Egypt's National Low Carbon Hydrogen Strategy – Short Version

Rev 10

European Bank for Reconstruction & Development (EBRD)

09 January 2024

215000-00078-REP-SD02

Advisian
Worley Group

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PROJECT 215000-00078-REP-SD02: Egypt's National Low Carbon Hydrogen Strategy – Short Version

Rev	Description	Author	Review	Advisian approval	Revision date
Draft	Draft	P Cohen/ P Janiak	N Knight	N. Knight	02.09.22
1	Updated with Egypt comments	P Cohen/ P Janiak	N Knight	N. Knight	26.09.22
2	Further Updates	P Cohen/ P Janiak	N Knight	N. Knight	28.09.22
3	Final Update & Updated Disclaimer	P Cohen/ P Janiak	N Knight	N. Knight	25.10.22
4	Final updates with MoP comments	P Cohen/ P Janiak	N Knight	N. Knight	30.10.22
5	Updated Vision	P Cohen/ P Janiak	N Knight	N. Knight	04.11.22
6	Final updates with MoP comments	P Cohen	N Knight	N. Knight	12.12.22
7	Final with further updates	P Cohen	N Knight	F Alanis	16.02.23
8	Updated governance	P Cohen	N Knight	N. Knight	28.04.23
9	Updated governance	P Cohen	N Knight	N. Knight	05.09.23
10	General Update	P Cohen	N Knight	N. Knight	09.01.24

Table of Contents

Appendices

Table list

Figure list

The intent of this document is to provide a draft, high-level strategy for the future of low carbon hydrogen within Egypt, complete with the main technical details and analysis that has helped form this strategy.

This **SHORT** version contains the key messages but without the technical details. Both documents lay out the short-term and long-term vision of the role that low carbon hydrogen can play in Egypt including the following key areas:

- International context and export market potential
- Overview of hydrogen value chain and priority end users within Egypt
- The action plan and mechanisms required to turn the vision into reality

The strategy is the start of the journey for low carbon hydrogen and will require review and updating as this emerging market matures and develops.

The intent of this full document is that it is for internal use only at the relevant ministries.

Executive Summary

Egypt will play a leading role in the supply of hydrogen and its derivatives for the developing low carbon hydrogen economy. Egypt will take advantage of its competitiveness to fulfil its ambitious plans for the hydrogen sector, targeting up to 8% (5.6 MTPA) of the tradable market by 2040 and requiring around 60 USD billion of investment.

Exploiting current experience in both grey and electrolytic hydrogen production and ammonia production and export will enable Egypt to quickly establish itself as a major global hydrogen hub. Additionally, the excellent renewables and gas reserves, combined with Egypt's strategic location, means Egypt will be amongst the world's leaders as demand for low carbon hydrogen grows significantly over the next few decades.

Egypt will cement its position as a world leader through a phased approach:

2020s – Pilot Projects

Building on Egypt's hydrogen experience the pilot projects will lay the foundations for the developing low carbon hydrogen economy and export market. Providing close support for initial projects, and establishing a fit for purpose governance structure

2030s – Scale Up

Securing market position in the growing hydrogen economy, using the lower costs for hydrogen to support the wider decarbonisation of Egypt replacing grey hydrogen. Scaling up hydrogen production to the GW scale and beyond

2040s – Full Market Implementation

Maintain market position in the low carbon hydrogen economy

Using hydrogen across society to support decarbonisation and secure Egypt's low carbon future in industry and transport

To enable the hydrogen economy to develop quickly during the pilot phase and in preparation for scale-up, Egypt will:

- Utilise the existing, substantial industry experience and knowledge
- Enable access to the significant renewable capability and capacity
- Provide support to develop at strategic locations with geographical proximity to Europe and access to global maritime traffic through the Suez Canal. Building on existing experience and infrastructure with ports and export facilities
- Establish the governance structure/legislation to minimise the barriers, including:
  - Enabling access to the necessary land infrastructure and utilities
  - Setting a clear governance structure, which simplifies decision-making to set hydrogen projects faster in motion, encouraging investments, and envisages a regular Strategy monitoring, review and update
  - Prioritise legislative and regulatory framework reviews that focus on reducing potential barriers and administrative burdens, providing both sufficient certainty and flexibility to investors and project developers
- Work with investors to consider a mix of financing mechanisms to de-risk and improve the profitability of low carbon hydrogen and stimulate its market uptake in the country

- Build on the track record of attracting overseas investment in renewables and use hydrogen diplomacy to secure international assistance for launching low carbon hydrogen projects and accelerating hydrogen technologies deployment and
- Work with international bodies to ensure transparency that hydrogen produced complies with low carbon standards with the "guarantee of origin".

The benefits to Egypt in achieving the vision:

Economic Benefit – The low carbon hydrogen economy is expected to be at least double the current demand, with some predicting it will increase almost seven times, with much of this hydrogen being expected to be traded on the international market. Obtaining a significant proportion of the market will provide a major boost to Egypt's GDP in the order of **10-18 billion USD**[1] by 2040. At the same time, Egypt should target greater amounts of the value chain, such as completing a greater proportion of the assembly within Egypt. Additionally, Egypt's expertise in DRI could also enable a quicker move to low-carbon steel, opening further lucrative markets.

Jobs – It is expected that over **100,000 jobs** will be created, a high proportion being highly skilled. With the right training, the domestic workforce will take many of these. Contracts with international companies should stress the need to maximise the domestic value chain and workforce use. It is estimated that each 1000 MW facility would require a workforce of around 750 personnel.

Energy Security – An increase in hydrogen produced locally will provide increased energy security to Egypt, with less reliance on petroleum imports.

Decarbonisation – The development of the hydrogen economy will not only help Egypt decarbonise but enable Egypt to support decarbonisation globally.

[1] Assumes that Egypt produces between 6-10 MT of hydrogen per year at a value of around 1.80 USD/kg.

Acronyms and abbreviations

Acronym/abbreviation	Definition
ATR	Auto Thermal Reformer
BCMA	Billion Cubic Metres per Annum (of gas flow)
BEV	Battery Electric Vehicle (BEV)
CBAM	Carbon Border Adjustment Mechanism
CfD	Contracts for difference
COO	EBRD's Countries of Operation
CO2e	Carbon dioxide equivalent
CCGT	Combined Cycle Gas Turbine (Power Generation)
CCS	Carbon Capture and Storage
CNG	Compressed Natural Gas
DSM	Demand Side Modelling
EGMM	European Gas Market Model
EnC	Energy Community, also referred to in the past as the Energy Community of South East Europe
EOR	Enhanced Oil Recovery
EPMM	European Power Market Model
ETC	Energy Transitions Commission
ETS	Emissions Trading Scheme
EV	Electric Vehicles
FCEV	Fuel Cell Electric Vehicle
FOB	Free On Board
GO	Guarantee of Origin
HPU	Hydrogen Production Unit
HVDC	High Voltage Direct Current
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
LCOH	Levelised Cost of Hydrogen
LNG	Liquefied Natural Gas
LOHC	Liquid Organic Hydrogen Carrier

Acronym/abbreviation	Definition
LSFO	Low Sulphur Fuel Oil
MENA	Middle East, North Africa
MTOE	Million Tonnes of Oil Equivalent
NCGH	National Council for Green Hydrogen and its Derivatives
NDC	Nationally Determined Contributions
OEM	Original Equipment Manufacturer
O&M	Operating and Maintenance
PtH	Power to Hydrogen
SEMED	South and Eastern Mediterranean
SMR	Steam-Methane Reformer
RES	Renewable Energy Sources
TPA	Tonnes Per Annum (kTPA = 1000 tonnes per annum)
TRL	Technology Readiness Level
TSO	Transmission System Operator

1 2030 and 2040 Vision

"Egypt will be one of the global leaders in the low carbon hydrogen economy, utilising world-leading expertise and innovation in hydrogen and derivatives production/export, the excellent renewable resource, gas reserves and its strategic location."

Egypt can achieve its vision to become a world leader in low carbon hydrogen production and its derivatives by utilising the following building blocks:

- Existing strong industry experience and knowledge
- Significant renewable capability and capacity
- Strategic location, geographical proximity to Europe and access to global maritime traffic through the Suez Canal
- Existing experience and infrastructure with ports and export facilities
- Ensuring the governance structure/legislation is in place to minimise the barriers to developing low carbon hydrogen and derivatives economy. This includes:
  - Enabling access to the necessary land infrastructure and utilities
  - Setting a clear governance structure, which simplifies decision-making to set hydrogen projects faster in motion, encouraging investments, and envisages a regular Strategy monitoring, review and update
  - Prioritise legislative and regulatory framework reviews that focus on reducing potential barriers and administrative burdens, providing both sufficient certainty and flexibility to investors and project developers
- Consider a mix of financing mechanisms to de-risk and improve the profitability of low carbon hydrogen and stimulate its market uptake in the country
- Build on the track record of attracting overseas investment in renewables and use hydrogen diplomacy to secure international assistance for launching low carbon hydrogen projects and accelerating hydrogen technologies deployment and
- Work with international bodies to ensure that hydrogen produced complies with low carbon standards with the transparent "guarantee of origin".

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[2] The GDP was calculated based on consumer spending on the cost of hydrogen production if Egypt were to achieve the ambition (6-10MTPA at 1.8USD/kg) as set out in the hydrogen strategy, it did not include any additional taxes or assume a market price or foreign investment for the hydrogen as this is uncertain at this time. This and the wider economic benefits of developing a hydrogen economy should be regularly reviewed to ensure it lines up with Egyptian Growth plans.

should target greater amounts of the value chain, such as completing a greater proportion of the assembly within Egypt and manufacturing hydrogen derived products.

Jobs – It is expected that over **100,000 jobs** will be created, a high proportion being highly skilled. With the right training, the domestic workforce will take many of these. Contracts with international companies should stress the need to maximise the domestic value chain and workforce use.

Energy Security – An increase in hydrogen produced locally will provide increased energy security to Egypt, with less reliance on petroleum imports. To achieve this, it will be essential to ensure the renewable electricity used to produce hydrogen is additional (and not resulting in increased gas demand for electricity production), and a proportion of the hydrogen produced is made available to be used in Egypt's domestic market to directly replace fossil alternatives.

Decarbonisation – The development of the hydrogen economy will not only help Egypt decarbonise but enable Egypt to support decarbonisation globally.

2 Low Carbon Hydrogen Context

2.1 International Context

In May 2022, the EU unveiled its REPowerEU Plan in response to the hardships and global energy market disruption caused by the ongoing Russian-Ukrainian crisis, with the intention of ending the EU's dependency on Russian fossil fuels.

As well as increasing the ambition of the EU's renewable hydrogen production to 10 million tonnes annually by 2030, the REPowerEU Plan also sets a target of 10 million tonnes for renewable hydrogen import, also by 2030.

This represents a significant opportunity for Egypt to export hydrogen to the EU, although Egypt will not be alone in considering hydrogen exports to the region. Other MENA countries, such as Morocco, Algeria, Saudi Arabia and Oman, and even countries as far away as Namibia, can be expected to develop projects to supply renewable hydrogen to the EU.

Japan is another promising large market, particularly interested in blending ammonia into their coal power stations, with an estimated demand of 500,000 tons per year into the 2040s. Ultimately, Japan's hydrogen strategy suggests a demand for 20Mt of hydrogen. It is unclear how much can be met domestically.

2.1.1 Hydrogen Production

Current annual global hydrogen demand is estimated at around 90 million tonnes, with around 70 million tonnes generated as pure hydrogen and 20 million tonnes as carbon-containing synthesis gas, where hydrogen is part of a gas mixture. This excludes hydrogen, produced as a by-product of some industrial processes (particularly oil refining and chlor-alkali production) and then re-used as a feedstock or fuel. Egypt's hydrogen demand is estimated to be around 2.0% of global hydrogen demand.

Future hydrogen production is expected to substantially increase as the world looks to decarbonise and improve energy security; the end users for low carbon hydrogen are discussed in Section 3.2. The expansion rate is uncertain; there are areas where hydrogen or a derivative is essential to enable decarbonisation and others with more cost-effective alternatives, such as electrification. Therefore, there is a large range of estimates for future hydrogen demand in the literature; we estimate that the hydrogen economy will be 60% larger by 2030 and 400% larger by 2050, with 25% of the supply traded intentionally. While the estimates may vary, the use of low carbon hydrogen as a means to achieve the 1.5C Paris Agreement climate goal is undisputed. The initial demand for low carbon hydrogen is expected to be located in the USA, Europe, South Korea and Japan, with the most significant import market being Europe.

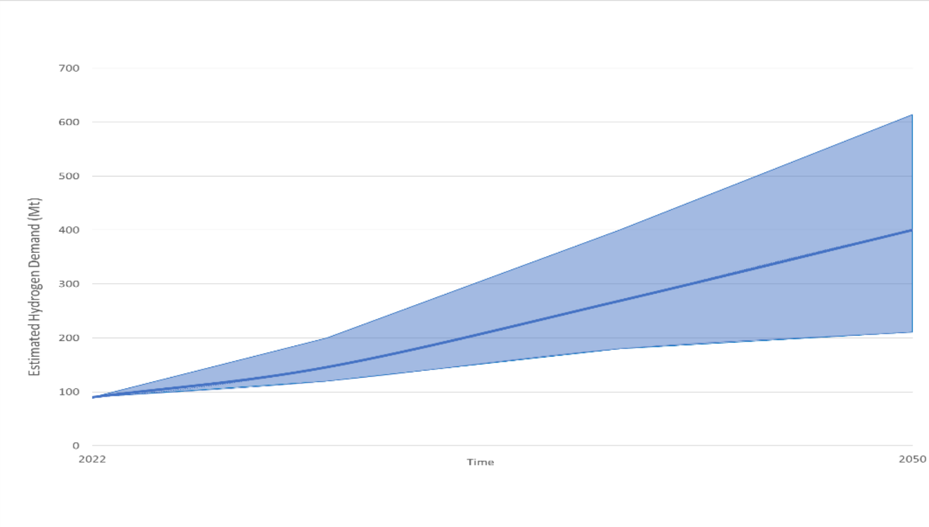

Figure 2-1 Range of estimates for future hydrogen demand

2.1.2 Export Market

Advisian's analysis of the export market potential and Egypt's renewable potential indicates two potential and credible scenarios:

- Central Scenario
- Green Scenario

The 2030 scenarios are based on upcoming global energy policies (such as REPowerEU and Fit for 55,) which are expected to influence the demand for low carbon hydrogen and products.

2.1.2.1 Central Scenario

By 2030, Egypt will produce 1.5 MTPA of green hydrogen and derivatives, requiring 19 GW of installed renewable energy. This increases to 5.8 MTPA in 2040, with 3.8 MTPA for export, 5% of the anticipated tradable market in low carbon hydrogen. In addition, green hydrogen starts to become competitive, with grey hydrogen replacing some demand in refineries, ammonia/methanol, steel, and some heavy duty transport applications.

This central scenario is summarised below.

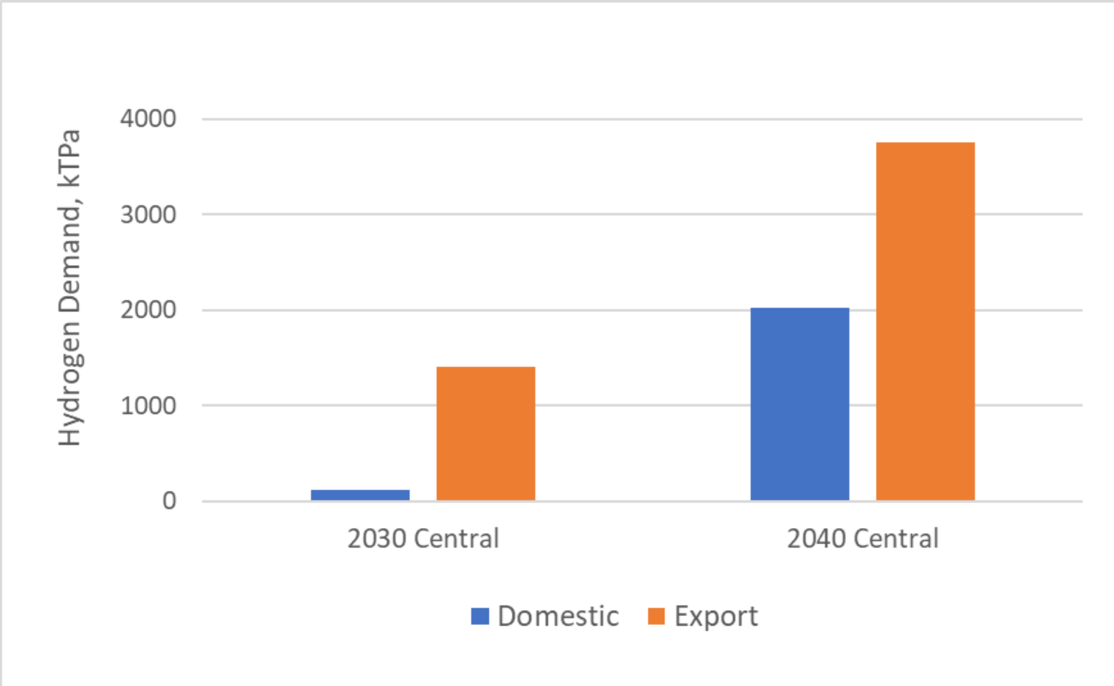

Figure 2-2 Central Scenario - Domestic and Export Hydrogen Demand produced in Egypt

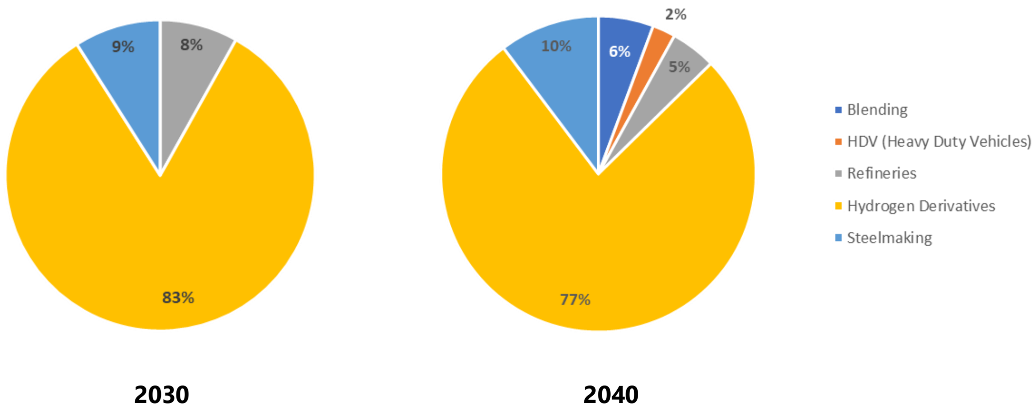

Figure 2-3 Central Scenario - Domestic Hydrogen Demand Sectoral Split

Only a small proportion of low-carbon hydrogen produced is expected to meet local demand in 2030, predominantly from the production of hydrogen derivatives. Demand for derivatives and steel is expected to increase with population growth. By 2040, demand for hydrogen is expected to be blended into the gas grid to supply hydrogen to industries not located in the coastal regions (where green hydrogen will be produced owing to water scarcity); hydrogen is also expected to be used in the heavy goods transport sector.

Table 2-1 Central Scenario – Key metrics

	2030		2040	
Hydrogen production (annual)	0.1 Mt Domestic	1.4 Mt Export	2 Mt Domestic	3.75 Mt Export
Electrolyser Capacity	13 GW		48 GW	
Additional RES requirement	19 GW		72 GW	
Electrolyser Investment required	10 USD Bn		24 USD Bn	

2.1.2.2 Green Scenario

A more ambitious scenario could be considered whereby Egypt targets an aggressive 8% share of the expected tradable global H2 demand (5.6 MTPA by 2040). In addition, green H2 becomes competitive with grey, replacing demand in refineries, and policy mechanisms (such as carbon price) promote a switch away from natural gas. Refineries and ammonia/methanol transition to 100% green hydrogen, with most steel plants converting to hydrogen DRI; there is increased blending into the gas grid to meet industrial demand, and half of the heavy-duty transport converts to hydrogen.

This ambitious green scenario is summarised below:

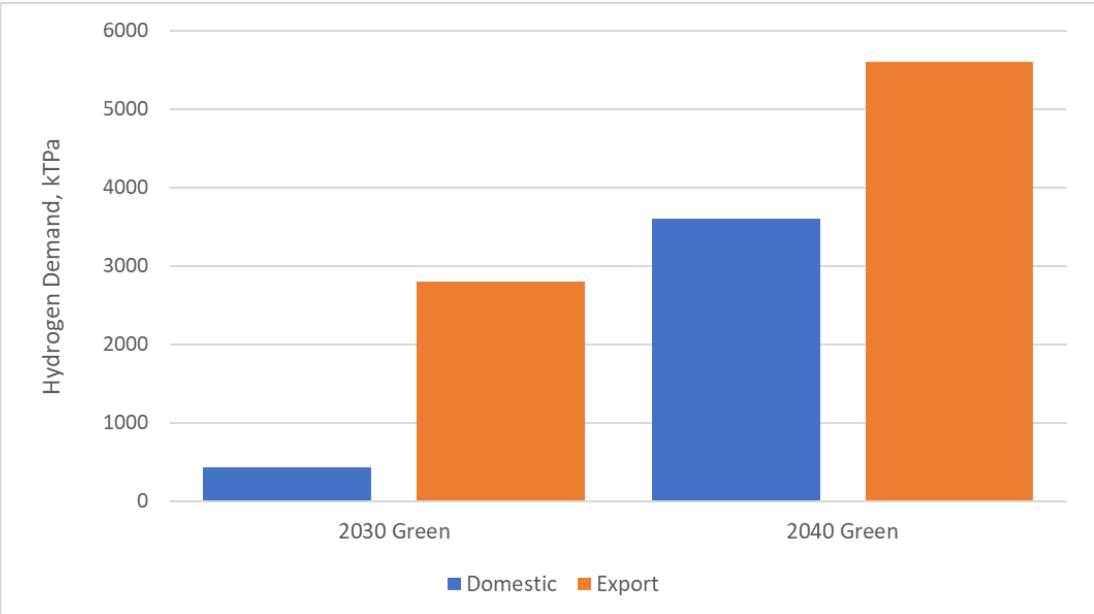

Figure 2-4 Green Scenario - Domestic and Export Hydrogen Demand produced in Egypt

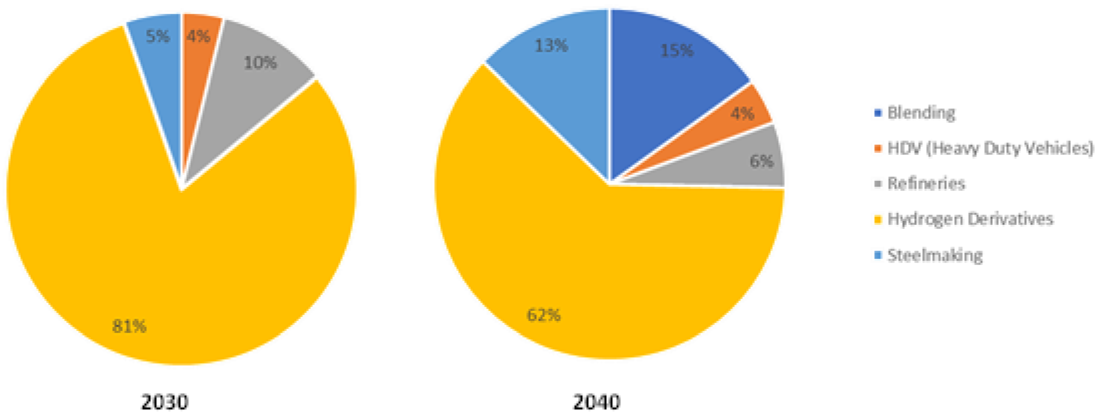

Figure 2-5 Green Scenario - Domestic Hydrogen Demand Sectoral Split

Similarly to the central scenario, however, a greater switch away from the high carbon alternative is expected. Additionally, an increase in low carbon steel production (for both domestic and export markets) is expected, as is replacing grey hydrogen with low carbon hydrogen.

Table 2-2 Green Scenario – Key Metrics

	2030		2040	
Hydrogen production (annual)	0.4 Mt Domestic	2.8 Mt Export	3.6 Mt Domestic	5.6 Mt Export
Electrolyser Capacity	27 GW		76 GW	
Additional RES requirement	41 GW		114 GW	
Electrolyser Investment required	22 USD Bn		34 USD Bn	

2.2 National Context

Being the most populous country in the region, Egypt has been facing a rapid increase in energy demand. Currently, fossil fuels (gas and oil) still account for just under 90% (88% in 20/21) of the total primary energy supply, and while the country has continued expanding its renewable energy capacity, the share of renewables in total power generation accounted for 12% in 2020/2021.

In the 2018 Integrated Sustainable Energy Strategy, currently undergoing a revision process to include an extended timeline (up to 2040), the government prioritised an energy diversification strategy through the development of renewables (with an electricity generation target of 42% by 2035) and improved energy efficiency. The National Energy Efficiency Action Plan (2018-2022) focused on improving the quality of electric power transmission to decrease the losses in the electricity distribution network and on implementing energy efficiency measures – such as renovations, rooftop PV panels and LED bulbs – in major electricity-consuming sectors, e.g., buildings.

The expansion of renewables accompanies the early initiatives to launch a hydrogen market. As of August 2023, Egypt signed 23 memorandums of understanding (MoU) for developing hydrogen production plants with partner companies; additionally, during COP27, nine partnership agreements were signed with leading international developers. The agreements envisage three phases: 24.63 GW of renewables to supply 9.86 GW of electrolyser capacity in the pilot phase, with an additional 57.3 GW of renewables to supply 24.55 GW of electrolyser capacity in Phase 1 and 19.35 GW of renewables and 9.4 GW of electrolysers in Phase 2. This amounts to, in total, 101.3 GW of additional renewables to supply 43.9 GW of electrolyser capacity.

3 Hydrogen Value Chain

Egypt has a long history of producing and consuming hydrogen; the current hydrogen demand is estimated to be about 2% of the global annual hydrogen demand, produced primarily from fossil fuels.

Unlike many of its potential competitors, Egypt does have experience in producing green hydrogen. Constructed in 1960 (when natural gas was not available locally), KIMA Fertilizers Company in Aswan Governate for a time operated the world's largest green hydrogen plant at 150 MW using hydroelectric power from the Aswan Dam. The original electrolysers were replaced in 1977 and operated until 2019, when they were replaced with a natural gas-based grey hydrogen plant. The facility used green hydrogen to manufacture ammonia, nitric acid and ammonium nitrate. Globally, natural gas-based technology became the dominant technology for this process in the 60s/70s when the steam-methane reformer (SMR) technology took off.

There are many hydrogen production pathways and many end-use applications available in Egypt. These are both briefly described below.

3.1 Hydrogen Production Pathways

The table below summarises the main hydrogen production pathways and their applicability to Egypt. All the options below, except for grey hydrogen, can be considered low carbon hydrogen. It should be noted that currently, there is no globally accepted definition of low carbon hydrogen. Therefore, the specific carbon intensity of an individual production pathway requires calculating and comparing against the end user's required carbon intensity specification.

Table 3-1 Summary of Hydrogen Production Pathways and Applicability to Egypt

Production Pathway (Carbon Intensity)	Process/Feedstock	Comments	Applicability to Egypt
Grey (8.5 – 10 $kgCO_2/kgH_2$)	Steam methane reforming or auto-thermal reforming of natural gas or coal	95% of current global H_2 demand	Well known and used extensively in Egypt
Blue (0.8 – 4.4 $kgCO_2/kgH_2$)	Combines grey hydrogen production with carbon capture and storage	Carbon capture can be retrofitted to an existing grey H_2 plant	Requires CO_2 storage locations to be defined; the time needed to develop CO_2 storage is significant, 5-10 years
Green	Electrolysis of water using renewable power	Globally largest operating electrolyser in China at 100 MW	Egypt has experience with the process and the potential renewable capability. It is likely to require water desalination
Turquoise	Pyrolysis of natural gas	In the early stage of development, it produces solid carbon as a product	Not proven for large-scale H_2 production

Production Pathway (Carbon Intensity)	Process/Feedstock	Comments	Applicability to Egypt
Pink	Electrolysis of water using power generated from nuclear		
Bio	Gasification of biomass or waste	Early stages of commercialisation	Feedstock availability within Egypt could limit the production to 1.3 MTPA

The focus of this strategy is green and blue hydrogen as a means to produce low carbon hydrogen, given that these can be produced at scale. The other options may be of interest but will be smaller, project-specific opportunities as opposed to driving the strategy.

3.1.1 Green Hydrogen Production Review

Given the renewable power potential in Egypt, green hydrogen is of significant interest as a means to produce low carbon hydrogen; the key factors to consider for the production pathway are the renewable power potential and the impact on water.

3.1.1.1 Impact on Renewable Energy

Egypt has around 2850 MW of existing hydropower capacity, which supplies approximately 7.2% of the total Egyptian power generation. The excellent wind resources are in the Gulf of Suez and, for solar, particularly around the South West and Benban. Solar and wind renewable electricity only accounts for around 5% of total generation capacity, with an ambitious target to increase the renewable energy share to 42% by 2035[3]. The excellent renewable resources combined with an ambitious renewables target (along with a reliable electricity grid) should allow for significant green hydrogen production within Egypt.

Egypt has been expanding its solar and wind energy capacity recently, recording an over four-fold increase (from 690 MW in 2014/2015 to 3,016 MW in 2019/2020). Such growth was possible thanks to establishing a favourable policy, legislative and institutional framework, including investment law with incentives such as tax reductions for new and existing projects, net metering (with the recently increased capacity from 5 MW up to 20 MW), feed-in tariffs (accompanied by currency guarantees and international arbitration terms), and competitive bidding based on independent power producers' model.

Egypt has high wind energy potential, especially in the Gulf of Suez area, with a stable wind speed of around 8-10 m/s. Recently, a new potential area in the east and west of the Nile River, in the Beni Suef

[3] This ambition is expected to be brought forward to 2030

Governorates and El Kharga Oasis, has been untapped. These areas have wind speeds between 5 m/s and 8 m/s, suitable for electricity generation.

It should be noted that the above renewable energy targets have been set to decarbonise the country's fossil fuel-based electricity generation. In this context, expanding green hydrogen production should be conducted bearing in mind that objective and the availability of dedicated renewable energy supplies to run electrolysers so as not to slow down this process and, inadvertently, promote increased fossil fuel consumption for electricity generation. In the EU, the risk of diverting renewable power towards electrolysis at the expense of decarbonised power generation is also recognised. To address this, the requirement for "additionality" for renewable hydrogen projects has been introduced in policy, such that the power requirement for electrolysis must be supplied for new, or at least recent, renewable power investments.

3.1.1.2 Impact on Water

The United Nations predicts that Egypt could be water-scarce by 2025. Supplying a share agreed upon by international treaties at 55.5 billion cubic meters (BCM) per year, the Nile River is Egypt's main source of fresh water. The remaining potable water resources available provide an additional 20 BCM, including groundwater aquifers, reuse of agricultural drainage and treated wastewater, rain and floods, and desalination.

With population and economic growth, there has been a sharp decline in the annual freshwater resources available per capita, pushing the country closer to the severe water scarcity threshold (500 cubic meters per capita per year). Climate change impacts, water pollution, and geopolitical factors (such as the Grand Ethiopian Renaissance Dam) are expected to exacerbate water stress in Egypt. Egypt is implementing a substantial investment program towards the efficient use, reuse, and generation of new water sources as a national priority.

Green hydrogen requires significant quantities of high-purity water. Currently, systems use up to 13 kg water/kg hydrogen (as electrolysers are improved, the water demand is expected to be reduced to around 9kg/kg).

However, the disposal of the resulting brine may increase costs significantly. Historically, brine was disposed of through a single outfall; the resulting highly concentrated brine was found to suffocate the seabed with a plume extending for several kilometres. Modern discharge practices, which conform to IFC Performance Standards, look to maximise the brine dispersion and have been found to mitigate the impact; however, brine disposal should be limited near sensitive or productive habitats. Ultimately, if brine cannot be discharged back to sea, it will require to be discharged to an evaporation pond.

Water reuse – Fresh water scarcity means that it is unlikely that green hydrogen will be produced at scale inland. However, it is possible to treat wastewater from a sewage treatment works sufficiently to be used for hydrogen production. The processes required range from settling, activated sludge, activated carbon, filtration, UV processes, and reverse osmosis. This range of processes has been proven in Namibia[4]. The added advantage of collocating hydrogen production is that the oxygen could be used to improve the efficiency of the wastewater treatment process. However, this would have to be examined on a case-by-case basis as the water may also be fit for human consumption.

[4] https://journals.openedition.org/factsreports/6341

3.1.2 Blue Hydrogen Production review

Blue hydrogen production at scale can only be achieved technically if the required carbon storage is available. The competitiveness of blue to green hydrogen depends on the price of natural gas.

3.1.2.1 Carbon Storage Requirements

The potential for large-scale CO_2 storage is a pre-requisite for blue hydrogen production unless CO_2 can be exported in large volumes by pipeline or ship.

Implementing carbon storage projects can be a lengthy process and typically takes up to 10 years from conception to reality. Given the early stage of investigation into storage facilities in Egypt, the realistic time frame for blue hydrogen is 2030 onwards.

3.1.2.2 Impact on Natural Gas Market

The majority of natural gas produced, ~62 BCM, is to meet Egypt's demand (mainly for power and industry), one of the largest in the MENA region; the remainder is exported, typically by LNG.

New pipelines can be designed for 100% hydrogen service; however, converting existing pipelines designed for natural gas service to carry hydrogen blends needs investigation on a case-by-case basis. It is generally accepted that, in most cases, a blend of hydrogen in natural gas of up to 20% is technically feasible with minimal capital investment in the pipeline and associated compressor system. Operation above this level may be feasible from a pipeline perspective, but the capital investment for compression modification starts to become substantial.

Based on the latest research, it is credible that hydrogen could be blended into the gas network up to 20% by volume without impacting downstream users, which equates to 11 million tonnes of hydrogen per year. This blending rate is unlikely to be achieved but gives an idea of the potential scale of demand from blending.

3.2 Hydrogen Applications

Many sectors within Egypt may have a low carbon hydrogen demand to enable decarbonisation; these are summarised in the table below.

Table 3-2 Summary of Hydrogen Applications and Applicability in Egypt

Class	Possible role of hydrogen	Current H2 Demand	Future H2 Demand	Applicability to Egypt
Industrial Feedstock: Ammonia	Egypt's ammonia production uses grey H_2 as a feedstock; this could be replaced with low carbon hydrogen	Estimated to be 1 MTPA	Expected to increase with low carbon ammonia export potential	Well established industry with the potential to grow

Industrial Feedstock: Oil Refining	Egypt's refineries have SMR H_2 production; this could be replaced with low carbon hydrogen	Estimated to be 0.14 MTPA	It is only expected to increase if refining capacity is expanded	Well established industry – limited potential to grow
Industrial Feedstock: Methanol	Conventional methanol is produced by reforming natural gas; the alternative combines low carbon hydrogen with CO_2	Estimated to be 0.27 MTPA	Globally, demand for methanol is expected to increase alongside biogenic CO_2	New industry that offers potential, especially in the shipping industry
Industrial Feedstock: Steel (Direct Reduced Iron) process	DRI process currently uses natural gas reformed to H_2 & CO, partial replacement with low carbon hydrogen possible	n/a (DRI production estimated to be 6 MTPA).	Up to 0.14 MTPA of H_2	Possibility to grow, with idled plants back online
Transportation: Land	Hydrogen can be used in fuel cells to generate electricity for an electric vehicle.	n/a		Currently limited, as electric vehicles have a cost advantage
Transportation: Shipping	The shipping industry is expected to adopt alternative fuels such as green methanol and green ammonia	n/a	Increase	Significant as the strategic location makes for a competitive bunkering hub
Transportation: Aviation	Aviation is a difficult sector to decarbonise; hydrogen may provide the solution with sustainable aviation fuel or directly as hydrogen	n/a	Increase	
Fuel for industry	Displacing natural gas as a fuel source for industry in furnaces, boilers and kilns.	n/a	Up to 20% blended in existing natural gas pipelines	It is significant if decarbonisation targets incentivise the use
Power and grid balancing	Like a battery, hydrogen is generated with excess power and converted back to power when there is a shortfall.	n/a	Likely to be limited to longer duration storage and potentially peaking plants if moving to fully decarbonise the electricity grid	Potentially useful to maintain grid stability during times of low renewable power production

Ultimately, the use of hydrogen throughout the economy depends on when the hydrogen technologies are commercially available and how they compare to the alternatives, including the incumbent fuel and low carbon alternatives (mainly electrification). With the supply of hydrogen likely to be limited due to the availability of electrolysers and the construction of renewables, it is important to prioritise using low carbon hydrogen in areas where it will likely provide maximum benefit to Egypt.

Table 3-1 Priority of Applications

Application	Incumbent	Dependence on Hydrogen for decarbonisation	Economic Gap	Ready by 2030
Ammonia	Reformed methane, then Haber Bosch	High, alternative electrochemical synthesis at low TRL	Low, especially for the export market	
Methanol	Reformed methane then reacts with the catalyst	High, although limited by the availability of biogenic CO2	Med, biogenic CO2 would have to be acquired	
Oil refining	Reforming methane or light ends	Med, reliant on CCS for the majority of emissions savings	Low, Green hydrogen is competitive with grey in the 2030s	
Iron and Steel	Reformed methane to DRI	Med, CCS is an option and full electrification (although low TRL)	Med, new major plant items required	Expected to be available around 2030
Transport - Cars	Petrol/Diesel	Low, likely higher costs compared to electrification	Expected to be higher than diesel/electrification	
Transport - Buses	Diesel	Low, likely higher costs compared to electrification	Expected to be higher than diesel/electrification	
Transport - HGV	Diesel	Med, competitive with electrification at longer distances	Expected to be higher than diesel	
Transport - Mining	Diesel	Med, competitive with electrification	Expected to be higher than diesel	
Transport - Rail	Diesel	Med, competitive with electrification at longer distances	Expected to be higher than diesel and potentially electrification	
Transport - Aviation	Jet Fuel	High, although electrification may be possible on some routes	High but the only low carbon alternative for longer routes	SAF will be available by 2030
Heat – Low Temp	Natural gas	Low, likely higher costs compared to electrification	Higher cost than natural gas to 2040 and electrification	Safety trials

Application	Incumbent	Dependence on Hydrogen for decarbonisation	Economic Gap	Ready by 2030
				planned for 2025
Heat – High Temp	Natural gas	Med, technologies are more developed than electrification	Higher cost than natural gas to 2040 and electrification	Some applications will be available
Power – Longer duration storage	n/a	Alternatives such as CAES and pumped storage	Uncertainty surrounding the cost of utilising geological storage	Beyond salt caverns, geological storage is still to be tested

4 Opportunities for Egypt

As mentioned in the Vision, Egypt is in a strong position to play an important role in the nascent low carbon hydrogen economy, benefitting from current knowledge in grey and electrolytic hydrogen production and ammonia production and export. As discussed in Section 4, the excellent renewables and gas reserves, combined with the strategic location of Egypt along one of the main shipping routes close to crucial import markets, means Egypt will be amongst the world's leaders as demand for low carbon hydrogen grows significantly over the next few decades.

The table below summarises Egypt's key advantages.

Table 4-1 Summary of Egypt's Key Advantages

Area	Sector	Egypt Advantage
NATURAL RESOURCES	Renewables	Excellent wind resource in the Gulf of Suez and solar, particularly in the south and around Benban.
	Gas Reserves / CO2 Storage	The natural gas fields provide a potential source of natural gas for blue hydrogen production.
	Location	Egypt is very well placed geographically as a major shipping hub, with easy access to the Mediterranean Sea and Suez Canal, which could accommodate more than 20% of international shipping.
	Water	Egypt has a wealth of experience in desalination.
ASSETS AND INFRASTRUCTURE	Domestic Gas Demand	Egypt has one of the highest domestic gas demands across the MENA region, with gas predominantly used in the power and industry sectors. Hydrogen could initially be blended into the gas network before it is upgraded to a 100% hydrogen grid.
	Ammonia/ Methanol Industry	Egypt's ammonia and methanol industries provide a focal point for green and blue production. There are also emerging markets for both as shipping fuels.
	Steel Industry	Egypt's steel industry (apart from one blast furnace) uses the direct reduced iron (DRI) process route, in which iron ore is converted to sponge iron. In this process, hydrogen and carbon monoxide are produced by reforming natural gas and act as the reducing agent. There are options for incremental hydrogen injection to displace the natural gas route.
FINANCIAL	Overseas Investment	Egypt has successfully attracted agreements with major players such as Siemens, Scatec, Eni, Masdar, AMEA Power, Maersk and ACWA for renewables and hydrogen investments.

The main options for future hydrogen demand in Egypt are as follows:

- Use of low carbon hydrogen in the production of ammonia creating low carbon fertiliser products.
- Use of hydrogen in the production of methanol and ammonia for use as marine fuels, or export as energy carriers.
- Use of hydrogen in further power-to-X applications, such as sustainable jet fuel production.
- Use of hydrogen for other mobility applications, such as buses, trains (passenger and freight), heavy goods vehicles (HGV) and mining operations, where electrification is not credible.
- Use of hydrogen as a fuel for power generation, for long term energy storage, to balance the grid, and to replace natural gas consumption.
- Use of hydrogen as an industrial fuel to displace fuel oil or natural gas in more energy-intensive industries such as steel production.

In each of these options listed above, there will be different economic drivers. The primary consideration is the increased costs compared to using the “incumbent” fuel that is displaced (usually natural gas and diesel).

5 Action Plan

Following the analysis of the current situation regarding the hydrogen market, both in Egypt and globally, as well as based on international best practices in enabling low carbon hydrogen expansion according to different market maturity stages, the Consultant suggests a phased approach to hydrogen economy development in the country.

Figure 5-1 below summarises graphically the approach, including:

- pilot phase (in the 2020s),
- scale-up phase (2030s),
- full implementation phase (2040).

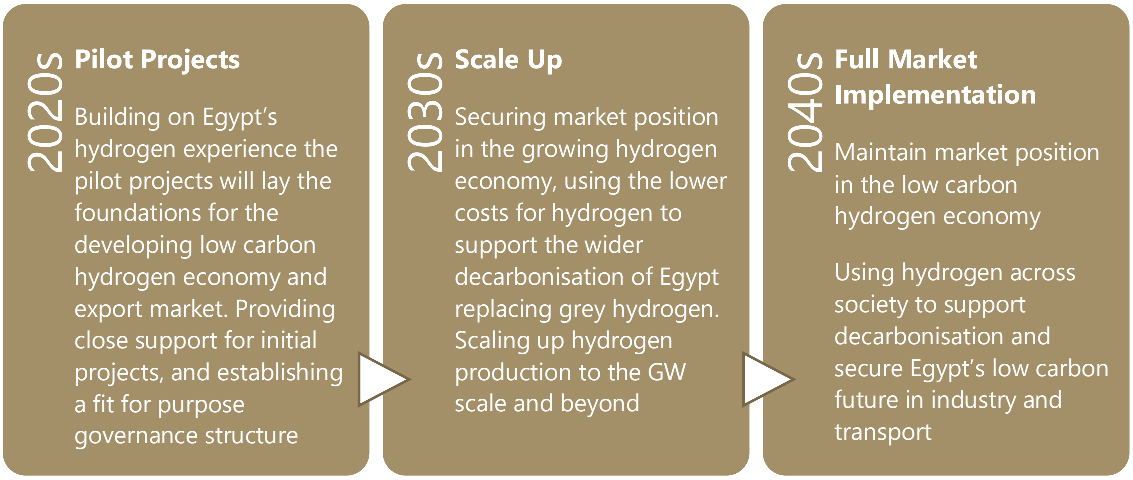

Figure 5-1 Summary Action Plan

Each phase is described in detail below:

5.1 Pilot phase:

Immediate actions – governance framework

- Creation of thematic working groups within the technical secretariat, which will include a focus on developing future frameworks for MOUs which set out how to maximise the economic benefit to Egypt;
- Organisation of stakeholder roundtables in Egypt (hydrogen market actors) and hydrogen diplomacy (active participation in international initiatives).

Short-term actions (next one to two years) – market development incentives

- New pilot projects identification, preparation and delivery (know-how and knowledge transfer, hydrogen production and export); incorporation of lessons learned from the ongoing MoUs and conclusion of new agreements);
- Conducting studies, reviews and assessments (National Hydrogen Council working groups on: enabling laws and regulations; existing infrastructure; low carbon hydrogen definition; carbon

pricing/tax implementation; financial assistance for first hydrogen projects; a roadmap for R&D and capacity building/skills development; public awareness campaign, benchmarking incentives against international best practice, and maximising benefits to Egypt).

Mid-term actions (next three to five years) – continued support for hydrogen technologies deployment and expansion – in particular through:

- Preparing and issuing the needed regulations for paving the way for investors and providing the enabling environment for the low carbon hydrogen industry.
- Development of a national strategy for short-term and longer-term public support to be applied across the whole hydrogen value chain (to ensure short-term competitiveness while establishing the hydrogen economy and planning long-term revenue generation for Egypt);
- Roll out of sustainable development laws and regulations to incentivise the production of low carbon hydrogen;
- Review of future-proofing natural gas infrastructure investment for the transition to hydrogen, and other natural gas pipeline extensions to industrial users; conducting a technical feasibility study of blending up to 100% hydrogen to future proof the industry and power generation; setting guidelines to increase hydrogen blending into the current gas grid for industrial areas;
- Development of a strategy for low carbon hydrogen integration and gradual phase-out of the grey hydrogen production plants, but also how hydrogen can be blended into the existing steel plants;
- Increase the scope of decarbonisation within the country by considering new hydrogen uses, e.g., local transport, ports and terminals, and low carbon ammonia/methanol production;
- Establish the likely costs of carbon capture and CO_2 transfer to storage sites. Prepare a strategy to develop CCS hubs around key industrial areas;

Long Term Actions (next five to ten years) – considering the uncertainty related with long term planning, these actions should focus on reassessing the hydrogen market (at the international and national scale) and natural gas price and adjusting Egypt's approach to further development of hydrogen economy in the country.

5.2 Governance

Considering the governance models existing internationally, Egypt's specific energy sector context, the following Governance structure will apply to hydrogen in Egypt.

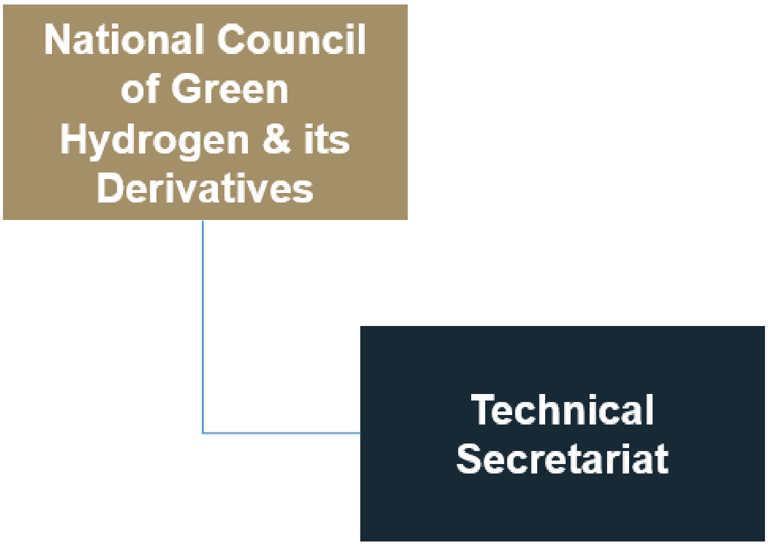

Figure 5-2 Hydrogen Governance Structure in Egypt

The National Council for Green Hydrogen and its Derivatives (NCGH) aims to unify the state's efforts to stimulate investment in the field of green hydrogen and its derivatives, in line with the requirements of sustainable development and the state's plans for economic and social development, and to ensure its competitiveness at the international and regional levels. The main responsibilities of the NCGH include

- Following up on the implementation of the national strategy for green hydrogen,
- Proposing the update of the strategy in light of the international and national developments,
- Approves policies, plans and mechanisms necessary to implement and update the strategy,
- Coordinating between ministries and concerned authorities, and proposing the necessary solutions to overcome investment obstacles in the field of green hydrogen and its derivatives,
- Reviewing the legislation, regulations and rules regulating the field of green hydrogen and its derivatives, and proposing necessary updates.

To enable smooth coordination of actions across Egyptian government institutions also to create a strong sense of inclusion and ownership over the process and address the need to develop competency in and awareness of the hydrogen economy across Egyptian public administration, the NCGH will bring together leadership representing other relevant institutional stakeholders including:

- **Prime Minister (Chairman)**
- Minister of Electricity and Renewable Energy
- Minister of Petroleum and Mineral Resources
- Minister of Justice

- Minister of Planning and Economic Development
- Minister of International Cooperation
- Minister of Finance
- Minister of Environment
- Minister of Housing Utilities, and Urban Communities
- Minister of Transport
- Minister of State for Military Production
- Minister of Water Resources and Irrigation
- Minister of Public Business Sector
- Minister of Trade and Industry
- Chairman and Managing Director of Suez Canal Authority
- Chairman of Suez Canal Economic Zone (SCEZone)
- First Assistant to the Prime minister (Rapporteur)
- Executive Director of The General Authority for Free Zones and Investment (GAFI)
- Chief Executive Officer of The Sovereign Fund of Egypt for Development and Investment
- Representative of Ministry of Defense

The responsibilities of the Technical Secretariat shall be addressed by the Cabinet. The members shall include:

- First Assistant to the Prime minister (Chairman)
- Chairman of Cabinet's Advisory Board
- Chairman of Information and Decision Support Center (IDSC)
- Representatives from all National Council of Green Hydrogen members.

The private sector is essential to enable the development of the hydrogen economy in Egypt. The private sector will be invited to participate in council or technical secretariat meetings as required. Moreover, discussions with the hydrogen developers will continue to take place in various roundtable meetings.

5.3 Targets

The 2030 and 2040 vision, introduced in Section 1, and the hydrogen market scenarios presented in Section 4, set the direction and overall ambition for the hydrogen economy development in Egypt outlining key elements of the strategic framework, such as the creation of a leading international export hub for hydrogen and its derivatives, and achieving energy security in the country.

Accordingly, the expected strategic outcomes by 2040 include:

- Production of 5.6 million tons of low carbon hydrogen
- Reaching 8% of the global hydrogen market
- Setting up and localising the electrolyser manufacturing industry
- Contribution to decarbonisation efforts of Egyptian flagship industrial sectors
- Contribution to the growth of the country's economy by boosting GDP (USD 10-18 billion), providing upwards of 100,000 thousand new jobs

5.4 Sectoral Measures

Considering the previously outlined action plan and the outcomes of the priority analysis (see Section 3.2), the following sectorial measures should facilitate the adoption of hydrogen in Egypt:

- Promote the wider use of renewable hydrogen in industry. At the moment, the application of hydrogen is concentrated in oil refining, the fertiliser industry and iron and steel production. These sectors provide a reliable demand and favour greater use of hydrogen. From the cost-effectiveness perspective, renewable hydrogen use should be encouraged especially in those sectors where there is no alternative option to decarbonisation. Following the example of hydrogen front running countries, the measure could be achieved by the introduction of: (a) funding programmes for decarbonising existing hydrogen production, new merchant production, and transformation projects on hydrogen-based fuel switching (i.e., e-fuels, ammonia) and low carbon hydrogen new applications; (b) production support mechanisms for operational expenditures (e.g., ten-year tax credits per kg of hydrogen, feed-in tariff scheme with a ten-year fixed-price subsidy or contracts for difference); (c) binding targets and obligations on demand sectors (e.g. industrial consumers requiring a fixed amount/share of energy/fuels to come from hydrogen) and (d) fiscal policies such as carbon pricing, tax differentiation for goods depending on their climate impact, and tax relieves to enable a partial or total deduction of expenses incurred on green products from taxes;
- Promote and encourage the creation of hydrogen clusters , where hydrogen supply and demand already are or could be located nearby through bringing together relevant market players, viable project concept that leverages local assets and addresses local needs, public support, off-take commitments and efficient operation and maintenance services
- Assess the feasibility of setting low carbon hydrogen targets for the initial market development phase (up to 2030) in those sectors, where electrification is not the most efficient option and where there is no viable sustainable alternative to it. Draft the corresponding sector decarbonisation strategies and action plans that specify emission reduction targets and milestones[5];
- Design financial and administrative support measures for R&D, demonstration, and scale-up projects, such as grants, preferential loans, tax exemptions, or simplified authorisation procedures;
- Design a system for monitoring hydrogen production and consumption (by type of hydrogen, and by consumption sector), for data collection and progress evaluation;
- Encourage the application of renewable hydrogen in the transport sector by promoting hydrogen and fuel cell technologies in local transport (including captive fleets) and ports/terminals. Draft an enabling regulatory framework for the production and consumption of synthetic fuels made from renewable hydrogen. Simplify the process of fuel cell and hydrogen vehicles and vessels approval/certification process. Support the development of a network of hydrogen refuelling stations.

[5] See Green Hydrogen for Industry, A guide to policy making, IRENA, March 2022

- Review the technical, regulatory, and quality aspects relevant from the perspective of injection and use of hydrogen in the natural gas grid, considering the use of the existing facilities for low carbon hydrogen transport and/or storage. In addition, assess the need to adapt industrial and power-generating gas-fired devices to facilitate their safe operation with higher hydrogen concentrations.

6 Financing Mechanisms

Several financial support mechanisms will be required to implement the hydrogen strategy. This section describes the key areas that should be considered.

6.1 Concessional Finance

Today, most low carbon and green hydrogen projects require public funding for improved technology competitiveness and project viability. Concessional finance offers below market rate finance (in the form of low interest loans with a longer repayment period, technical assistance grants, loan guarantees and – to a lesser extent – equity investment with a less value in shares requirement) for targeted projects (e.g., having a transformative effect on a region or sector), often conditioned on achieving specific policy goals (e.g., reducing energy intensity of the economy, specific sectors' decarbonisation rates etc.). Concessional finance is provided by development banks and multilateral funds (e.g., Climate Investment Funds Clean Technology Fund) and could play an important role in accelerating hydrogen technologies deployment and expansion, especially in countries such as Egypt.

Egypt should build on its track record of attracting overseas investment in renewables and use international assistance for launching its first low carbon hydrogen projects. Among the potential donors and international financial institutions supporting the development of the hydrogen market in the country there could be:

- EU institutions with their assistance schemes targeting green transition, including climate resilience, energy, and environment, channelled within the framework of the Economic Investment Plan for the Southern Neighbours (i.e., Egypt and other countries of the south Mediterranean) under the new Neighbourhood, Development, and International Cooperation Instrument (NDICI) for the years 2021-2027. Most probably, this support will be provided in a form of grants, loan guarantees and blended finance (with loans awarded by multilateral development banks, such as EIB, EBRD, IMF and the World Bank).
- Additional funding could be mobilised regarding the planned EU and Egypt signing of an MoU on green hydrogen and ammonia production, which together with the envisaged development of the "Mediterranean Green Hydrogen Partnership" aimed at establishing hydrogen trade between Africa, Europe, and the Gulf will form a basis for investments in hydrogen economy development in Egypt and the region[6].
- EBRD's loans and assistance for the energy sector constitutes another potential source of funding for energy sector infrastructure modernisation, renewables, energy efficiency as well as alternative energy, such as hydrogen.
- Dedicated funds such as: Green Climate Fund (with its adaptation, mitigation, and cross-cutting theme programmes), Climate Investment Funds, Green Growth Fund, and Global Environment Facility will constitute an important source of concessional finance for green hydrogen production.
- Another potential source of assistance for hydrogen production could come through the Gulf Cooperation Council Fund following its active role in supporting renewable energy investment projects.

[6] EU strengthens climate and energy cooperation with Egypt in view of COP27, press release, European Commission, Brussels, 11 April 2022, ec.europa.eu/neighbourhood-enlargement/news/eu-strengthens-climate-and-energy-cooperation-egypt-view-cop27-2022-04-11_en

- Since 2008, the German government has been involved in a long-term energy sector collaboration with its Egyptian counterparts through the Joint Committee on Renewable Energy, Energy Efficiency and Environmental Protection. The cooperation encompasses utility-scale renewable energy facilities, national energy efficiency strategy, renewables and energy efficiency in utilities and industry, climate finance and capacity development. Another opportunity for hydrogen projects development in Egypt could come in relation to the recently launched (EC's approval in December 2021) H2Global funding instrument, which brings together 16 large German firms to buy green hydrogen and its derivatives abroad through long-term contracts and re-sell them in Germany via annual auctions. The difference between the purchase price of the hydrogen derivatives and the sales prices will be covered by funds from the German Federal Ministry for Economic Affairs and Energy. Egypt could also count on bilateral donor assistance from such countries as Italy, UAE, and the US.

6.2 Foreign Investment Possibilities

As previously alluded, Egypt has signed 23 MOUs and nine partnership agreements with a range of low-carbon hydrogen project developers and investors. It is estimated that by 2030 these first pilots should result in 24.63 GW of renewables to supply 9.46 GW of electrolyser capacity. This is planned to increase to 101.3 GW of renewables supplying 43.9 GW of electrolyser capacity over the subsequent phases.

These initiatives are of utmost importance for launching the development of the hydrogen sector in the country. Including a gradually-phased and WTO commitments-consistent local content requirement (to derive a certain amount of the final value of a good or service from domestic firms, either by purchasing from local companies or by manufacturing or developing the good or service locally) will add value to Egypt's economy in terms of technology transfer, new local jobs creation and support in decarbonisation efforts.

The MoUs signed to date send a clear, promising signal to the market and investors, and should be continued. Hydrogen diplomacy being high up on the Government's agenda is a noteworthy element of Egypt's approach that should be supported by the introduction of a transparent set of rules and incentives facilitating hydrogen project implementation (see next section). Following the envisaged pilot phase of MoU implementation, NCGH should establish a dedicated working group that assesses the actual impact of the first hydrogen initiatives on the local economy and analyses the benefits of different business models used to deliver the agreements, e.g. BOT, BOOT, or PPP.

6.3 Support from Egyptian Government

The Egyptian government is aiming to provide an incentive package to support attracting investments to the country's emerging low carbon hydrogen economy.

7 Strategy Progress Tracking System

This section explains the proposed approach to monitoring and assessing the progress in Egypt's Hydrogen Strategy implementation, setting the proposed indicators and metrics that will be used to track and evaluate the outcomes.

The NCGH will be responsible for monitoring the strategy implementation yearly, monitoring the strategy and providing recommendations on its required reviews and updates. While tracking the progress, the principles of flexibility, transparency and forward-thinking, bearing in mind the key drivers of hydrogen market development in Egypt, i.e., creating a leading export market and ensuring the country's energy security, should be applied.

Based on the hydrogen production and uses forecast included in the preceding analysis, the following indicators and metrics are proposed:

If having a **Central** level of ambition

By 2030

- Progress with the implementation of signed MoUs for hydrogen production
- Overall hydrogen production capacity (13 GW) and the corresponding renewable energy capacity (19 GW)
- Low carbon hydrogen use in industry (ammonia and steel production), presented in % or tons.

By 2040

- Overall hydrogen production (48 GW) and the corresponding renewable energy capacity (72 GW)
- Global leadership in the hydrogen export market (5% / 3.5 million tons/year)
- Low carbon hydrogen use in industry (ammonia, methanol and steel production, refineries, heavy-duty transport applications), presented in % or tons
- Contribution to GDP growth by an estimated USD 10-18 billion and job creation by approximately 100 thousand new posts

If having a **High (Green)** level of ambition

By 2030

- Progress with the implementation of signed MoUs for hydrogen production
- Overall hydrogen production capacity (27 GW) and the corresponding renewable energy capacity (41 GW)
- Low carbon hydrogen use in industry (ammonia and steel production), presented in % or tons.

By 2040

- Overall hydrogen production (76 GW) and the corresponding renewable energy capacity (141 GW)
- Global leadership in the hydrogen export market (8% / 5.6 million tons/year)
- Low carbon hydrogen use in industry (ammonia, methanol and steel production, refineries, heavy-duty transport applications), presented in % or tons,

- Contribution to GDP growth by an estimated USD >18 billion and job creation by over 100 thousand new posts

In addition, the proposed system will track and assess:

- Impact of delivering memorandum of understanding and other contracts concluded between Egypt and hydrogen sector developers and investors (in GW of production capacity, investment made, jobs created, export volumes and directions, domestic consumption, and types of applications). Additionally, the Council should be tasked with developing a future framework for MOUs which sets out how projects should maximise the benefits to the national economy, with a range of KPIs, ensuring the renewable electricity used is additional, enabling Egypt to reduce gas demand, and a proportion of hydrogen produced is for the domestic market;
- Effectiveness of government incentives granted to first-of-a-kind hydrogen projects (trends in concluded contracts, committed production capacity, levels of investment, type of beneficiary companies);
- Impact of research and development projects, knowledge transfer, and capacity building programmes as well as public awareness campaign implemented in the framework of the Strategy (number of projects implemented; the number of patents; the number of personnel trained, trends in permitting and licensing procedures eligibility and duration, the target audience of outreach campaigns, perception on hydrogen technologies deployment).

Appendix A
Useful Hydrogen Conversions

Hydrogen Flow Basis	Yearly		Daily		Hourly		Reference conditions
	UOM	Amount	UOM	Amount	UOM	Amount	
Standard Gas Flow	BCMA	**1.00**	mill Sm^3/d	2.74	k Sm^3/h	114.2	1 atm, 15°C
Standard Gas Flow			MMSCFD	96.8	MMSCFH	4.0	1 atm, 15°C
Normal Gas Flow	BCMA	0.95	mill Nm^3/d	2.60	k Nm^3/h	108.2	1 atm, 0°C
Mass Flow	kTPA	85.3	TPD	234	t/h	9.7	
Energy Flow (LHV)	GWh	2841	MWh	7784	MWh	324	
Energy Flow (HHV)	GWh	3358	MWh	9201	MWh	383	
Energy Flow (LHV)					MMBTUh	1107	
Energy Flow (HHV)					MMBTUh	1308	