylinders carrying compressed gaseous hydrogen from the point of production to the point of storage or use. Cylinders are one of the most common and safe means of transporting hydrogen
2. Refrigerated tankers delivering liquid hydrogen.

Transporting goods by road has its limitations due to its restricted capacity and reliance on carbon-intensive methods which will add to the lifecycle emissions of hydrogen. To overcome the current infrastructure gap, the UAE will explore the use of hydrogen tankers as a last mile transport option or as a transition step to more sustainable modes as the market develops. Etihad Rail is also exploring the feasibility of hydrogen transport by rail through specialised rolling stock prior to an established hydrogen pipeline network.

Shipping Transport

Shipping is expected to play a significant role in transporting hydrogen and its derivatives from the UAE. The UAE has 12 commercial trading ports, including oil ports which include 310 berths and a cargo tonnage capacity of 80 million tonnes. According to the World Shipping Council, the UAE has two of the top 50 container ports in the world [51].

The main ports include Zayed and Khalifa Ports in Abu Dhabi, Mina Rashid, and Jebel Ali Ports in Dubai. The Khalifa Port in Abu Dhabi is the first semi-automated port in the MENA region, demonstrating UAE's commitment to continuous port infrastructure development [52]. Modifications such as hydrogen terminals with ample storage capabilities to the existing ports will be required to ship hydrogen and its derivatives. The import requirements and business case will dictate how to transport and store the hydrogen.

For longer distance travel, hydrogen should be converted to a denser form to make its transport more cost effective. It can be converted to ammonia, liquid organic hydrogen carriers (LOHCs) or synthetic hydrocarbon fuels, such as methane and methanol, or it can be liquified. Ammonia has excellent potential as a hydrogen storage and transport medium in the UAE. As ammonia is liquid at room temperature, it is easier to store without the need for compression or refrigeration. It is also more energy dense, allowing it to have a more favourable energy-to-volume ratio compared to hydrogen gas. Cost and safety remain significant barriers to the shipping of hydrogen, with further research and innovation needed to mature these technologies. Challenges in efficiency, scalability, and cost of cracking still need to be addressed.

The UAE is making significant progress toward accelerating the maturity of this supply chain. The UAE has MoUs in place with Japan and Germany to support their decarbonisation efforts through the shipment of low carbon hydrogen and its derivatives. The outcomes of these engagements are reflected in successful trial shipments of hydrogen in the form of ammonia to Germany. In January 2023, Masdar signed an MoU with four Dutch companies, Port of Amsterdam, SkyNRG, Evos Amsterdam and Zenith Energy, to develop liquid organic hydrogen carriers and liquid hydrogen shipments between two main ports. Additionally, ADNOC signed an MoU with thyssenkrupp Group to focus on the development of a commercial-scale ammonia cracking after transportation. [53]

Storage

The method of storing hydrogen will vary depending on demand requirements, including seasonality in both export and local demand and short-term firming of intermittent Renewable Energy.

Hydrogen Storage Above Ground

The need for medium-scale surface hydrogen storage will grow with increased demand. Hydrogen storage may vary between facilities or regions, but a steady hydrogen supply from a bulk storage unit allows for more consistent piping and extraction. Hydrogen above ground can be stored in compressed or liquified hydrogen containers as hydrogen carriers or metal hydrides.

The UAE already has above ground hydrogen storage. In the near term, above-ground storage is expected to remain the UAE's primary storage option as below-ground storage options are developed.

Hydrogen Storage Below Ground - Salt Caverns

Underground storage provides a high-volume capacity alternative to tank storage. The primary forms of underground storage include salt caverns and depleted oil fields and aquifers. The UAE is utilising carbon captured in enhanced oil recovery (EOR) to increase output from existing oil and gas fields.

The UAE is home to several evaporate deposits, including the Hormuz salt of Eocambrian age, Miocene salt and the Jebel Dhanna, a breached salt dome in the Western Region of Abu Dhabi near the Ruwais Industrial hub and hydrocarbon port. At present, hydrogen storage in salt caverns is not yet technologically mature and requires significant global research and development efforts before it can become a feasible option for the long-term storage of hydrogen in the UAE.

The map shows the UAE's natural underground storage sites that can be potentially used for hydrogen. [54]

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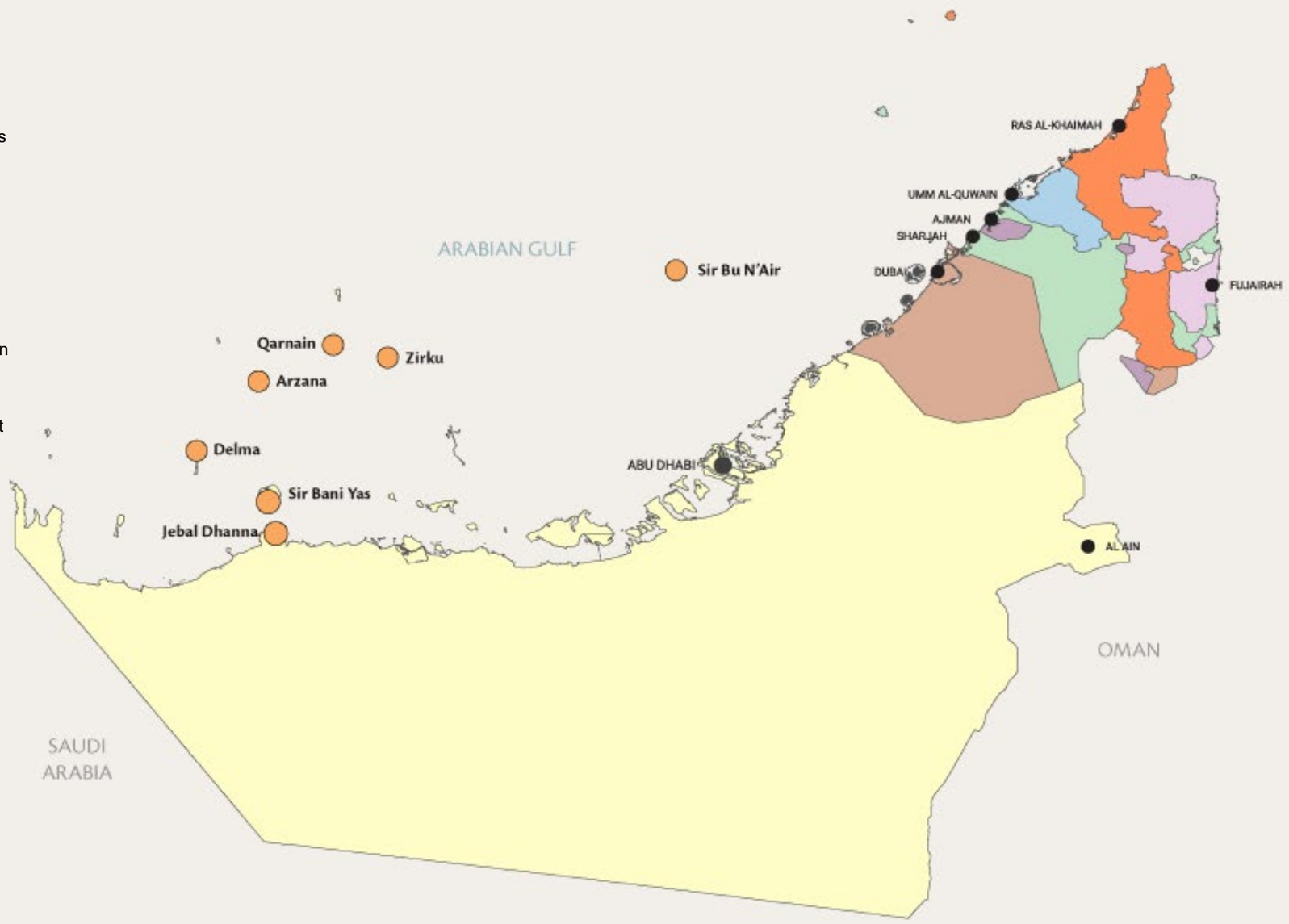


Low carbon hydrogen oases and clean energy precincts

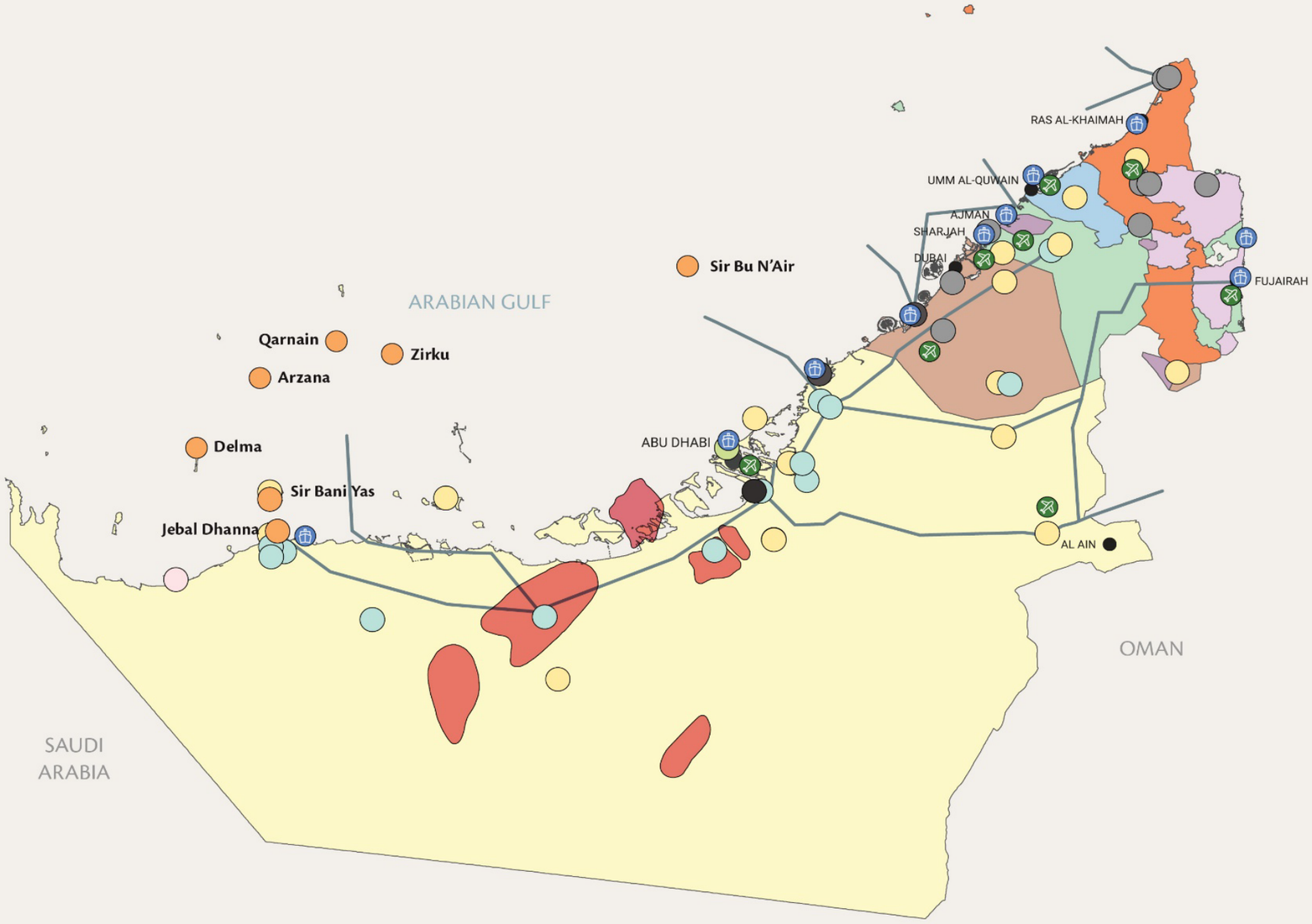
These hubs and clusters will play an important part in establishing a hydrogen value chain in the UAE.

The UAE will establish hydrogen oases as a practical approach to accelerating industry adoption of hydrogen, cultivating a supply chain, and enabling infrastructure. The oases will support demand generation and optimisation of development costs through co-locating production and end-use applications in clusters, removing network barriers, and providing commercial opportunities to test and validate technologies. Clusters are being adopted globally as best-practice for scaling the supply chain while minimising infrastructure costs.

The hydrogen oases will consider existing and new pipelines for distribution, depleted oil wells for carbon storage, and potential connections to salt caverns for high-volume storage. The RES capacity coming online over the next few decades, as detailed in the UAE Energy Strategy 2050, poses another challenge for existing grid networks. Grid requirements for low carbon hydrogen will need to be considered for long-term hydrogen production in parallel with decarbonising the grids.

Concentrations of the industry provide the most opportunity for UAE to establish and scale hydrogen oases within a short timeframe. Ruwais and KIZAD are existing industrial clusters with storage capacity that could be suitable areas for hydrogen oases. Abu Dhabi Department of Energy is pursuing clean energy clusters and hydrogen oases isolated from the broader UAE electricity system, creating micro-systems that avoid grid management problems. This accelerates and simplifies planning, given that co-location of hydrogen use, and renewable electric generation may not always be practical or technically possible.

The UAE will focus collaborative efforts towards establishing the oases by ensuring a clear policy timeline, financing and allocation of resources, and transparency of information to investors and developers.



Cement

Lafarge Emirates Cement
Sharjah Cement Factory
Union Cement Company
Ras Al Khaimah Co. for White Cement
Fujairah Cement Industries
National Cement Company
Gulf Cement
Star Cement
Pioneer Cement
Ras Al Khaimah Cement Company
Emirates Cement Factory

Tentative CCUS sink

Bab
Bu Hasa
Asab
Rumitha
Shanayel
Al Dabbiya
Aluminum
DUBAL
EMAL

Potential Cavern

Delma
Sir Bani Yas
Arzana
Qarnain
Zirku
Sir Bu N'Air
Jebal Dhanna

Nuclear Plants

Barakah

Iron, Steel and Aluminium

Emirates Steel
Emirates Global Aluminium Al Taweelah
Emirates Global Aluminium Jebel Ali

Fertilisers

Ruwais Fertilizer Plant

Clean Energy Projects

Hatta Hydroelectric plant
Sir Bani Yas wind farm
Al Dhafra Solar Project
Shams 1 CSP Plant
Noor Abu Dhabi Solar Project
Masdar City Station
MBR Solar Park
Umm Al Quwain Solar Project
Landfill Solar Project
Ras Al Khaimah Solar PV
Al Nurai Floating PV, Abu Dhabi
Murawah Island Solar Project
Warsan WastetoEnergy Project
Sharjah WastetoEnergy Project
AlDhafra landfill
Al Ain Bioenergy
Dubai Waste Management Center

Hydrogen and Ammonia

TazizRuwais chemical hub
Masdar Demonstration plant
UAE Hydrogen Hub
Mohammed bin Rashid Al Maktoum Solar Park
Abu Dhabi, Khalifa Industrial Zone
TAQA & Abu Dhabi Ports
TAQA & Emirates Steel
Sharjah WastetoH2 Plant
ADNOC & TAQA
Ruwais Ammonia (FERTILI and II)
Ruwais Hydrogen Plant
CO2 pilot injection Rumaitha field
Al Reyadah CCUS plant (Emirates Steel) Phase I

Emirates

- Abu Dhabi
- Dubai
- Sharjah
- Ajman
- Umm Al Quwain
- Ras Al Khaimah
- Fujairah

Action Plan

The UAE's strategic framework outlines an action plan to becoming a top global producer of low carbon hydrogen.

The ten elements underpinning this framework are the enablers that the UAE stakeholders, including government, industry, and academia, will collaborate around to build the hydrogen value chain. In the market creation phase, the UAE will focus on four priority elements critical to demand generation and to scale production capacity to achieve its ambitious targets.

Across all the ten elements listed, there will be relevant policy actions that need to be addressed. The UAE government will work with stakeholders to establish a clear governance framework and identify the necessary measures to remove barriers and provide feasible investment opportunities to accelerate the UAE's hydrogen economy.

Market Creation Phase

The elements are focused on establishing the domestic market to scale production capacity and generate higher ICV through export of green products. Export of hydrogen and derivatives is important, but the UAE see the domestic market as the foundation to a strong hydrogen economy.

	Focus Areas
Policy, Regulation, and Standards	– Develop a clear regulatory framework for hydrogen – Provide robust policy incentives to accelerate investment and confidence – Create hydrogen-associated codes and standards – Establish a Hydrogen Certification Scheme (guarantee of origin)
Finance and Investments	– Provide project funding and financing to support developers in all areas of the low carbon hydrogen supply chain
Industry Development and Demand Activation	– Activities to scale up the adoption of hydrogen – Implementation of pilot scale and commercial scale projects to accelerate industry transition to a low carbon hydrogen – Resources and equipment adapted or changed to support industry transition
Global Collaboration	– Enhance institutional engagement (including government, academic, trade and industrial entities) – Establish demand and supply partnerships for hydrogen and its derivatives – Develop large-scale projects that can progress the development of the supply chain

The Ministry of Energy and Infrastructure is currently developing key policy levers to accelerate the UAE hydrogen economy.

The final elements outline how the UAE will consolidate efforts to achieve its hydrogen economy ambition by 2031 and build a sustainable hydrogen economy beyond. Although the following elements are critical in the short term horizon until 2031, they also represent longer-term investment horizons and will ultimately shape the UAE's future in meeting and exceeding 2050 and 2071 ambitions.

	Focus Areas
Sustainable Commercial and Economic Models	– Develop commercial models across the supply chain to provide stability and predictability for market players – Establish a hydrogen entity that conducts consultations, helps identify and implement commercial models at the national scale.
Resources and Assets	– Scale up low carbon hydrogen production, including the linking of production to renewable energy growth plans – Consideration for hydrogen in the competition for resources, land, water, and geological assets within the energy transition
Enabling Infrastructure	– Identify potential pathways for developing the UAE's infrastructure, including transport, storage, high voltage transmission and oases – Develop required hydrogen transport systems – Determine the potential of UAE's geological storage – Developing the critical export infrastructure for hydrogen
Skills and Education	– Develop a national hydrogen workforce development plan, competency framework and training needs – Re-skill expertise in existing industries to support the hydrogen value-chain – Cultivate workforce to match demand due to industry uncertainties – Response plan to support evolving technological changes and the corresponding need for rapid competency updates
Research and Innovation	– Advance and expand hydrogen research and innovation efforts – Increase industry-led activity and involvement – Dedicate funding toward research and innovation – Create the relevant institution to transition innovation from the lab to commercialisation
Climate, Safety, and Social Drivers	– Define hydrogen's role in the UAE's Net Zero by 2050 Pathway – Align Health and safety authorities across the emirates on key actions to deliver on the targets for H2 safety codes and standards – Deliver public awareness on low carbon hydrogen – Educate consumers and end-users on low carbon hydrogen

Policy, Regulation, and Standards

Establishing policies, regulations and standards that foster investor confidence and activate the UAE's hydrogen market is a priority enabler. The UAE recognises the importance of having a clear regulatory framework covering all supply chain components, from production to end-use.

Some significant policy directions supporting the UAE's low carbon hydrogen development include the updates to the UAE's Energy Strategy 2050 and the UAE's Net Zero Strategy and the launching of the Sustainable Aviation Fuel 2050 Roadmap, which are currently under development.

The UAE is currently working on the following relevant initiatives:

– Abu Dhabi Department of Energy (DoE) issued a draft low carbon hydrogen policy for stakeholder comments in October 2022, with anticipation for release in the coming year. The DoE's hydrogen policy aims to provide a framework to encourage investments for producing hydrogen competitively, stimulate demand and provide market stability. Hydrogen is designated as a strategic sector, and Hydrogen Oases and Clean Electricity Clusters will be created to facilitate cost optimisation and economies of scale from shared infrastructure.

– A low carbon Hydrogen Support Committee led by the Abu Dhabi Department of Economic Development (DED) will facilitate permitting, regulatory, economic, and financial support for hydrogen projects on a case-by-case basis.

– In 2019, Emirates Authority for Standardization and Meteorology (ESMA) completed its draft technical regulations on hydrogen-fuelled vehicles, making the UAE the first country in the Middle East and Africa region to establish a hydrogen-related regulation. [55]

– As the UAE's low carbon economy continues to emerge, the UAE will continue to establish policies and regulatory frameworks, including quality and safety standards, codes, and certificates of origin, which are essential for developing the hydrogen economy. The policies will be developed and implemented by working closely with all stakeholders, including Federal Ministries and agencies, Emirates governments and Municipalities, and the industry.

– Environment Agency Department Abu Dhabi (EAD) is exploring a cap-and-trade system to accelerate emissions reduction across industry in the line with the UAE Net Zero 2050 strategy [56]

Proposed way forward

Focus area	2023 – 2025	2026 – 2028	2029 – 2031
A clear regulatory framework for hydrogen	- UAE's policy and regulatory framework developed, with incentives to support the development of enabling elements of the hydrogen value chain - DED has established low carbon hydrogen support committee to accelerate hydrogen projects	- Engagement with Emirates to support an accelerated planning and permitting system in place that is simplified for hydrogen-related projects, including alignment to existing UAE environmental best practice	- The long-term policy and regulatory framework in place to support transparent future hydrogen economy expansion in response to market growth
Robust incentives to accelerate investment and confidence	- Market mechanisms in place for hydrogen production (See Commercial and Economic models section) - Establish enablers to incentivise low carbon hydrogen adoption in steel, aluminium, cement, and heavy goods vehicles - Leverage developing carbon pricing mechanisms to support industry transition	- Policies aligned with cross-border trade agreements for low carbon hydrogen-related products - Establish enablers to incentivise low carbon hydrogen adoption with sustainable aviation fuels and ancillary grid services - Market price set for hydrogen oases consumers	- Regulation in place incentivising low carbon hydrogen adoption in steel, aluminium, cement, and electricity production - Regulation in place to support hydrogen end-use applications for transport sectors such as rail and heavy goods vehicles
Creating hydrogen-associated codes and standards	- Define technical standards in production, transportation, storage, and end-use applications - Define technical standards for hydrogen derivates - Set clear carbon intensity definitions, thresholds, and boundaries for low carbon hydrogen	- A low carbon hydrogen standard in place and aligned with international standards - Licensing framework for low carbon hydrogen production, conversion into derivatives, transport, storage, trading, and supply in place	- Develop internationally recognised safety standards for hydrogen derivatives - Establish internationally acceptable hydrogen safety codes and standards - Updates to standards based on new findings as the supply chain infrastructure continue to develop
Hydrogen Certification (Guarantees of origin scheme)	- Engagement with key export markets and international entities to establish the required Guarantees-of-Origin certification scheme that is satisfies cross-jurisdictional requirements	- An internationally recognised Guarantee-of-Origin certification scheme and tracking system implemented	- Review the certification scheme and re-assess

Finance and Investments

Establishing appropriate financial mechanisms will ensure the UAE is internationally competitive.

Providing the required finance and investments to accelerate and sustain the development of a hydrogen supply chain is a priority to ensure the UAE is amongst the top global low carbon hydrogen producers. The UAE's position as a trade and international finance hub will be leveraged to ensure finance and investments are directed to developing significant projects and initiatives.

The UAE continues to play a significant role in sustainable financing and investment growth through the Sustainable Finance Working Group (SFWG), in alignment with the UAE's commitment to the Paris Agreement. The SFWG works towards improving sustainable finance by enhancing disclosure, governance practices, and communication of a clear taxonomy.

At the emirate level, the Dubai Sustainable Finance Working Group, and the Abu Dhabi Global Market (ADGM) have created agendas to establish and implement sustainable frameworks. Similarly, the Government of Dubai launched the Dubai Green Fund (DGF) to fund investments in green and sustainable projects aligned with Dubai's Clean Energy Strategy.

The Ministry of Industry and Advanced Technology (MoIAT) is implementing a strategy called Operation 300bn, aiming to raise the industrial sector's contribution to GDP from AED 133 billion to AED 300 billion by 2031 [57]. The strategy focuses on 11 industrial sectors, including hydrogen. Additionally, the Emirates Development Bank's [58] allocation of AED 30 billion to support priority industrial sectors over five years will be pivotal in accelerating industrial development, financing 13,500 SMEs and creating 25,000 jobs in five primary sectors.

In addition, the UAE has launched the UAE Carbon Alliance with the aim of advancing decarbonization efforts and developing a carbon market ecosystem. The alliance's founding members include leading organizations such as FAB, TAQA, ACX, and Masdar, along with the UAE Independent Climate Change Accelerators (UICCA). The alliance will establish national cooperation in decarbonization, create frameworks for carbon financing, and enhance knowledge of carbon markets. It will support the transition to a green economy and help achieve net zero goals through carbon credits. The alliance plans to establish a resilient and transparent carbon market, attracting investment towards decarbonization projects and providing a market-based mechanism for corporations to accelerate their transition. The UAE Carbon Alliance will foster inclusive dialogue among stakeholders, align private and public sectors, and drive government strategies. Organizations committed to decarbonization are encouraged to join and collaborate with the alliance.

The UAE will collaborate with financial institutions and regulatory bodies to establish an environment conducive to regional foreign investment activity. Bridging the cost gap will be fundamental to UAE hydrogen's competitiveness with other fuel sources and countries. Leveraging low-cost resources, the UAE will target a competitive levelised cost of hydrogen for both sectoral demand and export.

Proposed way forward

Focus area	2023 – 2025	2026 – 2028	2029 – 2031
Provide project funding and financing to support developers in all areas of the low carbon hydrogen supply chain	- Benchmark production cost compared to the most cost-effective reference - Strategic partnerships established with key financial entities - Reduction of LCOH through cost support (to be determined, but potential options include electricity, technology, land, and off-take support) - A committee established as a centre for all low carbon hydrogen financing and investment activity	- Low-interest sustainable financing allocated - A National Low Carbon Hydrogen Fund and Mechanism established - Revenue support guarantee	- Low carbon hydrogen fund programme - Establish ongoing low-interest sustainable financing options for low carbon hydrogen projects - Private sector investment mobilised in manufacturing of major supply chain elements - Increase funds allocation for new financing opportunities for increasing renewable energy projects dedicated to hydrogen production
Dedicate funding toward research and innovation	- Establish a Hydrogen Innovation Fund (also a policy priority)	- Capital grant funding programme-in place	

Industry Development and Demand Activation

A strong hydrogen economy will be demand-driven. The UAE has established a strong local presence in steel, aluminium, chemicals and refining industries through its oil and gas leadership.

To scale production capacity, the UAE will explore the application of low carbon hydrogen across existing industries and support adoption to stimulate regional demand. It is becoming clear that the opportunity from import countries for green steel and aluminium is high. The UAE will act efficiently to secure long-term supply agreements that can strengthen the growth of its low carbon hydrogen economy.

The industrial sector will rely on hydrogen to decarbonise their supply chains in alignment with the 2050 Net Zero Strategic initiative. Key hard-to-abate sectors include refining, chemicals, aluminium and steel, and transport. These sectors are forecasted to potentially consume 2.1 mtpa of hydrogen annually to meet 2031 net-zero targets. The application of hydrogen within these industries requires significant transition efforts and ongoing collaboration between industry, regulators, and investors to ensure a feasible transition is achieved.

MoIAT has announced more than 30 industrial projects valued at 6 billion dirhams ($1.63 billion). Additionally, the UAE's industrial sector has secured over $2.7 billion in offtake agreements, further strengthening the localization of products and pushing the total value of targeted products to an impressive $32 billion. Efforts to bolster the industrial sector extend beyond the project announcements. The UAE's national oil company, ADNOC, will allocate more than 20 billion dirhams to procure structures and metal products from domestic companies. Moreover, the sector will benefit from competitive financing initiatives, including substantial contributions of 5 billion dirhams from First Abu Dhabi Bank and 1 billion dirhams from Mashreq Bank.

The maturity for the industry to adopt hydrogen technology will occur in different stages. Industries ready to adopt hydrogen include UAE’s refineries, steel and aluminium, and chemicals, including fertiliser production.

Proposed way forward

Focus area	2023 – 2025	2026 – 2028	2029 – 2031
Activities to scale up the adoption of hydrogen	- Establish channels of communication between regional off-takers and producers to foster relationships and opportunities for sectoral supply	- Platform established to foster stakeholder communication within the planned hydrogen oases ensuring market demand meets production aspiration - Government engagement, including formal consultation on initiatives, challenges, and opportunities	- Initial pilot projects transitioned to a commercial scale
Implementation of pilot scale and commercial scale projects to accelerate industry transition to a low carbon hydrogen	- Low carbon hydrogen partially adopted in the aluminium and steel industry through a series of pilot projects - Low carbon hydrogen partially adopted in refining through a series of pilot projects	- Pilot oil refining projects transition to commercial scale - Global carbon trading market involvement supporting industry transition to low carbon trajectories	- Low carbon hydrogen partially adopted in mobility, aviation, and shipping through a series of pilot projects - Pilot aluminium and steel projects transition to commercial scale
Resources and equipment adapted or changed to support industry transition	- Identification of key critical equipment needs for hydrogen adoption in target sectors	- Continued technology development and testing across the value chain to enable a broader range of applications and less developed technology	- OEMs established in the UAE developing resilience in the local hydrogen supply chain - UAE as a hydrogen technology export hub

Global Collaboration

Collaboration is crucial to scale low carbon hydrogen production. Strong government-to-government and commercial relationships are necessary to overcome the obstacles and hesitation that may delay investments.

The UAE will consider global trends and lessons learned to drive market growth and establish strong trade routes to inform its low carbon hydrogen development decisions. Relevant collaborations will support scaling export of hydrogen and its derivatives, including ammonia, kerosene, and methanol and becoming a top global producer of low carbon hydrogen.

The UAE has signed several bilateral agreements, including Memorandums of Cooperation (MoC) and MoU's between countries, including Japan, South Korea, United States and Germany. These agreements establish foundations for potential trade synergies, investment opportunities, technical and economic feasibility studies, and joint R&D initiatives across clean energy.

The UAE is well-known for its global commitment to collaboration and investment in clean energy. Masdar, one of the world's largest and fastest-growing renewable energy companies, with its global presence in over 40 countries, leverages its extensive expertise in clean energy to lead the development of renewable energy projects across Africa and the world.

Masdar's commitment to investing in green hydrogen is crucial in the global transition to clean energy. The company's interest in green hydrogen for sustainable aviation fuels has resulted in a billion-dollar strategic alliance to drive the UAE hydrogen economy by developing green hydrogen electrolyser capacities in the UK, Egypt, and other countries. Masdar is part of a partnership with the Abu Dhabi National Energy Company (TAQA) and Mubadala Investment Company that aims to consolidate renewable energy and green hydrogen efforts. The partnership will have a combined committed capacity of over 23 gigawatts of renewable energy to reach over 100GW by 2030.

The UAE Ministry of Foreign Affairs and International Cooperation (MoFAIC) launched Etihad 7. The programme is aimed at public and private sector funding dedicated to financing renewable energy projects in Africa to provide clean electricity for 100 million people by 2035.

The UAE's efforts to invest in clean energy and hydrogen globally are crucial to the growth of the hydrogen market. By leading the development of renewable energy projects and green hydrogen capacity, the UAE is helping to unlock the potential of hydrogen and bring it to the forefront of its energy mix. The UAE is also providing much-needed funding and support for clean energy projects, creating a favourable environment for the growth of the hydrogen economy. Additionally, its partnerships with leading energy companies and institutions drive innovation and promote collaboration, which is critical for developing the hydrogen market.

The UAE's efforts to invest in clean energy and hydrogen are essential for developing the hydrogen market and transitioning to a cleaner, more sustainable energy future. The UAE's commitment to developing its low carbon hydrogen economy through global collaboration signals a strong message on its transition to clean energy.

Proposed way forward

Focus area	2023 – 2025	2026 – 2028	2029 – 2031
Enhance institutional engagement (including government, academic, trade and industrial entities)	- COP28 leveraged to support international alignment to overcome current barriers including clean supply chains and certification - Membership in key hydrogen intergovernmental partnerships to facilitate information sharing on policies, codes, standards, and safety	- Leverage global trade MoUs by extending agreements to attract international OEMs - Provide opportunities to global institutions for in-country research and development	- UAE to establish a world-leading innovation hub attracting international researchers
Establish demand and supply partnerships for hydrogen and its derivatives	- Agreements for export of green products (steel, aluminium) established	- Agreements totalling at least 0.1 mtpa low carbon hydrogen trade	- Agreements totalling at least 0.6 mtpa low carbon hydrogen trade
Develop large-scale projects that can progress the development of the supply chain	- International technology codes and standards assessed - Opportunities assessed for international investment across the supply chain - One low carbon hydrogen project developed beyond financial close - Low carbon ammonia exported to international partners	- International technology codes and standards implemented - Develop three international low carbon hydrogen projects - Framework to facilitate cross border-trade established	- Framework in place enabling cross-border pipeline/ shipping trade - Framework for international hydrogen trade and competitive open market in place - Significant global portfolio of hydrogen projects either wholly UAE entity owned or in partnership with international partners

Sustainable Commercial and Economic Models

Sustainable commercial and economic models are needed to stimulate and sustain the growth of the hydrogen market in the UAE. They enhance confidence for investment into low-maturity technology and supply chains.

These models draw the flow of capital to previously non-profitable investments to encourage project development across the supply chain. Without sustainable models, market failure poses a significant risk to rapidly scaling the supply chain, incentivising actors to hold on to emission-intensive products and technologies.

The UAE will explore standard models to design a UAE-based hydrogen economic model that supports the hydrogen supply chain's ongoing development. Some of the different models that will be considered are listed below:

– Contracts for Difference (CfD): CfDs could help bridge the cost gap between low carbon hydrogen and alternative fuels of greater carbon intensity. For example, natural gas could help encourage hydrogen production and end-use growth in the UAE as it secures a specific price for each unit sold or purchased, encouraging end users to purchase hydrogen for a guaranteed price. Similar models are employed across renewable energy globally.
– Regulated Asset Base (RAB): RABs incentivise private investment into public projects, helping guarantee developers' payback. Hydrogen is treated as a national utility, such as the gas, electricity, and water networks, helping to create the lowest capital cost basis for projects to reach construction.
– Hydrogen Purchase Agreements (HPA): HPAs are a market-driven model that could link supply and demand. HPA's would work similarly to PPA's, where an HPA between a green hydrogen producer and the end user on a specific sale price for an amount of hydrogen used over an agreed timeframe.
– Other auction-based mechanisms to promote a timely and effective power to synthetic fuels (PtX) market ramp-up on an industrial scale like the H2Global mechanism.

Another key aspect that will be considered is the respective roles of public and private financing through instruments such as Public Private Partnerships (PPP). These models are required to be established to ensure effective and consistent procurement within the nascent industry. This will also drive appropriate risk allocation within the hydrogen projects in development. An effective combination of different models will ensure the long-term sustainability of the hydrogen market through scaling and maturity.

Proposed way forward

Focus area	2023 – 2025	2026 – 2028	2029 – 2031
Develop commercial models across the supply chain to provide stability and predictability for market players	- Commercial Model assessment completed, and procurement policy defined	- Appropriate commercial mechanism (model) identified and implemented to enable Hydrogen Production at a commercial scale for sectoral use and exports - Appropriate commercial model for Hydrogen storage and network infrastructure defined and in place	- Competitive open market in place, including a path to subsidy-free production and use
Establish a hydrogen entity that conducts consultations, helps identify and implement commercial models at the national scale.	- Design a best-fit governance model that supports the UAE's development of a hydrogen economy	- Governance structure established and accelerated actions identified in the strategy - Governance bodies establish smaller working groups to investigate key supply chain components	- Governance structure manages ongoing hydrogen economy development

Resources and Assets

The UAE will leverage its strong natural resources and assets to accelerate its hydrogen economy and produce globally competitive hydrogen at low levelised costs. The energy harnessed from the UAE's abundant sunshine and gas reserves will support reaching net zero by 2050 and help transition the UAE's energy economy.

Despite existing strengths in renewable sources, the UAE will need to overcome several challenges in advancing the low carbon hydrogen supply chain. One global challenge is the high demand for electrolysers essential for green hydrogen production. Integration of large capacity RES into the existing grid is another global challenge due to its uncertainty Current planned renewable capacity focuses on grid decarbonisation as a priority, and with the grid nearing capacity, an additional allocation of RES for hydrogen will need to be managed.

With electricity feedstock as a significant driver of costs in hydrogen production today, appropriate allowances will be required to account for the scale of energy capacity needed. Besides dedicated (off-grid) renewables for hydrogen production, hydrogen will need to be a key consideration for major solar energy projects connected to the grid.

With plans for increasing nuclear energy levels, the long-term potential for more efficient clean hydrogen production from high-temperature electrolysis also needs to be realised.

As natural gas is expected to be a key part of the future energy system, with 50% of the energy expected from natural gas by 2050 in the Net-Zero pathway, the CCUS infrastructure will be linked to hydrogen, and non-hydrogen projects will need to be developed continuously over time.

Given that water will be a critical resource for electrolytic hydrogen production, with 9kg needed to produce 1kg of hydrogen, the allocation of water to hydrogen projects requires attention when planning for the geographic location of projects. The UAE has limited water resources due to its arid climate and high population growth. Though desalination is an energy-intensive process, it is estimated to add no more than USD 0.02 to the cost of electrolytic hydrogen production per kg [59].

The UAE is taking a cluster-based approach to establishing a hydrogen supply chain and mitigating the scaling and bottleneck risks. Clean energy clusters will be developed for the co-location of energy users, with the potential for dedicated sub-grids to manage new RES coming online with limited connection to the grid for electricity generation at the lowest cost possible.

ADNOC, John Cockerill Hydrogen, and Strata Manufacturing have formed a strategic collaboration to produce electrolysers in the UAE for domestic and international markets. Supported by MoIAT, this agreement aims to boost the UAE's green hydrogen economy, promote local industry, and attract investment through in-country manufacturing. [60]

These are the key steps the UAE is taking to establish a supply chain to manage resources efficiently and in the least cost approach.

Proposed way forward

Focus area	2023 – 2025	2026 – 2028	2029 – 2031
Scale up low carbon hydrogen production, including the linking of production to renewable energy growth plans	- CCUS master plan outlining forecast storage capacity for blue hydrogen and carbon capture requirements for synthetic fuels	- 7 low carbon hydrogen production plants operating - Roadmap outlining approach to onshoring locally needed critical materials and equipment	- 5.1 mtpa of carbon storage capacity developed for blue hydrogen - UAE a top global producer of low carbon hydrogen - Critical hydrogen supply chain manufacturers located in the UAE
Consideration for hydrogen in the competition for resources, land, water, and geological assets within the energy transition	- Renewable energy identified for hydrogen production - Water master plan for electrolytic hydrogen to account for additional water requirements - Potential sites identified for the development of hydrogen oases	- 40 km^2 of land made available for low carbon hydrogen production and required RES - 4 GW of RES capacity developed for hydrogen - Discussion paper on potential approaches to increase electrolyser capacity (include energy storage and GCC transmission corridors)	- Up to 94 km^2 of land made available for RES - 15.4 GW of RES capacity developed for hydrogen - One hydrogen oasis in development

Enabling Infrastructure

Large-scale deployment of hydrogen will require a well-designed and cost-efficient system for hydrogen storage, distribution, and transmission (transport), connecting the supply sources to the demand centers to establish a liquid market.

The UAE will invest in and establish the necessary infrastructure to support hydrogen production, storage, distribution, and application for regional and international markets. ADNOC and Masdar spearhead this effort with ambitious targets and clear investment agendas within the UAE and globally. Leveraging existing resources and capabilities, the UAE is well-positioned to scale quickly and efficiently to meet global and sectoral hydrogen demand.

A challenge for the UAE is determining the optimal geographical distribution of production and consumption sites to ensure the required supply chain infrastructure evolves efficiently. Greater cooperation is needed amongst hydrogen stakeholders to design this system based on factors such as sectoral demand evolution, size, and type of technologies for production, the location of infrastructure relative to resources such as renewables and carbon dioxide storage sites for producing low carbon hydrogen, and evolution of the existing natural gas and electricity networks, amongst other considerations.

While in the next decade, the infrastructure is expected to develop in a distributed manner, with key demand and supply centres, the architecture of this network at the national level will depend on the progress made in adopting hydrogen in the UAE energy system. With increased renewables and production volumes of hydrogen (for sectoral use and exports), the connection of electrolysers to the electricity grid will be increasingly important. Any planning work relating to the grid connection of electrolysers will need to be linked to plans for decarbonising the grid such that the hydrogen produced meets the carbon intensity standards of importing nations.

One strategic advantage for the UAE is the existing carbon capture, utilisation, and storage (CCUS) infrastructure. While the existing CCUS application is mainly for enhanced oil recovery and is an area of continued advancement, the CCUS capability potentially positions the UAE as a leading supplier of blue hydrogen.

The UAE also has salt structures that could potentially be used for long-term underground hydrogen storage. The salt structures are concentrated offshore, with six potential locations lying a few kilometres off the shorelines into the Arabian Gulf.

The theoretical capacity could be anywhere between 1 mtpa to 3.8 mtpa (36.4 to 127.7 TWh). The capacity of the most significant salt formation, “Delma,” represents as much as one-quarter to one-third of the capacity. The viability of using these and their actual capacities depend on the formation and the cavern type. Investigations regarding actual capacity need to start soon to utilise such enormous potential in the medium-term future.

Proposed way forward

Focus area	2023 – 2025	2026 – 2028	2029 – 2031
Identify potential pathways for developing the UAE's infrastructure, including transport, storage, high voltage transmission and oases	- The infrastructure plan for the UAE including: • Prospective hydrogen oases • Micro-grid and sub-system plan in place to support dedicated RES transmission to hydrogen oases • Grid capacity requirements • Hydrogen pipeline backbone including Right of Way • Road transport • CCUS • Storage requirements • Export infrastructure, including ports • Feasibility of sub-systems assessed supporting energy transmission to proposed hydrogen hubs	- Energy infrastructure in place for hydrogen oases, including established network trading (micro-grid networks)	- Enabling infrastructure is established and growing in line with the market requirements
Develop required hydrogen transport systems		- A network that connects production sites to ports - Infrastructure repurposed where applicable	- New hydrogen pipelines in place - CCUS infrastructure in operation for hydrogen
Determine the potential of UAE’s geological storage		- Construction of underground storage facilities underway	- Trial of underground hydrogen storage
Developing the critical export infrastructure for hydrogen		- Existing port facilities upgraded to meet hydrogen export demand and comply with international safety standards	- Hydrogen export infrastructure growth in the export market

Skills and Education

The UAE is dedicated to becoming a leading player in the global hydrogen market. The government is implementing initiatives to upskill its workforce, attract international hydrogen experts, and improve education and skills in the hydrogen sector.

To upskill its existing oil and gas workforce, the government offers training programmes that teach the latest technologies and processes in the hydrogen economy, such as hydrogen production, storage, transportation, and safety. Khalifa University also offers independent hydrogen programmes to build a professional network of skilled individuals.

With its stable economy and safe environment, the UAE attracts hydrogen experts worldwide. The government provides a favourable environment for these experts by offering incentives for investment and supporting research and development.

The UAE recognises the importance of having a well-educated and skilled workforce for a thriving hydrogen economy. The government is investing in research and development, offering hydrogen-focused training programmes, and supporting the creation of hydrogen-related curriculums in universities and colleges.

Clear and regular communication between academic institutions and industry ensures the workforce is upskilled appropriately. This collaboration allows academic institutions to understand the industry's needs and the industry to access a well-educated and skilled workforce.

The UAE is also committed to creating sustainable job opportunities for its citizens in the industrial sector. Through the Industrialist Program, developed in partnership with Nafis and the Ministry of Human Resources and Emiratization, the country aims to generate 5,000 such opportunities.

The Ministry of Climate Change and Environment is working with the Ministry of Education to integrate renewable energy and sustainable development into the national education system. Similarly, the Ministry of Energy and Infrastructure aims to collaborate with the Ministry of Education on hydrogen learning in school curriculums to educate youths on the basics of hydrogen to encourage an increase in university enrolment and workforce growth in hydrogen-related fields. The Ministry of Education is also developing a hydrogen tool kit for schools and universities to expand knowledge of the sector amongst both teachers and students.

Proposed way forward

Focus area	2023 – 2025	2026 – 2028	2029 – 2031
Develop a national hydrogen workforce development plan, competency framework and training needs	- Collaboration with industry and educational institutions established to identify and assess skills needs	- Hydrogen skills roadmap strategy developed - Facilitate private sector investment in hydrogen skills education and training	- Hydrogen skills roadmap implemented - Expand collaboration with industry and educational institutions to continue to identify and address emerging hydrogen skills education and competency needs
Re-skill expertise in existing industries to support the hydrogen value-chain	- Oil and gas sector collaboration established to upskill oil and gas workforce to support the hydrogen value chain	- Adopt incremental upskilling to complement existing education and training - Develop industry-informed hydrogen certifications or accreditations to address specialised training needs	- Revise courses to reflect technology changes and implementation in the UAE
Cultivate workforce to match demand due to industry uncertainties	- Review of existing curriculum in the UAE for hydrogen to identify gaps in existing education	- Scholarship-based early-career educational and technical training exchange programmes with international partners established	- Promote job creation opportunities through skills development support for in-country value creation for hydrogen-related manufacturing
Response plan to support evolving technological changes and the corresponding need for rapid competency updates	- UAE's National Qualifications Centre should add hydrogen skills to its framework of national qualifications	- Establish a framework for a specialised hydrogen technical education and vocational skills institution	- Upgrade piloting and training facilities and expand the training network locally in the UAE

Research and Innovation

The success of the hydrogen economy and the value captured by the UAE hinges on its ability to innovate at the national level.

While some hydrogen technologies are ready for scale-up, research and development activities by universities and private and public sector entities will remain critical for driving down costs and increasing competitiveness.

The United Arab Emirates boasts a robust and cutting-edge research and innovation ecosystem, as evidenced by its top ranking in the 2021 Global Innovation Index within the Middle East and North African region and among the top 33 globally [61].

The UAE has invested AED 14 billion annually in innovation, with AED 7 billion explicitly directed toward research and development [62]. This investment is reflected in the UAE's vast network of incubators and accelerators to provide training, financing, and expert support for product development. This strong foundation needs to be leveraged to support R&D efforts in the hydrogen sector. DEWA's Innovation Centre at the Mohammed bin Rashid Al Maktoum Solar Park is a global incubator exploring hydrogen and renewable energy technologies critical to hydrogen in the UAE. [63]

Robust programmes are necessary for the coming decade to ensure relevant technologies achieve commercial scale by 2031. The existing programmes, such as the Research and Innovation Center on CO_2 and H2 (RICH Centre) at Khalifa University, focus on advancing technologies and processes across the hydrogen supply chain, from production, transportation, and storage to end-uses. These programmes will be expanded across the UAE's academic and industrial entities to increase the rate of innovation. The allocation of funding mechanisms to priority challenges, including technical efficiency, technology lifetime, materials development, system optimisation and innovations in all supply chains, will reduce bottlenecks and scalability.

In addition to government funding, a policy framework can mobilise the private sector to invest in next-generation technologies, such as using hydrogen for high-grade heat in industrial processes, shipping, synthetic fuels, and hydrogen in gas turbines for power production.

In the near-term more demonstration projects are needed to ensure that these technologies reach commercialisation early this decade and unlock the full potential of hydrogen demand. Pertinent demonstration projects include using hydrogen in the Direct Reduced Iron (DRI) process for iron- and steelmaking; producing ammonia and methanol using electrolytic hydrogen from renewable energy; using hydrogen in heavy-duty transport; and using ammonia in shipping.

The UAE is actively exploring various technologies across the hydrogen value chain and seeking to advance their development. These technologies include synthetic fuels, direct air capture, turquoise hydrogen, and blockchain, among others. ADNOC and Siemens are exploring pilot blockchain technology for certifying the carbon intensity of a range of products. The UAE's ambition is to increase the maturity of these technologies establish itself as a leader in the development, manufacturing and export of advanced hydrogen technologies.

Proposed way forward

Focus area	2023 – 2025	2026 – 2028	2029 – 2031
Advance and expand hydrogen research and innovation efforts	- Increased contribution, leveraging existing membership of Mission Innovation	- Demonstration projects showcasing technologies in end-use sectors starting at technology readiness levels (TRL) of 5+	- Recognised as a global centre of research excellence for hydrogen technologies - Demonstration projects with technologies reaching TRL 8
Increase industry-led activity and involvement	- Establish partnerships with leading hydrogen technology companies and research institutions	- Industry-led technology development & testing across the value chain	
Create the relevant institution to transition innovation from the lab to commercialisation	- Establish a Hydrogen Innovation Hub focussed on key R&D priorities, with the function to bridge any gaps between academia, industry, and research	- Programmes to support and accelerate next-generation technology development, inclusive of industry, power, transport	

Climate, Safety, and Social Drivers

The UAE's ambitions to tackle climate change are at the heart of developing a hydrogen economy.

The UAE's National Net Zero by 2050 Pathway targets interim carbon reduction of 18% and 60% by 2030 and 2040, respectively, and becoming net zero by 2050. Low carbon hydrogen is critical in achieving these ambitions. The UAE has a significant carbon-intensive industrial and transport presence. Clear articulation of hydrogen's role in reducing these emissions is required to be communicated and embedded in future planning and development.

Although the UAE is home to some global industry leaders, it is also home to multiple communities and small and medium enterprises. Acceptance, adoption, and advocacy of low carbon technologies are critical to the UAE economy and will be a significant factor in the success of the hydrogen economy. Education on hydrogen, its applications and safety across the supply chain will need to be addressed. Campaigns, platforms, and toolkits will be made available to support communities and businesses throughout this transition.

The UAE has developed social impact contracting guidelines focusing on increasing social and economic value outcomes in developing a net-zero society. These guidelines set standards for public-private partnerships, emphasising transparency, stakeholder engagement, and clear targets and performance indicators. The Social Impact Contracting guidelines could be applied in developing hydrogen projects in the following ways.

– Public-private partnerships: The guidelines encourage partnerships between the government and private sector to develop hydrogen projects. This allows for the sharing of resources and expertise to achieve common goals.
– Clear targets and performance indicators: The guidelines require the establishment of clear targets and performance indicators for each project. This would ensure that the impact of the hydrogen projects is measurable, and that progress can be tracked.
– Monitoring and evaluation: The guidelines set standards for monitoring and evaluating projects to ensure that they deliver the intended social impact and identify any improvement areas.
– Transparency and stakeholder engagement: The guidelines emphasise the importance of transparency and stakeholder engagement, which could be applied to developing hydrogen projects by ensuring that all stakeholders are informed and involved in the decision-making process.

Using Social Impact Contracting guidelines in hydrogen project development, the UAE can focus on sustainable, accountable projects and deliver the intended social impact while generating financial returns.

Proposed way forward

Focus area	2023 – 2025	2026 – 2028	2029 – 2031
Define hydrogen's role in the UAE's Net Zero by 2050 Pathway	- Define hydrogen's contribution within the UAE's Net Zero by 2050 Pathway	Specific hydrogen offtake targets by industrial sector to achieve Net Zero	
Align Health and safety authorities across the emirates on key actions to deliver on the targets for H2 safety codes and standards	- Hydrogen and derivatives specific health and safety codes and standards in place across the hydrogen supply chain	- Health and safety codes and standards reviewed to ensure alignment with international best practice	- Continuously update and refine hydrogen safety codes and standards based on lessons learned and technological advancements, while fostering collaboration among authorities to share best practices
Deliver public awareness on low carbon hydrogen	- A national campaign outlining the role of hydrogen in the race to abate global carbon emissions - Launch marketing campaigns to disseminate educational content on low carbon hydrogen through various channels	- Conduct training workshops and seminars for health and safety authorities across the emirates to ensure a consistent understanding and implementation of hydrogen safety protocols	- Widespread awareness of the potential for hydrogen
Educate consumers and end-users on low carbon hydrogen	- Create informational materials and resources for consumers and end-users, highlighting the advantages and practical applications of low carbon hydrogen in their daily lives	- Platform developed for engagement with small to medium enterprises (SMEs) on potential benefits on the adoption of hydrogen	- Toolkit available for SMEs to navigate hydrogen adoption (costs, benefits, climate mitigation, safety, and technology)

Making it real

A well-defined governance structure will strengthen the control and track implementation of strategic goals and actions outlined in the UAE's National Hydrogen Strategy. The governance structure will comprise four layers, the Federal Hydrogen Committee, the Hydrogen Strategy Advisory Council, the Working Groups, and the Coordination Office.

Federal Hydrogen Committee

The Federal Hydrogen Committee, chaired by the Undersecretary of the Ministry of Energy and Infrastructure, will be responsible for the overall implementation of the strategic objectives by facilitating cohesive support on required Cabinet decisions relating to policy, regulatory, fiscal, and non-fiscal interventions. The Committee will include Undersecretaries of key government ministries assigned and responsible for monitoring and updating the performance of each of the ten elements of the hydrogen strategy.

- The Ministry of Energy and Infrastructure will act on recommendations and facilitate decisions regarding Policies, Regulations, Standards, Resources & Assets, Global Collaboration and Enabling Infrastructure.
- The Ministry of Education will be responsible for acting on recommendations and facilitating decisions related to Skills and Education.
- The Emirates Research and Development Council will be responsible for acting on recommendations and facilitating decisions related to Research & Innovation.
- The Ministry of Finance will act on recommendations and decisions regarding Finance & Investments.
- The Ministry of Industry and Advanced technology will act on recommendations and decisions related to Industry Development and Demand Activation.
- The Ministry of Climate Change and Environment will act on recommendations and decisions on Climate, Safety, and Social Drivers.
- The Ministry of Economy will be responsible for recommendations and decisions on Sustainable, Commercial and Economic Models.

Hydrogen Strategy Advisory Council

The Hydrogen Strategy Advisory Council will include senior leaders of major hydrogen stakeholders who will be responsible for providing recommendations to the Federal Hydrogen Committee. The Council will play a crucial role in engaging with the Federal Hydrogen Committee towards realising the UAE's hydrogen ambition.

The Hydrogen Strategy Advisory Council will:

- Collaborate to identify, inform, and promote actions for enabling the production, transmission, storage, and end of low carbon hydrogen across different sectors to accelerate the UAE's sectoral demands and export needs.
- Oversee the activities of the Working Groups.

The council will consist of stakeholders from relevant Emirates and organisations that play a significant role in the hydrogen transition.

Working Groups

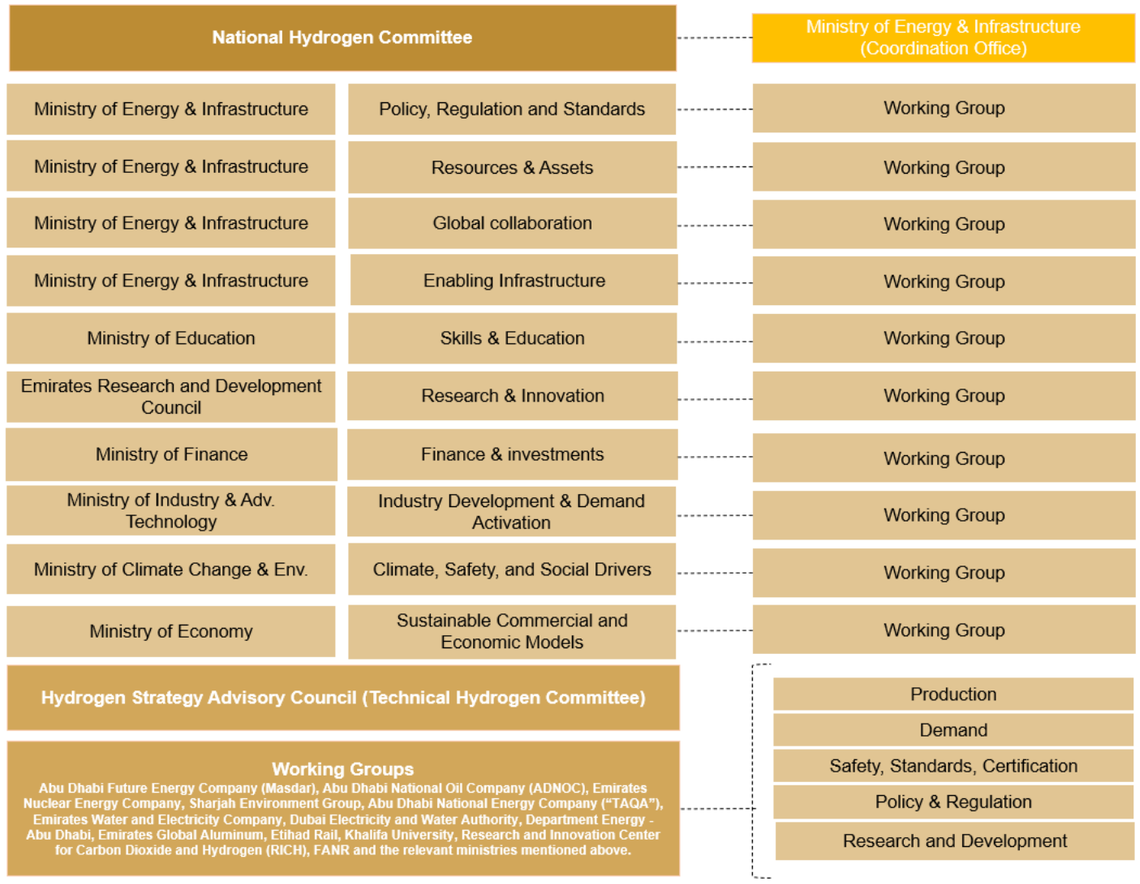
The Working Groups will comprise five layers of expert focus groups in Production, Demand, Safety, Standards and Certification, Policy and Regulation, and Research and Development. The Working Groups will collaborate with the existing groups, such as the National Hydrogen Technical Committee, the Abu Dhabi Hydrogen Alliance, and the Hydrogen leadership Initiative, on existing and new priorities as the market develops.

These working groups will actively engage stakeholders in the community to educate and collect insights.

Coordination Office

The Ministry of Energy and Infrastructure will act as the Coordination Office to facilitate and coordinate the activities of the National Hydrogen Committee, the Hydrogen Strategy Advisory Council, and the Working Groups. The coordination office will be responsible for tracking and reporting activities regarding the actions and progress of recommendations of the National Hydrogen Strategy. Terms of Reference will be established to define the detailed organisation, including structure memberships, objectives, priorities, and meeting schedules of the Hydrogen Strategy Advisory Council and the Working Groups.

Proposed collaboration model



Appendix A

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