Ministry of Foreign Affairs

Force Field Analysis Hydrogen Egypt

Analysis on potential collaborations in the field of hydrogen between Dutch and Egyptian stakeholders

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REPORT

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Client: Dutch Enterprise Agency (RVO), EKN-Cairo (Embassy of the Kingdom of the Netherlands in Egypt)

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Acronyms

AUSDE	Arab Union for Sustainable Development and Environment
CERF	Climate and Energy Response Facility
CO2	Carbon dioxide
EBRD	European Bank of Reconstruction and Development
EEHC	Egyptian Electricity Holding Company
EETC	Egyptian Electricity Transmission Company
EKN Cairo	Embassy of the Kingdom of the Netherlands
G2G	Government to government
GHG	Greenhouse gas
GIZ	Gesellschaft für Internationale Zusammenarbeit
H2	Hydrogen
IFC	International Finance Cooperation
LH2	Liquid hydrogen
MoU	Memorandum of Understanding
NREA	New and Renewable Energy Authority
PoR	Port of Rotterdam
SAF	Sustainable Aviation Fuel
SCZone	General Authority of Suez Canal Economic Zone
TSFE	The Sovereign Fund of Egypt

Executive Summary

Introduction

Since 2019, Egypt has been shifting its focus from oil and gas to renewable energy sources. Due to its favourable geographical location close to Europe and with extraordinary solar and wind energy potential, Egypt views green hydrogen as a significant export opportunity. Moreover, the European Union, has set import targets for 10 million tons of low carbon hydrogen annually for 2030. The Netherlands specifically has a large focus on utilising green hydrogen to reduce their carbon footprint. Therefore, a solid relationship and cooperation in the field of green hydrogen could be of added value for both the Egyptian energy transition and securing supplies for Dutch domestic demand.

Purpose

The aim of this study is to provide the Embassy of the Kingdom of the Netherlands in Cairo (EKN Cairo) and the Netherlands Enterprise Agency (RVO), with a comprehensive overview of potential collaboration areas between the Netherlands and Egypt for the advancement of green hydrogen in Egypt. The focus of this report is to highlight specific themes and aspects of green hydrogen development where the Netherlands can offer valuable expertise and support to Egypt. The final goal is to assist Egypt in its transition towards sustainable energy and contribute to the country's efforts in achieving a greener future.

Methodology

The research is composed of three phases:

1. Desk research on the current and potential state of the Egyptian hydrogen market.
2. Interviews in Egypt with important Egyptian and international stakeholders.
3. Analysis on the Egyptian hydrogen market using a market transformation model.

Key findings

This report firstly provides insight into the current market phase of the Egyptian hydrogen market. From this analysis the conclusion can be drawn that the Egyptian hydrogen market is relatively well developed, with multiple frameworks, regulations and incentives in place or being prepared by the government. Furthermore, Egypt has been able to attract many green hydrogen project developers, with an overall of twenty-nine signed MoUs between the government and developers. There are, however, still areas of improvement.

The study highlights several risks and considerations related to Egypt's sustainability targets and the development of green hydrogen. Technical concerns arise from electricity demand for hydrogen production and the impact an electricity grid connection between hydrogen and renewable energy production sites might have on the stability of the grid. Moreover, environmental concerns arise from the potential impact of brine discharges on marine ecosystems due to a potential shortcoming in national regulations governing brine discharges. High initial costs, a lack of off-takers and supply chain risks pose financial and scalability challenges, although these are considered global challenges. Financing may also pose challenges due to associated country risks, such as external debt and high inflation. Addressing perceived risks and providing a stable investment environment is essential for attracting and maintaining investors in Egypt's green hydrogen sector.

Among a series of possible challenges that were found, another potential risk we would like to highlight is that the hydrogen production might interfere with the renewable energy targets set by the Egyptian government. The targets for renewable energy production and hydrogen production could be conflicting as they both will be demanding on the global supply chain of renewable energy technology and on the electricity grid. However, it is unlikely all the green hydrogen projects will be developed within the upcoming decade, which somewhat alleviates the urgency of the matter.

Recommendations

The study identifies significant collaboration potential between Egypt and the Netherlands driven by several factors:

- Egypt's hydrogen market has progressed due to its government's regulations and incentives for hydrogen projects.
- Egypt and the EU both have ambitious hydrogen production targets, indicating a growing potential for hydrogen trade between them.
- Dutch entities possess expertise in areas like green maritime fuel, brine disposal, net congestion, hydrogen transport, and environmental policy, making them possible contributors to Egypt's hydrogen transition.
- Opportunities for government-to-government collaboration exist for technology and knowledge transfer in policy-related aspects.

The shortlist of collaboration opportunities presents promising avenues for advancing green hydrogen initiatives, fostering knowledge exchange, and supporting the transition to sustainable energy solutions in Egypt.
By actively engaging in these collaboration opportunities, The Netherlands can play a crucial role in promoting sustainable green hydrogen practices in Egypt. By sharing expertise, facilitating partnerships, and supporting knowledge transfer, both nations can work together towards a greener and more environmentally friendly energy future.

1 Introduction

Egypt has emerged as a strong player in the international race to develop low-cost exportable hydrogen. In November 2022 Egypt hosted the Convention on Climate Change (COP27), in which four main items were discussed: climate finance, adaptation, loss and damages and increased ambition. Hosting COP27 offered Egypt strategic advantages, including global leadership, economic opportunities, diplomatic relations, knowledge exchange, and domestic policy impact. Egypt showcased its commitment to climate action, attracted investments and strengthened diplomatic ties.

According to the 2023 report on global greenfield investment trends by fDi Intelligence (fDi Markets, 2023), Egypt stood out as the primary beneficiary of greenfield foreign direct investment (FDI) in the Middle East and Africa region last year. In fact, it held the second position globally as the largest recipient of greenfield FDIs. In 2022 alone, Egypt attracted an estimated 107 billion USD in FDIs. This remarkable achievement can be largely attributed to the presence of 17 green hydrogen projects, which accounted for 97% of the total inbound FDI into Egypt in 2022. In terms of project count, the United Arab Emirates (UAE) leads with 879 projects, while Egypt boasts 148 projects.

A force field analysis on the green hydrogen sector in Egypt

EKN Cairo, the Embassy of the Kingdom of the Netherlands in Egypt, believes that supporting the Egyptian government in green hydrogen projects will help implement climate mitigation ambitions and result in climate action, as well as in potential commercial activities. Furthermore, the Netherlands will be an importer of hydrogen to cover the domestic demand in the future. Therefore, a solid relationship and cooperation in the field of green hydrogen could be of added value regarding trade and securing supplies for Dutch domestic consumption.

The goal is firstly, to learn more about the latest status and potential of the Egyptian Hydrogen market by conducting a force field analysis of the green hydrogen sector in Egypt. Secondly, the goal is to provide EKN Cairo and RVO with an overview of cooperation opportunities between the Netherlands and Egypt for the development of green hydrogen in Egypt, with the aim to support Egypt in its energy transition.

Methodology

To gain a comprehensive understanding of the green hydrogen market's development in Egypt, a series of 11 interviews were conducted with key stakeholders. The purpose was to gather insights into the current phase and status of the market. The interview questions were designed using a "transformation model" framework, which helped structure the discussions and gather valuable information from diverse stakeholders. By leveraging this framework, the interviews provided valuable insights into the present state of the Egyptian hydrogen market. Furthermore, this approach facilitated the organization of ideas and identification of potential collaboration opportunities between Dutch and Egyptian stakeholders.

The basis for understanding the market is a framework in which the *System-Loop Market Transformation Model* (Nijhof, 2022) is combined with the *Theory of Market Transformation Phase Model* of Simons & Nijhof (Simons, 2020). Based on this framework we can draw conclusions about the development of the market as well as outline appropriate directions and collaboration possibilities for the future.

Overall, the process that was used to conduct the analysis went as followed:

Desk Research
- Analysis on the current state of Egyptian hydrogen market
- Analysis of the stakeholders in the Egyptian hydrogen market
- Analysis on the potential and the challenges for green hydrogen in Egypt

Interviews
- Definition of interview questions from transformation model framework
- Organisation of eleven interviews with stakeholders in Cairo and Ain Sokhna
- Definition of a list of challenges specific to the green hydrogen market in Egypt

Transformation model
- Plot of interview results in the transformation model
- Definition of the current Egyptian hydrogen market phase from transformation model
- Analysis on how to bring the Egyptian hydrogen market into a more mature market phase

Collaboration
- Recommendation on potential collaboration opportunities with Dutch stakeholders
- Definition of additional effects from the green hydrogen transition in Egypt
- Recommendation on potential focus for additional research

Reading guide

The analysis is done through interviews with key stakeholders in the Egyptian hydrogen market. The interview results are underlined by desk research (Chapter 2 and 3) and the utilisation of a transformation model (chapter 3.4). The result of the study is described in chapter 4, composed of a list of challenges and areas of potential collaboration.

Sector study focuses on green hydrogen

Hydrogen production plays a critical role in Egypt's future energy landscape. Green hydrogen production relies on renewable energy sources like solar and wind. Electrolysis is used to split water into hydrogen and oxygen, with electricity generated from these renewable sources powering the process. On the other hand, grey hydrogen is produced through a steam methane reforming (SMR) process, using natural gas. When addressing the future of Egypt this report will only focus on green hydrogen. The current method of hydrogen production in Egypt is primarily grey.

2 Setting the scene

Hydrogen development is shaping a new global market for cleaner energy alternatives. Its versatility spans across sectors like transportation, industry, and power generation, while challenges like scaling production and infrastructure need addressing. Collaborative efforts, technological advancements, and supportive policies are key drivers in propelling the hydrogen market's transformation towards a cleaner and more sustainable energy future. This chapter focuses on the environment in Egypt in which the green hydrogen sector operates.

2.1 Global green hydrogen supply chain and challenges

The hydrogen supply chain involves the production, purification, storage, and transportation of hydrogen. Several barriers limit current global distribution of hydrogen, such as high hydrogen production cost, the absence of dedicated infrastructure, and the properties of hydrogen that make large scale storage a technological challenge.

The *production* of green hydrogen is done through electrolysis splitting water into hydrogen and oxygen using renewable electricity.

The *transportation* of hydrogen over shorter distances is usually done through pipelines, which are specifically designed to handle high pressure hydrogen. Another method which is utilized for smaller volumes of hydrogen is through high pressure (700 bar) tube trailers. These are trucks that carry multiple hydrogen gas cylinders.

In the case of *overseas export*, hydrogen can be converted into ammonia for easier and cost-effective shipping, which can then be converted back into hydrogen at the destination for utilization or distribution. In addition to converting hydrogen into ammonia for overseas export, another method of transportation in the green hydrogen supply chain is utilizing liquid hydrogen. To convert hydrogen into liquid form, the gas needs to be cooled to extremely low temperatures, below its boiling point of -252.87°C (-423.17°F). This process condenses the hydrogen gas into a liquid state, significantly reducing its volume and making it more feasible for transportation and storage.

The *storage* of hydrogen can be in gaseous, or liquid state. Liquid hydrogen is stored in cryogenic tanks or containers that are well-insulated to maintain the low temperatures required for keeping hydrogen in its liquid state. These cryogenic tanks are designed to minimize heat transfer and prevent hydrogen from evaporating back into a gaseous state. Once the liquid hydrogen reaches its destination, it can be re-gasified and converted back into its gaseous state for utilization or distribution. Gaseous hydrogen is stored at high pressure in either gas cylinders, or in underground storage facilities. For the storage of large volumes of hydrogen, underground salt caverns prove the highest potential. Salt caverns are underground cavities formed in salt deposits. Whether hydrogen storage in salt caverns can prove a suitable solution for Egypt depends on the availability of large underground salt layers. Generally, salt caverns used for industrial purposes, such as natural gas or hydrogen storage, are typically located in salt layers at depths ranging from several hundred to over a thousand meters. The availability of such salt layers in Egypt has not been found in literature.

In general, the emerging green hydrogen supply chain is currently in its infancy, undergoing active development while facing a multitude of technical challenges.

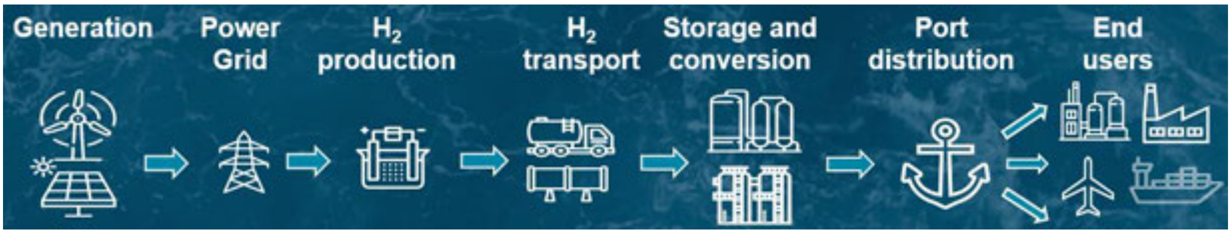

Figure 1: Hydrogen supply chain

2.2 Current Egyptian energy system

Traditionally, Egypt has been heavily dependent on fossil fuels, particularly natural gas and oil, to meet its energy needs. The country has significant reserves of natural gas, which have been a major contributor to its energy production and export revenues. Since 2019, Egypt has been shifting its focus from oil and gas to renewable energy sources. The energy sector is the largest source of Green House Gas (GHG) emissions in Egypt. As such, Egypt's long-term energy strategy is focused on increasing renewable energy generation, becoming a hydrogen hub, and decreasing local energy demand (Ahram Online, 2022). In 2016, the Egyptian government, with support from the Cabinet of Egypt, released the Integrated Sustainable Energy Strategy for 2035, which aimed to reduce the country's energy demand by 18% and increase the share of renewable energy to 42% by 2035. This is illustrated in Figure 2. However, in 2022, Egypt made an important update to this plan by advancing the target to achieve the 42% renewable energy goal by 2030 (Egypt Oil & Gas, 2022). On July 3, 2023, the Egyptian Minister of Electricity and Renewable Energy further revised the strategy, now setting a more ambitious objective of reaching 60 percent dependence on renewable energy by 2040. The high renewable energy targets will require vast improvements on the existing electricity grid.

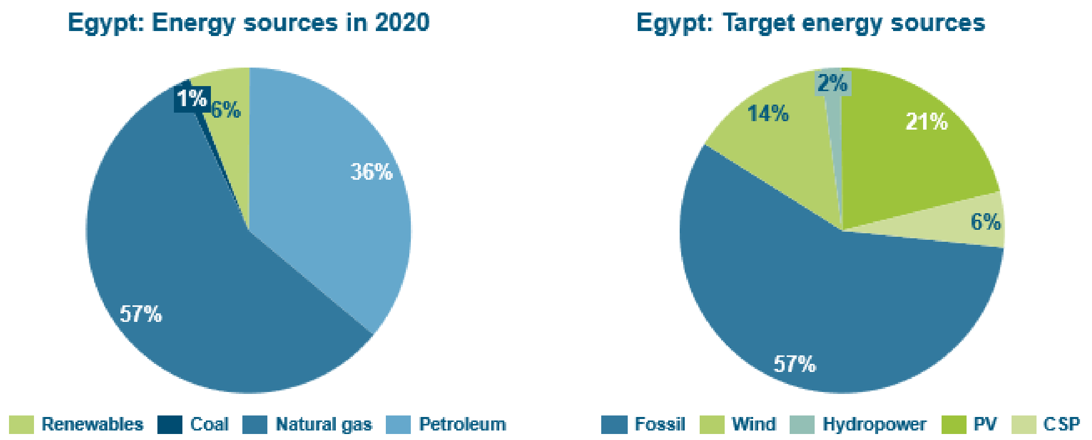

Figure 2: Left: The Egyptian energy sources in 2020. Right: The Integrated Sustainable Energy Strategy targets as set in 2016, meanwhile targets for renewables have been increased from 42% to 60%, specifics on how the target energy sources will adjust are not yet made public. (Egypt Oil & Gas, 2022)

Egypt has also been exploring other sources such as nuclear power to diversify its energy mix. The country has embarked on the construction of its first nuclear power plant, aiming to introduce nuclear energy as a dependable and low-carbon source of electricity. Furthermore, Egypt has been actively involved in regional energy cooperation, seeking to enhance energy trade and collaboration with neighbouring countries. Projects such as the Arab Gas Pipeline and the electricity grid interconnections with Sudan and Libya are examples of Egypt's efforts to strengthen regional energy integration.

2.3 Competitiveness of the Egyptian green hydrogen market

Egypt's strategic geographical location, renewable energy potential, and foreign relations position it as a promising candidate to establish itself as a green hydrogen hub. Within a finished Green Corridor, there will be substantial capacity for generating 12.6 GW of wind power and 57.3 GW of solar power, contributing to the nation's viability as a key player in the global hydrogen market.

From a regulatory standpoint, the Egyptian government is planning to introduce various incentives to turn MoUs into actions and encourage more investments in the energy sector. These incentives will be officially disclosed alongside the publication of the Green Hydrogen Strategy. The strategy, which is being developed in partnership with the European Bank for Reconstruction and Development (EBRD) and the Arab Union for Sustainable Development and Environment (AUSDE), seeks to position Egypt as a significant contributor to the global hydrogen market by aiming for an 8 percent share. Recently, the government has expanded the scope of the 2017 Investment law to include a diverse range of incentives detailed in chapter 3.1., aiming to create a favourable environment for green energy initiatives.

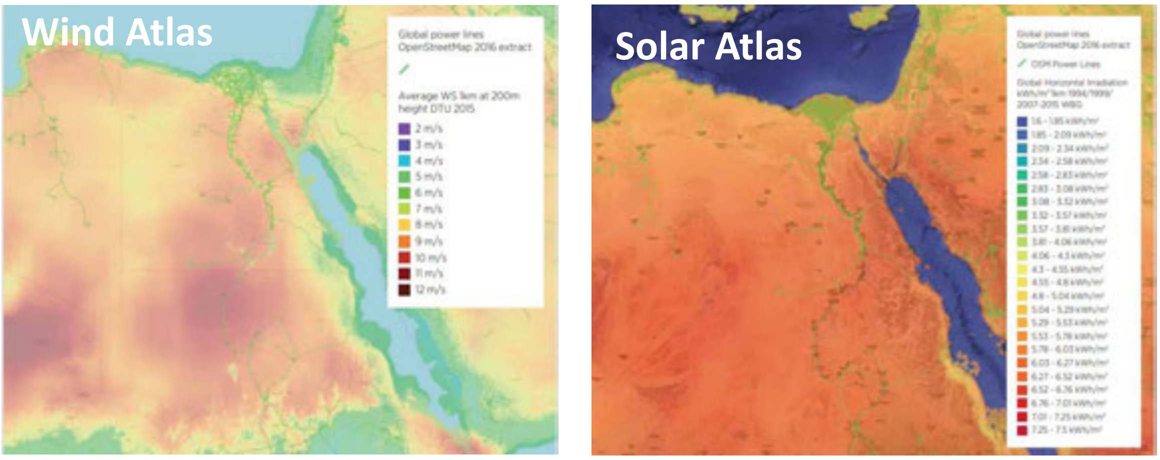

*Figure 3: **Left**: Egyptian wind atlas portraying average windspeeds in Egypt in m/s. **Right**: Egyptian solar atlas, portraying yearly solar irradiance. (IRENA, 2018)*

While Egypt is already using hydrogen locally to produce steel and petrochemicals, hydrogen is primarily being used to produce ammonia and nitrogen-based fertilizers. As of 2022, Egypt's ammonia production capacity stands at 6 million tonnes per annum, all based on hydrogen extracted from natural gas (grey ammonia). Globally, Egypt is the 6th largest urea fertilizer producer, and the 5th largest urea exporter. Existing ammonia production facilities therefore will help facilitate ramping up of production capacity if Egyptian companies are able to make the switch from grey to green production (Ammonia Energy, 2022). In 2021, Egypt exported 327 million USD in ammonia (OEC, 2021). Egypt is well positioned on both the Mediterranean and Red Seas. The Suez Canal Economic Zone has dedicated an area in the Sokhna Industrial Port for green hydrogen projects to allow ease of export to the EU and demanding markets. The main destination of ammonia exports from Egypt (in million USD) are: India (91.6), Netherlands (35), Turkey (32.9), South Korea (32.7) and Jordan (22.5) (OEC, 2021). Trade between the EU and Egypt is well established, and the EU is currently the largest overall importer of Egyptian productions at around 30% of total trade. The EU's hydrogen strategy aims to import 10 million tons of green hydrogen by 2030 (European Commission, 2022).

The country aims to create a Green Energy Corridor, a strategic initiative that focuses on developing and enhancing the country's power infrastructure. The green corridor facilitates the distribution of 100% renewable energy, such as solar and wind, directly from the source to customers, without disrupting or interconnecting with the current grid. The corridor will be located from around Aswan to Ain Sokhna. The primary goal of the Green Corridor is to facilitate the smooth integration of 70GW of renewable energy sources, such as solar and wind, into the national grid. By achieving this objective, the Green Corridor will play a crucial role in supporting Egypt's ambitious renewable energy targets.

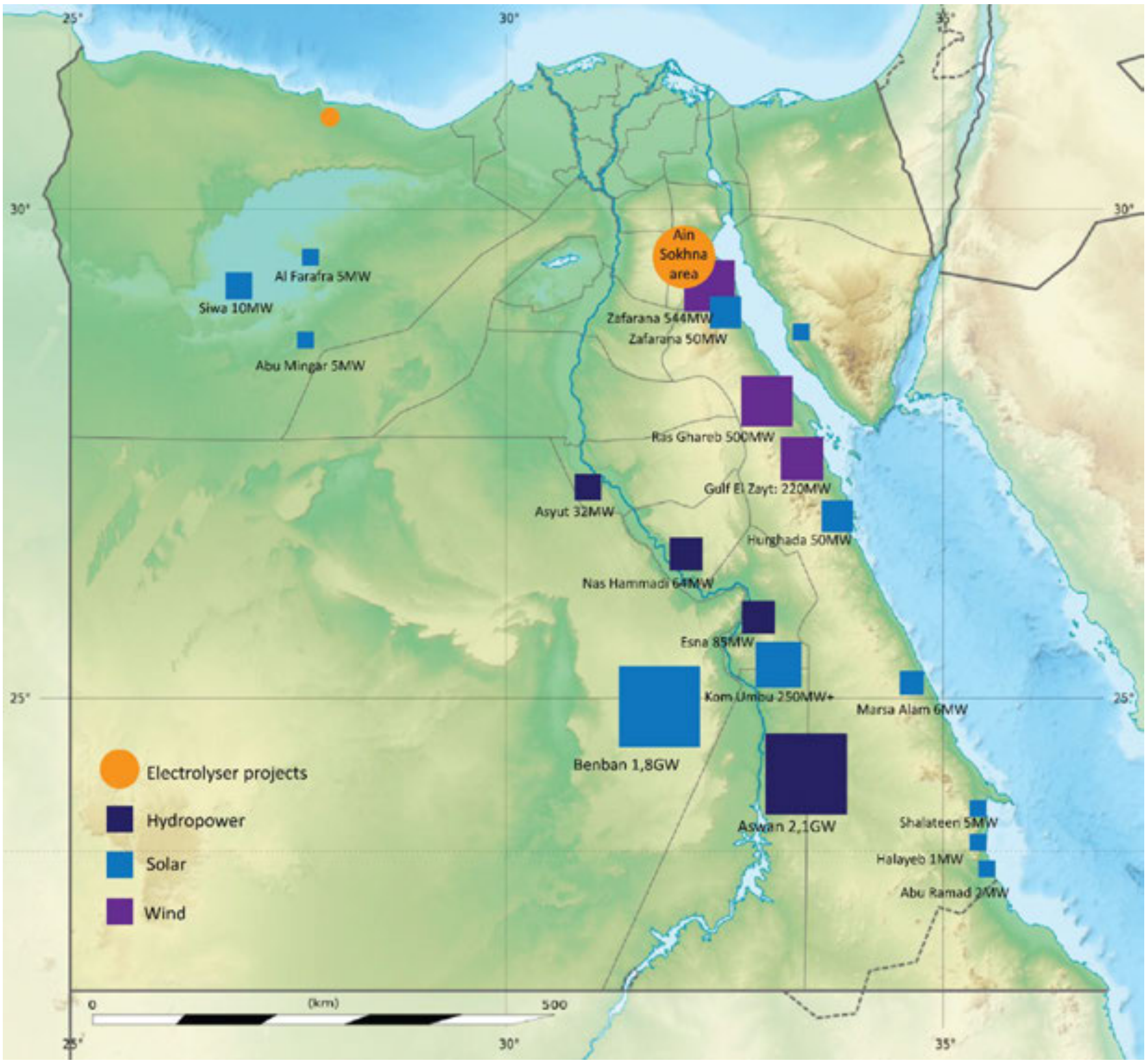

Figure 4: Overview of under development and operating renewable energy projects in Egypt.

The Egyptian government plans to designate land for the production of renewable energy aimed at generating green hydrogen. This land will be located inland, adjacent to the river Nile, extending over 800 km south from the Suez region. As a result, the green electricity generated will need to be transported across a considerable distance to the port, where it will undergo the conversion process into hydrogen. Renewable energy production locations compared to the Ain Sokhna area are illustrated in Figure 4.

2.4 Socio-economic context of the green hydrogen market in Egypt

Socio-economic factors limiting the potential for a growing green hydrogen economy in Egypt

Egypt faces various economic headwinds towards achieving its hydrogen potential. Debt levels in Egypt have risen to 155 billion USD in the first quarter of fiscal year 2022/2023 as reported by the Central Bank of Egypt (Ahram, 2023). In 2023, 45% of Egypt's budget is forecasted to be devoted to servicing national debt while inflation currently sits at around 30% (National Interest, 2023). Since 2022, the Egyptian pound has witnessed a massive devaluation, with exchange rates against the dollar going from around 16 EGP/USD to 31 EGP/USD. Such sudden changes added to the inflationary pressures and scarcity in foreign currency, impeding the country's ability to import various goods and services.

The economic challenges described might impact the speed of developing a green hydrogen economy in Egypt and the ability of the government to provide the necessary incentives for realizing the country's hydrogen ambition. Egypt's funnel of green hydrogen opportunities will compete against other global projects, many of which are in developed economies providing lucrative incentives such as the US's Inflation Reduction Act.

The economics of green hydrogen for domestic energy and industrial use cannot compete with electricity and fossil fuel-based solutions, at this stage. Switching domestic industrial and power use to a much more expensive hydrogen fuel compared to locally produced natural gas will be a challenge given the current local economic climate. This will limit the utilization of the produced green hydrogen to export markets either as a fuel medium or for industries targeting "green product" export such as steel and fertilizer production.

In addition, the increase in debt level with the subsequent impact on credit rating, coupled with the rising global interest rates increases the cost of financing for the planned green hydrogen projects.

On the social side, Egypt's green hydrogen strategy is expected to generate 100,000 jobs (Ahram Online, 2022). Whilst Egypt has experience in developing solar, wind and hydropower, experiences in green hydrogen production are currently limited. Lack of experience in the field of hydrogen is however a global challenge and not limited to Egypt.

Socio-economic factors that provide opportunities for a growing hydrogen economy in Egypt

Egypt's cost-effective labour force presents significant opportunities for developing green hydrogen infrastructure, attracting international companies to invest in the country's growing industrial base.

Egypt has a strong skilled and unskilled low-cost labour force base which helps strengthen its competitive advantage in developing infrastructure projects such as green hydrogen. The recent devaluation of the currency has further strengthened this position. Training programs by internationally experienced entities are essential and should focus on green hydrogen production, safety, storage, transportation, and regulation (HyDEX, 2023). Particularly, for the handling of ammonia, sufficient training centres are already in place in the Suez region.

To meet the required hydrogen demand both in Egypt and globally, the supply chain base for equipment and materials would require massive scaling up. This would provide an opportunity for international companies including Dutch suppliers in setting up manufacturing bases in Egypt for various components of the value chain including electrolysers. The Egyptian government is strongly supporting the expansion of the country's industrial base, particularly now as the country navigates its ongoing economic challenges.

Water Scarcity and global warming impact

Water scarcity is one of the biggest environmental and socio-economic challenges facing Egypt. A UNICEF report (UNICEF, 2021) highlights that Egypt has witnessed an annual water deficit of around seven billion cubic meters over the past years. The water challenges in Egypt are a result of soaring population of over 100 million people coupled with other factors such as the building of the Great Renaissance Dam in Ethiopia.

The increasing demand for water in urban and industrial areas located in arid and semiarid coastal zones has led to the exploration of alternative nonconventional water resources. Desalination plants are considered a feasible solution to address the significant water demand in arid regions, including Egypt. The country faces limitations in its water resources, primarily relying on the Nile River, and is expected to experience drought due to climate change and the construction of upstream dams. Desalination plants offer a potential means to mitigate water scarcity and meet the rising water demand in these challenging environments.

Egypt has recently expanded its water desalination capacity. Egypt currently has a desalination capacity of 917,000 m3 per day (Smart water magazine, 2022). At the end of 2022, the government announced an ambitious plan to expand the water desalination capacity by 8.8 million m3 per day with phase one of the program delivering 3.3 million m3 per day (Reuters, 2022).

Desalination plants use seawater through their intakes, extract and purify the water and have brine as a rest product. Brine is a solution that consists of water with a high concentration of dissolved salts. The brine is usually directly discharged back into the sea. However, these effluent brine discharges can create heightened levels of seawater temperature, salinity, and other substances that may have adverse effects on the water quality in the plant vicinity if they are not disposed correctly. Such changes in water quality can significantly impact the marine life and species living in the area.

For every cubic meter of desalinated seawater, up to one and a half cubic meters of brine or reject water from the desalination plants are disposed of into the sea or ground. Improper environmental control of this process can cause detrimental impacts on the marine environment. There are no national regulations for brine disposal specifically; however, the Egyptian Environmental Affairs Agency stated in the Waste Management Law No.202 of 2020 that it is illegal to dump hazardous materials or waste into the regional sea, continental shelf, exclusive economic zone, or high seas of Egypt (art.64) (UNEP, 2020). There are also regional regulations, mainly for the settlements along the Red Sea. This is due to the sensitive nature of the coral reefs in the region. (El-Sadek, 2009).

Other options for brine disposal are to further process the brine, to extract more water and to use the salts and minerals for other end products (Ariono, 2016). Several methods to process brine and to reuse it for other purposes are mentioned below:

Energy intensive discharge:

- Brine concentrator
- Crystallizer
- Spray dryer
- Evaporation pond
- Solar evaporation
- Wind-aided intensification of evaporation

Land application:

- Irrigation of salt tolerant crops and grasses
- Fish farming
- Spirulina (algae) cultivation

3 Developments in the green hydrogen sector in Egypt

The establishment of a functional supply chain requires the complex simultaneous development of multiple elements, collaboration among stakeholders, the implementation of legal frameworks, and the creation of incentives to drive the process forward. This chapter describes the activities in the hydrogen sector in Egypt.

3.1 Key stakeholders involved in the current hydrogen development in Egypt

Nine Egyptian state entities have been identified as key stakeholders that engage in permitting and/or participating as partners in the signed MoUs related to green hydrogen projects. A summary is given in the table below **(Stakeholders interviewed for this research have been highlighted in Red).** The full list of MoUs is found in Appendix A1.

Table 1: Stakeholders in the Egyptian hydrogen market, governmental bodies

Stakeholder	Description
Suez Canal Authority (SCA)	The SCA is responsible for all operations in the Suez Canal area, including anchorage services, piloting through the canal and during port entry & departure, tugging, and overall coordination of marine traffic in SC ports and the canal. SCA has deployed the 'green passage' initiative to promote the energy transition within its activities.
The Suez Canal Economic Zone (SCZone)	The Suez Canal Economic Zone owns 5 ports currently operated by the SCA, wherein the SCZone coordinates licensing, project development and provides incentives to potential investors. They attract and lease land to project developers in multiple zones and ports around the Gulf of Suez. Project developers have incentives set by government to develop in the SCZone. (See chapter 3.1)
Electricity Egyptian Holding Company (EEHC)	The Egyptian Electricity authority was established in 1976 to be responsible for all power plants, transmission, and distribution networks. In July 2001, the EEHC and subsidiaries were reconstructed, and the number of subsidiaries became sixteen companies, of which there are six companies for electricity production, nine companies for electricity distribution and the Egyptian Electricity Transmission Company (EETC). Currently EEHC is a partner in multiple MoUs related to green hydrogen projects.
The Sovereign Fund of Egypt (TSFE)	TSFE is a private investment fund established in 2018 (in accordance with law 177 of 2018) to shape, manage, and promote opportunities for investment in Egypt's state-owned assets by creating partnerships and co-investments with private investors. Currently partner in multiple MoUs related to green hydrogen projects. Helps setting up the right legal frameworks and procedures to ensure (international) private parties to invest. Takes part in private projects as an equity partner (<20% shareholder). Promotes the transition to privatizing public assets.
Ministry of Electricity & Renewable Resources	The Ministry of Electricity & Renewable Resources is the main point of contact to develop green hydrogen projects. They are responsible for renewable electricity in Egypt, they are the owner of electricity related public assets such as natural gas power plants.
New and Renewable Energy Authority (NREA)	NREA is the government institution which oversees the promotion and development of renewable energy projects which include solar and wind energy in Egypt. They are currently a partner in multiple MoUs related to green hydrogen projects. They oversee the allocation of plots of land for renewable energy production to project developers.

General Authority for Investment and Free Zones (GAFI)	GAFI has potential administrative authority for green hydrogen & energy transition projects & manages the newly established "Golden License [1] " initiative, which will allow comprehensive approvals & licensing
Ministry of Petroleum & Mineral Resources	The Ministry of Petroleum and Mineral Resources is responsible for the oil and gas sector, they own public assets related to the oil and gas sector.
Egyptian Natural Gas Holding Company (EGAS)	EGAS was established in August 2001, as an entity mandated to focus on the natural gas activities, adapting an effective action plan to organize and diligently handle the activities of the natural gas resources of Egypt to add value to the Egyptian economy.

Table 2: Stakeholders in the Egyptian hydrogen market, banks & NGO's

Stakeholder (non-Egyptian)	Role in green hydrogen
European Bank for Reconstruction & Development (EBRD)	The EBRD is funded by 71 countries. Their goal is to help set up a healthy investment climate, provide financial support in feasibility studies and eventually finance projects (loans) for green hydrogen. They have played a key role as a link between international project developers and the Egyptian governmental bodies. They are working with the European Union to support green hydrogen projects in the Suez Canal Economic Zone as part of a new green hydrogen strategy being launched in Egypt.
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)	GIZ is an NGO funded by German government that helps to set up legal frameworks and focuses on capacity building in the green hydrogen sector.
International Finance Corporation (IFC)	Similar role as **EBRD**, however they are somewhat less present. Are involved in helping setup a healthy investment climate.

The public stakeholder landscape is complemented by private companies, which have capabilities and aspirations to participate in the emerging green hydrogen economy and wider energy transition landscape in Egypt.

[1] The "Golden License" in Egypt is a comprehensive approval granted to companies for establishing, operating, and managing projects, including building licenses and property allocation. It may include various incentives provided by the Investment Law and is given to projects contributing to sustainable development or public-private partnerships in specific sectors. (The General Authority for Investment, 2022)

3.2 Egyptian hydrogen ambitions, policy, and incentives

Green hydrogen ambitions

Building on the existing renewable energy foundation and the set renewable energy targets, Egypt has started developing a green hydrogen strategy in coordination with EBRD. As of August 15, 2023, the strategy has not been published yet, but the government has announced the strategy's ambitious goals during COP 27 including (Ahram Online, 2022):

- Acquire 8% market share of the global hydrogen market by 2050
- Green hydrogen to increase the country's GDP by $10-$18 billion by 2050
- Produce green hydrogen at the cheapest cost globally of $1.7/kg by 2050

The strategy is expected to reduce Egypt's reliance on imported oil and add over 100,000 jobs. In 2022, Egypt signed framework agreements for 9 hydrogen projects with a total cost of $85 billion, which are expected to generate 45,000 and 230,000 direct and indirect jobs respectively (Egypt Today, 2022). There is also a National Energy Strategy (2016) that entails targets for decarbonization and renewable electricity generation of a 100[2] GW by 2035.

Egypt hydrogen regulation

Currently, hydrogen projects in Egypt will be governed by the existing Gas Market Law No. 196 of 2017 since there is no specific law for hydrogen gas (Riad & Riad, 2022). The law is regulated by Egypt's Gas Regulatory Authority (GASREG), an independent public body that regulates Egypt's gas market activities, monitors the gas market, approves gas codes, grants licenses, implements tariffs calculation methods for gas services, and resolves conflicts between market stakeholders (Gas Regulatory Authority, n.d.). Shown below is a list of the relevant laws and ministerial decrees (Riad & Riad, 2022; Riad & Riad, 2016).

Table 3: Current Egyptian laws involved with the hydrogen economy.

Subject	Law	Ministerial Decree
Hydrogen	Gas Market Law No. 196 of 2017	Ministerial Decree No. 239 for 2018
Electricity	Electricity Law No. 87 of 2015	Ministerial Decree No. 230 of 2016
Renewable Energy	Renewable Energy Law No. 203/2014	
Environment	Environment Protection Law No. 4 for 1994	Ministerial decree No. 338 for 1994
Nuclear and Radiological Activities	Law No. 7 for 2010 Regulating Nuclear and Radiological Activities	Ministerial Decree No. 1326 for 2011
Suez Canal	Special Economic Zone Law No. 83 of 2002	Ministerial Decree No. 1625 of 2002 Ministerial Decree No. 2282 of 2015
Ports		Ministerial Decree No. 566 for 2002 regarding the conditions and controls for carrying out activities at the Egyptian Ports

[2] *The 100 GW was mentioned during an interview with NREA*

Egypt hydrogen incentives

Egypt will implement specific incentives, to be included in the hydrogen strategy, for green hydrogen projects to attract investments (Ahram Online, 2023). The current incentives for green hydrogen projects are based on Investment Law No. 72 of 2017, Cabinet Decrees No. 981 of 2022, and No. 104 of 2022 (Shehata & Partners, 2022). Egypt will be the first country to implement this type of production cost reducing incentives. Listed below is the list of the known incentives for green hydrogen projects in Egypt:

- 5 years exemption from stamp tax, some notarization and registration fees
- 2% fixed customs tax rate for imported equipment required for project's construction and operation
- Corporate tax rebate between 30-50% of the investment value for a duration of 7 years from the project start of operations date. The 30-50% is dependent on project location, with a higher incentive being given to projects set up in areas which are designated as "requiring development" by the Central Agency for Public Mobilization and Statistics such as the Suez Canal Special Economic Zone and the New Administrative capital (Riad & Riad, 2022).
- Companies can establish new customs points to enable products imports or exports
- Egyptian government may finance, partially or fully, utilities connection to the projects
- Egyptian government may partially finance technical staff training.

Hydrogen project allocation procedures

There is a procedure in place for launching green hydrogen production projects. These procedures make it easier and attractive for project developers to invest in hydrogen production projects in Egypt. The aim of this procedure is project development and is described as followed for the project developer:

1. Contact the Ministry of Electricity & Renewable Energy about your interest regarding the development of a green hydrogen project in Egypt.
   Developers:
   - Submit pre-feasibility study (technically and financially).
   - Submit PowerPoint presentation discussing green hydrogen project road map and their strategy.

   Sovereign Fund:
   - Provides requirements needed to sign MoU.

2. Sign a non-binding MoU. This MoU is signed between the project developers and the EEHC, NREA, TSFE and SCZone, see also chapter 0. After this MoU is signed, the project developers receive the first information on locations etc. so that a feasibility study can be conducted. It is mandatory that the project developer develops the entire supply chain, from renewable energy production to green hydrogen export. Therefore, the project developers often consist of a consortium. In total 42 GW will be allocated in the first renewable electricity plot east of the river Nile 850 km land inwards provided by the government dedicated to green hydrogen production. Furthermore, the government will facilitate the transportation of the electricity molecules towards Ain Sokhna port. In the port the SCZone will provide plots for electrolysers and ammonia production and will facilitate common user infrastructure such as pipelines, an export jetty, and desalination capacity. Storage can either be provided by a common user infrastructure or privately by the project developer on another piece of allocated land by SCZone.

3. Once the results are positive and the project developer wishes to continue the process, the next step is to sign a framework agreement with EEHC, NREA, TSFE and SCZone to further the commitment of the parties. This agreement provides, among other things, certainty on land allocation through government

commitment. The information provided in this stage can be used by project developers in their pre-Final Investment Decision (FID) phase. Part of this agreement is that the project developer commits to a schedule with agreed milestones and a 2M USD commitment bond to be paid by the project developer. The framework agreement sets out a timeline whereby project developers must carry out an initial pilot project followed by a second expansion phase to full production.

- Before or after the framework and based on the feasibility study and projected cost of hydrogen, ammonia, or hydrogen derivative, the developers' top management will decide on the produced end product and the quantities.

4. After the decision of developers' top management on the produced end product and its quantities, comes the Front-End Engineering Design (FEED) stage and then the Engineering, Procurement and Construction (EPC) stage.

   As green hydrogen projects are multi-themed, they involved many government entities. It is therefore sometimes difficult for international parties to navigate this involvement with the various local entities. For example, the plot allocation process would be clearer if there is only one entity responsible for hydrogen. During the interviews it was mentioned the government has the intention to work towards one entity, once the first green hydrogen projects have proven to be successful.

Memoranda of Understanding (MoU) signed

A total of 29 MoUs has recently been announced in relation to green hydrogen developments in Egypt. Egyptian green hydrogen agreements can be classified in two key categories:

- Hydrogen development projects and strategic agreements aiming to accelerate Egypt's domestic hydrogen economy.
- Green hydrogen projects mainly targeting development in the Suez Canal zone and aiming to export to the European market.

Projects are targeting hydrogen and ammonia production for a variety of uses including fertilizer production, marine bunkering, and fuel export. The maturity level and targeted development speed of the announced projects differ widely. A full list of MoUs, complete with scope, investments and references is found in the Appendix A1, Table 4 shows a summary.

Table 4: Memoranda of Understanding signed between Egyptian and international stakeholders

	Parties	Scope
1	EBRD, NREA, Ministry of Petroleum & Mineral Resources	*Develop a national hydrogen strategy.*
2	Orascom, SCATEC, Fertiglobe, TSFE	*100 MW electrolysers for 90.000 tons ammonia*
3	Siemens, EEHC	*100-200 MW electrolysers*
4	Belgian Consortium (DEME, FLUXYS, Port of Antwerp), EEHC, Abu Qir Company for Construction and management of Ports, EGAS	*500 MW of electrolysers, 700 MW wind and 800 MW solar*
5	Maersk, TSFE, SCZone, NREA, EETC	*MoU to develop green fuel for marine bunkering in the Suez Canal Economic Zone*
6	AMEA power, SCZone, TSFE, EETC, NREA	*390.000 tons of ammonia*
7	H2-Industries, SCZone	*Waste to hydrogen: 300.000 tons of H2*
8	Zero-Waste, Electricite de France, SCZone, TSFE, EETC, NREA,	*350.000 tons of ammonia, 650 MW solar*

9	SCZone, TSFE, EETC, NREA, Abu Dhabi Future Energy Company, Hassan Allam Utilities Company	*Two H2 plants of total: 4GW electrolyser, 480.000 tons H2, 2.3 million tons ammonia*
10	BP, NREA, EETC, SCZone, TSFE	*Feasibility study for H2 export hub*
11	Taqa Power, Votilia, SCZone, TSFE, EETC	*1 GW electrolysers, 2,7 GW solar and wind, 150.000 tons of H2*
12	ENI, EGAS, EEHC	*Feasibility of green and blue H2*
13	GE, PGESCO, Hassan Allam Construction, EEHC	*Strategic coop agreement on co-firing h2 for electricity production*
14	ACWA Power, SCZone, TSFE, EETC, NREA	*Feasibility study for H2 production.*
15	China Energy, SCZone, TSFE, EETC, NREA	*140.000 tons of H2*
16	DAI Global Company, SCZone, TSFE, EETC, NREA	*Feasibility: 2 million tons of ammonia*
17	OCIOR Energy, SCZone, TSFE, EETC, NREA	*1.1 million tons of ammonia*
18	Chemical Industries Holding Company, SCZone, TSFE, EETC, NREA	*Feasibility study on green ammonia*
19	ReNew Power, ELSEWEDY ELECTRIC, SCZone, TSFE, EETC, NREA	*220.000 tons of H2*
20	Globaleq, SCZone, TSFE, EETC, NREA	*3.6 GW electrolysers, 9 GW solar and wind*
21	Alfanar, SCZone, TSFE, EETC, NREA	*500.000 tons of ammonia, 100.000 tons of H2*
22	Fortescue Future Industries, SCZone, TSFE, EETC, NREA	*330.000 tons of H2*
23	Total Eren, Enara Capital, SCZone, TSFE, EETC NREA	*1.1 million tons of ammonia*
24	Actis, SCZone, TSFE, EETC, NREA	*Electrolysers from wind*
25	Toyota Tshusho, EGAS	*Feasibility for blue ammonia*
26	DNV, Petrojet	*H2 knowledge exchange*
27	Ministry of Petroleum, NREA, EU Commission – EU Green Deal	*Cooperation and trade agreement for H2*
28	Ministry of Petroleum, EU Commission for Energy, Ministry of Energy of Israel	*Cooperation on H2 for public sector*
29	Ministry of Petroleum, NREA, Ministry of International Cooperation, German Federal Ministry for Economic Affairs and Climate Action, German Federal Ministry of Economic Cooperation and Development.	*Trade agreement for H2 and LNG*

3.3 Current hydrogen activities in Egypt and potential future use cases

Current hydrogen demand

Currently Egypt relies on grey hydrogen for its hydrogen demand. Egypt produces hydrogen through the steam methane reforming process (SMR) using natural gas (The Oxford Institute for Energy Studies, 2021). In 2019, Egypt decommissioned the KIMA plant, an electrolysis-based ammonia plant located in Aswan (Ammonia Energy Association, 2023). Hydrogen production and consumption data in Egypt are not published, however, studies estimate the hydrogen market in Egypt at 1.8 million tons annually (The Oxford Institute for Energy Studies, 2021). For reference, the import target for the EU in 2030 is 10 million tons annually.
Hydrogen usage in Egypt is concentrated in four primary areas:

Table 5: Estimated current grey Hydrogen demand in Egypt

	Usage	Calculation basis	Quantity/%
1	Hydrogen usage in ammonia production in the fertilizer industry 7.8 million tons of nitrogen fertilizers	• 4.2 million tons of ammonia produced annually • 18% hydrogen in ammonia (based on molecular weight)	756 kilotons, 41%
2	Hydrogen usage for direct reduced iron production	• 8.95 million tons of direct reduced iron produced annually • 71.9 kg hydrogen required per ton iron	643 kilotons, 35%
3	Hydrogen usage for hydrotreating (or hydrodesulfurization) to remove sulphur and other impurities from petroleum products	• 204 million barrels refined annually (27.8 million tons annually) • 10.8 kg hydrogen required for hydrotreating per ton petroleum	300 kilotons, 16%
4	Hydrogen usage for methanol production (syngas)	• 1.2 million tons of methanol produced annually (Methanex, 2021) • 12.5% hydrogen in ammonia (based on molecular weight)	150 kilotons, 7%

Potential hydrogen demand and uses

During COP 27, The Egyptian Minister of Electricity and Renewable Energy presented an outline of Egypt's future hydrogen strategy (Reuters, 2022). The strategy highlighted Egypt's future hydrogen uses including fertilizer production, marine fuel, or fuel export in the form of ammonia or methanol, and transportation fuel including jet fuel, road- and rail transportation.

Green hydrogen export

Similar to Egypt's current hydrogen usages, many industries rely on grey hydrogen globally. The EU has established a hydrogen strategy and the REPowerEU plan that focuses on replacing fossil fuels with renewable and low carbon hydrogen (European Commission, 2022). The EU targets renewable hydrogen production and import of 10 million tons each by 2030. Green hydrogen is primarily expected to be used in transportation, and for industrial uses. Due to Egypt's close geographical location to Europe, multiple projects, currently under study, are targeting to supply

Europe with green hydrogen. An overview of these projects, applicable to more than just exports to the EU, is listed in Table 6, a full list is found in the Appendix A1.

Fertilizer production

Egypt is the world's fifth largest fertilizer exporter (The North Africa Post, 2022; State Information Service Egypt, 2023). Currently, there are over 10 green ammonia development projects in Egypt, mainly targeting European market export. Europe is targeting a carbon emissions reduction of 55% by 2030 and carbon neutrality by 2050 (Ammonia Energy Association, 2022). To achieve this goal, Europe must integrate carbon emissions reduction in the fertilizer sector, providing Egypt with a potential opportunity to sell green fertilizers or ammonia to Europe.

Marine and aviation fuel

The International Maritime Organization (IMO), a United Nations agency focused on marine regulation, has set a 50% carbon emission reduction target in 2050 compared to 2008 emissions for marine shipping (International Maritime Organization, n.d.). To achieve this target, the marine shipping industry must partially replace fossil fuels with low carbon or renewable fuels. Currently, renewable, or low carbon fuels such as methanol, hydrogen, and ammonia are expected to be the most feasible global shipping fuel alternatives while other fuels such as renewable natural gas, bioethanol, and biodiesels are more feasible for short distances (Xing, 2021). Egypt's geographical location makes it an ideal renewable marine bunkering hub since an estimated 12% of the global trade passes through the Suez Canal (Riad & Riad, 2022). Currently, there are green marine fuel development projects under assessment, one led by Maersk International, the other by Electricite de France (EDF) and Zero-Waste.

A similar export product that has potential in the future is renewable aviation fuel. Two viable options that see potential are Liquid Hydrogen (LH2) and Sustainable Aviation Fuel (SAF). To produce SAF, biofuels or carbon captured carbon dioxide (CO2) are reacted together with hydrogen to produce a synthetic fuel that can replace conventional jet fuel. 85% of the EU's aviation fuel should be sustainable by 2050 following targets set in Fit for 55 (European Parliament, 2022), this creates a large potential market for both LH2 and SAF. Egypt specifically has potential to produce SAF and LH2 for domestic consumption in the aviation sector. SAF also has great export potential. SAF is liquid in atmospheric condition, making it easy to transport. Challenges regarding LH2 transportation are explained in chapter 2.1.

Iron and steel production

The iron and steel industry's CO2 emissions account for 4% and 9% of Europe's, and the world's emissions, respectively (European Parliament, 2022). Egypt currently uses 643 kilotons of grey hydrogen for iron production. Multiple European companies are shifting to green hydrogen to reduce CO2 emissions from iron production. Egypt's largest iron and steel importers are Spain and Italy (Zawya, 2023). Egypt can implement a similar approach and produce low carbon iron, especially for export to Europe.

Industrial high temperature processes

Hydrogen holds promise for industrial applications, particularly in high-temperature processes. Despite global efforts to reduce fossil fuel usage, certain industrial processes are challenging to electrify due to their operating temperatures. In such cases, fuel combustion may be necessary or more cost-effective, and hydrogen has been proven to be a suitable replacement for natural gas in these high-temperature applications. Examples of sectors that can benefit from hydrogen in the transition to net-zero are the refinery sector, the chemical sector, glass production, cement production, and waste processing,

Peak electricity balancing

Over 75% of Egypt's electricity comes from fossil fuels (International Renewable Energy Agency, 2018), with natural gas being the primary energy source. To reduce reliance on natural gas and decrease CO2 emissions, the Egyptian

Government, GE, and Siemens are examining the feasibility of co-firing, which involves blending hydrogen with natural gas for electricity generation. In the future, as Egypt strives to achieve its high renewable energy targets, there may be significant peaks in electricity generation. To address this challenge, green hydrogen production can be utilized as a means of temporary energy storage. Technologies such as co-firing or fuel cells can be employed to generate electricity during periods of low renewable energy production.

Built environment

Studies in the UK (Tommy Isaac, 2019) explore blending hydrogen into the national gas grid to reduce carbon emissions. However, this approach is questionable even in the UK and highly unlikely to be economically viable in Egypt due to the significantly lower gas prices. Instead, another viable option is integrating hydrogen into off-grid energy systems for energy storage. In such systems, solar power can be utilized to generate electricity during the day, while hydrogen storage and fuel cells can supply electricity during night-time hours.

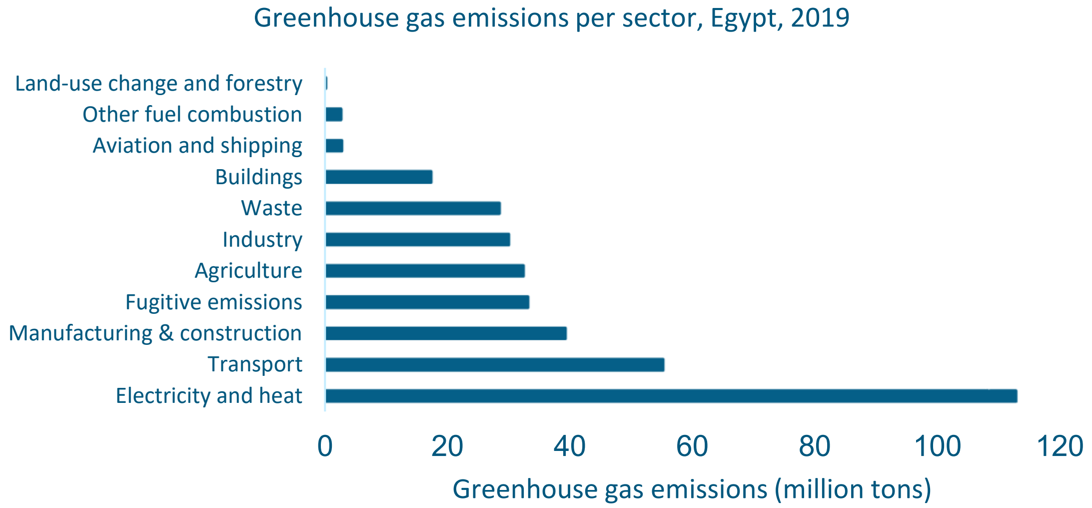

Figure 5: Carbon dioxide equivalent (CO2eq) emissions per sector in Egypt for the year 2019 (Our World in Data, 2020)

Mobility sector

As seen in **Error! Reference source not found.**, around 16% of greenhouse gas emissions in Egypt come from the transport sector excluding aviation and shipping. Although electrical vehicles have the largest short-term potential to abate these emissions there can still be a place for hydrogen particularly in the heavy transport sector, for example for long-haul freight transport and buses. These will essentially be electrically powered but use fuel cell technology and hydrogen as their energy source.

The development of hydrogen consumption within Egypt

Of the above-mentioned demand purposes for hydrogen, it is expected that in the short term the hydrogen will be primarily used for production processes that focus on exportable products. Given the current premium costs associated with green hydrogen production, it is unlikely that Egypt will transition significantly towards local use of green hydrogen within the next decade(s). The higher expenses involved in producing green hydrogen compared to conventional fossil fuel-based alternatives make it challenging to achieve widespread adoption and economic feasibility in the short term. However, advancements in technology and scaling up of production may gradually reduce costs, paving the way for increased use of green hydrogen in the future. The timing of the transition to green hydrogen is dependent on the cost reduction time path.

In the meantime, Egypt has additional opportunities to drive its energy transition. Notably, the country has already made significant steps in shifting from fossil fuels to cleaner natural gas, and its primary focus in the coming decade is shifting toward producing green electricity. This shift alone has a substantial impact on the energy transition. Moreover, Egypt can work on the electrification of its various sectors, as this proves to be a more efficient and cost-effective approach compared to hydrogen. However, due to the intermittent nature of electricity and the unsuitability of certain industrial processes to run on electricity, a comprehensive solution involves green hydrogen. Eventually, this resource will become vital to ensure a sustainable, uninterrupted energy supply and enable sectors that cannot rely solely on electricity to become sustainable.

Presently, Egypt is concentrating on both the transition to green electricity production and the export of green hydrogen. Meanwhile, the international hydrogen market is expected to evolve, leading to cost reductions. This progress sets the stage for local implementation of green hydrogen within Egypt, thereby addressing the remaining energy needs that cannot be met through electrification alone. Ultimately, the current development of Egypt's green hydrogen projects with an export focus is a crucial long-term strategy for achieving energy neutrality in the country.

3.4 Transformation models used for analysis of the green hydrogen market in Egypt

To gain a comprehensive understanding of the green hydrogen market's development in Egypt, a series of 11 interviews were conducted with key stakeholders. The purpose was to gather insights into the current phase and status of the market. The interview questions were designed using a "transformation model" framework, which helped determine the market phase in which the players in the Egyptian market currently are. The “market transformation model” was then applied to determine desirable actions to bring the market into a more mature phase. A more detailed description of the transformation models and the analysis can be found in Appendix A3.

The results showed that even though hydrogen supply chain technology is still in its developmental phase, the market has already achieved a significant level of maturity in Egypt compared to other competing countries. The government has started to implement regulations, incentives, and procedures regarding hydrogen projects and several large-scale hydrogen production projects are being realized. Nevertheless, the green hydrogen market is not mature yet, hence opportunities for collaboration have been identified for both government-to-government support as well as for project developers, as elaborated further in chapter 4.2.

However, a notable difference exists between the market phase in which governmental bodies are operating and that of project developers. The government appears to have a head start over project developers, suggesting that significant government-to-government (G2G) collaboration specifically in establishing procedures and legal frameworks might not be necessary. This is largely because entities such as EBRD, GIZ, and IFC are already fulfilling this role by aiding the government in advancing toward a mature market. Instead, more urgent challenges lie with project developers who are grappling, for example, to secure off-takers – a substantial bottleneck in reaching market maturity. While the market phase for project developers remains relatively low, it underscores a potential area for collaboration, as elaborated further in chapter 4.2.

System-loop market transformation model

The system-loop market transformation model states that there are four generic system loops that create a certain unsustainable outcome when they coincide. There are loops that have a reinforcing effect and loops that cause an imbalance or negative effect. The four loops are:

- Loop 1: *Market dynamics*: (reinforcing loop) focuses on what the market rewards and competes that lead to an unsustainable outcome.
- Loop 2: *Enabling environment*: (reinforcing loop) focuses on structures that support, strengthen and goals that prevent a sustainable outcome.
- Loop 3: *Mismatch benefits and effects*: centers on actors that are affected by the negative outcomes/unsustainable outcome.
- Loop 4: *Lack of alternatives*: which portrays if there are acceptable and viable alternatives visible that can be used to change behavior and thereby options to move from the negative outcomes/unsustainable outcome.

The system-loop market transformation model gives insight on how far the market is developed (the more stable, the further developed). Knowledge about the phase the market operates in is important. This model was used to set up the interview questions.

Theory of market transformation phase model

The model of Simons & Nijhof proposes a comprehensive framework to guide the market development of hydrogen through four distinct phases, each requiring specific actions from various stakeholders to move forward to the next market stage:

- **The inception phase** is when stakeholders have a general idea, but specific ambitions are still developing. There is a lack of structure, policies, or regulations, and limited resources like capacity and finance may be present. The stakeholder field is unclear, and the emphasis is on experimentation, setting up pilots, stimulating development, fostering innovations, and creating a sense of urgency.
- In **the competitive phase**, stakeholders pursue specific ambitions and actively seek collaboration opportunities to achieve their goals. Some structures are in place, but room for improvement remains. Policies and regulations are yet to be established, and sufficient resources are available on average. The focus is on improving activities to realize the ambition and develop a coordinating strategy, with organizations playing a relevant role in rewarding innovations and supporting progress.
- During **the pre-competitive and collaborative phase,** stakeholders work towards a shared ambition and coordinating strategy. Activities align with the common goal, emphasizing scaling up, with the government playing a consultative role. While some structures exist, improvements are possible. This phase involves policy and regulation development, supported by sufficient resources. The stakeholder landscape expands to include more companies, and monitoring activities, such as publishing market data or gathering emission data, start to take shape. Stakeholders play a crucial role in creating structures, facilitating development, and providing support to drive progress and achieve collective objectives.
- **Institutionalization**, the final phase, the coordinating strategy is integrated into relevant institutions. The focus is on monitoring activities to reinforce established policies and regulations. Clear structures, multiple policies, and sufficient resources are in place. The main objective is to further institutionalize existing regulations and improve monitoring. Stakeholders' roles in this phase involve promoting transparency, supporting institutionalization, and providing policy advice.

4 Future of the Egyptian hydrogen market

This chapter discusses the future of the Egyptian hydrogen market by looking at current challenges of the green hydrogen transition in Egypt.

4.1 Challenges of the green hydrogen transition in Egypt

The list below displays the challenges that are found through the desk research and the interviews.

Structure and regulations challenges in Egypt

1. **The existing project developer selection criteria could benefit from further refinement.**
   Currently, the study has found that criteria to select project developers, which plan to produce green hydrogen, can be better defined. As explained in chapter 3.1 there are plenty of incentives in place and a clear procedure to attract project developers to invest in the Egyptian hydrogen market. Although the attracted project developers are well-known experienced parties, there are no written down rules yet as to which project developers can sign MoUs. Currently, the project developer selection criteria are limited by the required pre-feasibility study and the 2M dollar commitment bond. In a more mature market this process would be more regulated, with stricter guidelines to establish technological knowhow, environmental consideration, experience, and financial capacity of project developers.
2. **Guidelines to distribute plots amongst developers could benefit from further refinement.**
   This study has not found sufficient criteria on how land is allocated for renewable energy production between the different project developers. Every project developer that signs a framework agreement gets a piece of land allocated in a specific area for generation of renewable energy. The process for allocation of this land between project developers is not entirely clear and could benefit from refinement.
3. **The current national regulations on brine discharge need to be further explored.**
   Currently, the government is planning several large-scale desalination projects, of which only a small part is dedicated to the production of green hydrogen. Specifically, for the green hydrogen projects, the planned desalination plant will dispose of brine in an eco-friendly way according to the Suez Canal Economic Zone. If brine is incorrectly discharged it can lead to environmentally harmful effects to the local eco system. Currently, it is not clear to us whether local regulations are sufficient to ensure brine discharge is done in an eco-friendly manner, hence further exploration is recommended. Since this is a new and important subject for Egypt, there is room for cooperation by international entities with experience on the subject.
4. **There is not one governmental entity responsible for hydrogen but several.**
   During the interviews it became clear that the Ministry of Electricity & Renewable Resources is in the lead for hydrogen projects. However, project developers have to engage with several other bodies as well. To make it clearer for developers, centralizing all activities related to hydrogen under a unified hydrogen entity would be beneficial.
5. **The EU should be aware that a large focus on green hydrogen import could affect national sustainability targets.**
   The renewable energy needed for hydrogen production might hinder future progress in making Egypt more sustainable. Although green hydrogen is envisioned as a clean energy source, its main application will be outside Egypt, with most of the produced hydrogen destined for export. The higher expenses involved in producing green hydrogen compared to conventional fossil fuel-based alternatives make it challenging to achieve widespread adoption and economic feasibility in the short term.

Currently, 42 GW of renewable electricity is planned to produce green hydrogen. Moreover, the Egyptian targets for renewable electricity are set at 100 GW[3]. For reference, the current total installed capacity in Egypt is 60 GW. To reach the targets huge projects need to be developed, requiring a lot of resources, workforce and logistics. The feasibility of accomplishing both objectives — constructing 100 GW for local renewable targets and establishing 42 GW for green hydrogen production — within the next ten years is challenging. However, it is unlikely that the entire 42 GW of green hydrogen projects will be developed within the upcoming decade, which somewhat alleviates the urgency of the matter.

6. **The transition to a hydrogen economy can have social implications on the demographic that is dependent on the traditional energy system.**
   The transition to a green hydrogen economy may have social implications, particularly for communities dependent on traditional energy sectors. Job displacement or shifts in employment opportunities can occur, requiring careful planning and investment in workforce reskilling and social support programs.

Capacity building challenges

7. **There is an overall need for expert knowledge and awareness on the topic of hydrogen and renewable energy.**
   From the discussions during the interviews this study has found sufficient awareness and knowledge from the responsible departments. However, the interviews also pointed out that outside of the responsible governmental bodies for hydrogen and renewable energy, there is an overall need for awareness on hydrogen and renewable energy topics. Specifically considering the necessary and noticeable switch that is happening in Egypt from fossil fuels to renewable energy and considering the factors that make Egypt a highly competitive location for hydrogen production. A lack of awareness and knowledge about climate change, renewable energy and hydrogen in the government can work against a successful transformation of the Egyptian energy system.
8. **There is a need for expert knowledge and capacity on green fuel bunkering.**
   Since over 30% of global container traffic traverse the Suez Canal, Egypt stands at the heart of global trade. This gives the SCZone the potential to make significant impact on reducing the carbon emissions from global maritime trade by providing green maritime fuel to passing vessels. To do so, it should become a top priority for the SCZone and related parties to become an expert on the topic of green maritime fuel bunkering and production. Supplying green fuels to ships could create a substantial local hydrogen demand, offering Egypt a means to capitalize on hydrogen production beyond its export potential. Nevertheless, green bunkering fuels are more difficult to handle than fossil fuels and require new safety systems and a skilled workforce.

Technical/environmental challenges

9. **Large green hydrogen production projects will put pressure on the electricity grid**
   At present, plans for renewable energy production and hydrogen production sites are located far apart, with hydrogen production centred near Ain Sokhna and renewable energy production further inland along the green corridor, this is illustrated in Figure 4. To transport the electricity generated, a considerable capacity on the electricity grid is needed. Egypt is presently planning on connecting substantial capacities of renewable electricity to the grid, firstly, for the national renewable electricity targets, and secondly, for the generation of green hydrogen over a distance exceeding 800 km in Ain Sokhna. This could impose substantial

[3] *The 100 GW was mentioned during an interview with NREA*

pressure on the electricity grid, potentially resulting in a highly unstable grid. The EEHC mentioned they have hired two consultants to investigate the future grid stability, and are considering the possibility of a "Green Corridor" which would be a dedicated grid for renewable energy which does not interface with the existing grid. An alternative approach could involve putting hydrogen production closer to renewable energy sources and transporting hydrogen through pipelines, thereby circumventing electricity transportation losses. Further research could explore the balance between electricity losses caused by the distance from Ain Sokhna and the allocation of plots based on energy production potential.

10. **There is a scarcity of water in Egypt, demand will increase slightly by hydrogen production.**
    There is a shortage of (demineralized-) water required for the hydrogen production process. Desalination plants are planned to provide the required water; however, the brine discharge may have negative environmental impact. Nevertheless, SCZone mentioned they are planning on attracting an off taker for the brine from the planned desalination plant in the Suez Canal Economic Zone dedicated to green hydrogen production. To put the extra water demand into perspective, the targeted 42 GW of hydrogen production would generate an approximate extra water demand of 28,5 MCM, this accounts for around 0,04% of the water demand from agriculture in Egypt and around 1,9% of total rainfall in Egypt (Nature, 2021).
11. **There is a global shortage on supply chain technology**
    There is a global shortage on the production of required supply chain technologies, such as the production of electrolyser stacks and wind turbines. The production of green hydrogen relies on various technologies and supply chain components, including electrolysis equipment and renewable energy systems. Egypt may face challenges related to technology dependence and supply chain risks, such as shortages, price volatility or limited availability of critical components such as electrolyser and wind turbines, which can impact the scalability and reliability of green hydrogen projects.
12. **There is limited availability of existing and natural hydrogen infrastructure**
    For a nationwide demand for hydrogen to develop, a national gaseous hydrogen distribution network is required. It is unlikely that Egypt will repurpose the existing natural gas pipelines for hydrogen use in the short term due to the high price of hydrogen compared to the local price of natural gas. There is no known salt cavern possibility in Egypt for large scale hydrogen storage, certainty on this subject would require further study.
13. **Transportation and export technologies are still under development**
    Overall, there are several challenges considering the export of hydrogen, or hydrogen carriers, as technologies are still being developed, an example of this is the conversion, storage and export of liquid hydrogen.

Investment/financial challenges:

14. **There is a lack of hydrogen off-take globally.**
    Currently, there is a significant lack of global hydrogen offtake, to such an extent that projects cannot be financed. This is also related to the challenge of attracting project developers to invest. Multiple subsidy and certification schemes are being developed in the EU (REpowerEU, Horizon Europe, REACT-EU, and H2Global) and in the US (Inflation Reduction Act). Key approaches look to be contracts for difference (CfD), government-led purchasing programs, and tax credits. The effects of these government schemes are yet to be seen.

15. **The global hydrogen market is not yet fully developed.**
    Early-stage high-risk green hydrogen projects face a significant challenge in obtaining Final Investment Decisions (FID) due to their dependence on long-term offtake agreements. These projects encounter multiple obstacles, such as the scarcity of willing off-takers who are prepared to pay a premium for green hydrogen, coupled with the absence of a fully established green hydrogen market. The transition from relying solely on expensive long-term offtake agreements in an early stage to the creation of a more attractive wholesale trading market for green hydrogen introduces considerable investment risks and presents a noteworthy challenge.
16. **Country risks can limit foreign investments.**
    Project developers may be dealing with associated country risks, such as external debt and high inflation. Egypt has a history of state-owned assets; however, the country has recently initiated a shift from state participation towards a more privatized asset structure. This is done to boost the share of private investments in the economy and reduce the external debts. The Sovereign Fund of Egypt was created with the aim to package and promote a wide array of state assets to private investors. With the signing of a new loan from the International Monetary Fund (IMF) a strategic program was made by the government in December 2022 which sets out the economic sectors from which the state plans to withdraw in the coming years, and those in which it intends to increase or reduce its involvement (Al Monitor, 2023). Nevertheless, the transition from a state involved mindset towards privatised markets takes time. Some energy assets are still publicly owned, and the Ministry of Petroleum and Mineral Resources hinted during their interview at plans to co-invest in downstream hydrogen related projects of already owned assets.
17. **Significant infrastructure investments are required from the Egyptian government.**
    Significant transformation, transportation, and storage infrastructure investments are required to enable Egypt to achieve its hydrogen goals. The initial costs associated with developing green hydrogen infrastructure, such as expansion of the electricity grid and common user infrastructure, can be significant. This may pose financial challenges, especially considering the large distances in current plans between hydrogen and renewable energy production. Considering Egypt's national debt, Egypt might encounter issues realizing the required infrastructure, while the absence of national infrastructure can hinder green hydrogen FDIs.
18. **Competition from other countries to deliver low-cost hydrogen.**
    There is competition by other countries to produce hydrogen that are considered more stable and have better, or comparable, renewable energy conditions. Example countries outside of North Africa with a low projected levelized cost of hydrogen in 2050 are: India, China, Chile, Colombia, Saudi Arabia, US, Australia, Mexico, and Spain (IRENA, 2022). Within North Africa, Morocco is making strides to become a regional leader in a green hydrogen economy.
19. **There is currently a shortage of foreign currency and there is a high inflation rate.**
    The shortage of foreign currency and the significant weakening of the Egyptian pound—around 20% against the USD in 2023—have led to high inflation rates. To address this, the Central Bank of Egypt (CBE) raised interest rates by 200 basis points in March. However, this move has affected investment and economic activity.

Structure and regulations challenge EU/global:

20. **Current regulations regarding requirements for green hydrogen production are ambiguous.**
On June 20, 2023, the European Union officially published two delegated acts that provide detailed rules on the EU's definition of renewable hydrogen. The first act outlines the conditions under which hydrogen, hydrogen-based fuels, or other energy carriers can qualify as renewable fuels of non-biological origin (RFNBOs). The second act presents a methodology for calculating life-cycle greenhouse gas emissions for RFNBOs.
These new rules are applicable to both domestic producers and international producers exporting renewable hydrogen to the EU. The rules are significant for the development of green hydrogen projects aiming to export hydrogen to the EU but are currently not yet implemented. However, obtaining more information about the specific criteria and details of these regulations is necessary to support the practical implementation of the framework.
21. **It is uncertain how the regulations in the EU hydrogen market are going to develop.**
The EU has set European-wide criteria for the certification of renewable and low-carbon hydrogen. These criteria also affect imported hydrogen from Egypt. The EU is also in the process of establishing a pilot scheme for a Carbon Contracts for Difference program, along with an EU-wide hydrogen pipeline and multiple investment and subsidy schemes. Since these market tools and investments are either newly introduced or under development, their effects are not yet fully known, which makes it difficult to predict a return on investment for green hydrogen projects.

Expected challenges that are being taken care of in Egypt

Some challenges were expected prior to the desk research and interviews, but have been solved or partially solved by Egypt:

- The green hydrogen project development procedure – the EBRD and TSFE have helped the government set up an attractive governmental procedure for consortia to start the development of a green hydrogen project. Although there is still some confusion among project developers on the number of governmental bodies involved, it is a great step towards a mature hydrogen market.
- Renewable electricity grid connection – EEHC has hired two consultants to investigate the incorporation of substantial amounts or renewable electricity into the grid.
- Meeting green hydrogen standards – The government has the intention to set up the green hydrogen projects in such a way that they will meet the green hydrogen requirements as set up by the EU. An example of this is the determination of whether to utilize the existing Egyptian electricity grid for transmitting electrons to produce green hydrogen or to construct a new dedicated electricity grid. This choice depends on the evolving EU guidelines for green hydrogen.
- Skilled workforce – Egypt has already experience with export of ammonia and LNG. Furthermore, there are three training centers in the Suez Canal region to train the workforce on ammonia handling and safety issues related to other gases and liquids.
- Production cost reduction by providing incentives and common user infrastructure – The government is making it attractive for project developers to enter the Egyptian market as the production costs are decreased as much as possible via tax breaks and common-user infrastructure.

4.2 Collaboration opportunities

Through review of interview results and the market phase framework an analysis is done for Embassy of the Kingdom of the Netherlands in Cairo, and the Climate and Energy Response Facility, to create a list of potential collaboration opportunities for Dutch companies in the Egyptian hydrogen sector. The focus of these opportunities is partly on enabling Egypt to reach its sustainability goals by government-to-government collaboration and partly on increasing trade between Egypt and the Netherlands. For more information on the highlighted possible areas of collaboration please reach out EKN Cairo or RVO.

Overall, the study sees great potential for collaboration between Egypt and the Netherlands. This is due to the following factors:

- The Egyptian hydrogen market has achieved a certain level of advancement, due to regulations and incentives set by the Egyptian government to promote hydrogen and hydrogen derivative projects.
- Targets for hydrogen production in Egypt are high, with 29 MoUs already signed. The European Union on the other hand targets 10 million tons of hydrogen import by 2030. Both sides are growing towards a future of hydrogen trade between Egypt and the EU. With the upcoming hydrogen trade potential between the EU and Egypt, it is becoming intriguing for Dutch companies interested in hydrogen to explore opportunities in Egypt.
- Dutch companies, research organizations and other stakeholders are well equipped to help Egypt with technological, regulatory, and knowledge-based aspects of the hydrogen transition. For example, on the topic of green maritime fuel, brine disposal, net congestion, hydrogen transport and environmental policy.
- Although the investment climate in Egypt holds challenges as explained in chapter 4.1, these challenges also give rise to the possibility of government-to-government collaboration in areas of technology and policy driven knowledge transfer.

In Appendix A4, a long list of collaboration opportunities is displayed which can serve as a source of inspiration for areas of potential collaboration. The list focuses not only on areas where the Netherlands can be of added value, but views possibilities for the Egyptian hydrogen sector as a whole.

5 Conclusion

This study on the Egyptian hydrogen market has been conducted in three phases.

- Phase 1 involved desk research to gather information on the current and potential state of the market, including policies, regulations, and key stakeholders.
- Phase 2 comprised interviews with important Egyptian and international stakeholders, which, combined with the desk research, formed the basis for analysis and collaboration recommendations.
- In phase 3, a transformation model was created to analyze the market's current phase and identify collaboration opportunities for its expansion.

Egypt's strategic location, renewable energy potential, and foreign relations position it as an ideal candidate to become a green hydrogen hub. The country's Green Corridor has the capacity to generate significant wind and solar power. The current grey hydrogen market in Egypt is estimated to be 1.8 million tons annually.

From a regulatory standpoint, the government is supportive and offering incentives to facilitate the translation of Memoranda of Understanding (MoUs) into actionable projects and encourage further investment. A procedure is in place for launching green hydrogen production projects, with a focus on project development. Although it is clear that the Ministry of Electricity & Renewable Energy is in the lead, the involvement of multiple governmental bodies can be confusing for project developers in the initial stages.

According to recent announcements, there have been 29 MoUs related to green hydrogen developments in Egypt. The Egyptian hydrogen market has achieved a certain level of advancement, due to regulations and incentives set by the Egyptian government. However, there is a difference in the market phase between governmental bodies and project developers, suggesting opportunities for collaboration to further mature the Egyptian hydrogen market and facilitate project development.

Several challenges have been highlighted throughout the study. The government's targets for renewable electricity production in Egypt may conflict with the production of green hydrogen. The conflict would be caused by a competition on the global supply chain for renewable energy technology and by competition on electricity grid availability. Additionally, securing long-term offtake agreements for high-risk green hydrogen projects is difficult due to the absence of a green hydrogen market and limited off-takers willing to pay a premium. Financing may also pose challenges due to potential associated country risks, such as external debt and high inflation. Furthermore, there is a global shortage of supply chain technologies required for green hydrogen production.

In conclusion, the study highlights the potential of the Egyptian hydrogen market as a green hydrogen hub, identifies challenges and collaboration opportunities, and provides recommendations for future actions to foster the growth of the market. By addressing these challenges and leveraging collaborative efforts, Egypt can unlock the full potential of its hydrogen market and contribute to a sustainable and green energy future.

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A. Appendix

A1 MoUs signed

Table 6: Memoranda of Understanding signed between Egyptian and international stakeholders

	Parties	Scope of Work	Investment & Production	Comments	Reference
1	• Ministry of Electricity and Renewable Energy • Ministry of Petroleum & Mineral Resources • EBRD	MoU to develop a national low-carbon hydrogen strategy including the global hydrogen market, and Egypt's green hydrogen production potential	N/A	Egypt's Minister of Petroleum and Mineral Resources announced in March 2023 that the hydrogen strategy is in its final stages	(European Bank for Reconstruction and Development, 2022), (Daily News Egypt, 2023), (European Bank for Reconstruction and Development, 2023)
2	• TSFE • Orascom • SCATEC (Norwegian) • Fertiglobe	Agreement to develop a green hydrogen plant for green ammonia production, 90,000 tons of green ammonia annually.	• 100 MW of electrolyser (260 MW of solar and wind). • 15,000 tons hydrogen • $80 million	• Final Investment Decision (FID) on the project in 2023 • The ammonia will be used for export and replace grey ammonia used by the Egyptian Fertilizer Company	(Orascom Construction, 2022), (European Bank for Reconstruction and Development, 2023)
3	• Siemens Energy • EEHC	MoU to develop a pilot project to set up the green hydrogen ecosystem in Egypt including green ammonia for export, hydrogen co-firing, and green hydrogen for steel production	• 100 - 200 MW of electrolyser	• Siemens 2030 roadmap includes 1.5 – 3.0 GW hydrogen projects	(American Chamber of Commerce in Egypt, 2022)
4	• Belgian Consortium (DEME, FLUXYS, Port of Antwerp) • EEHC • Abu Qir Company for Construction and Management Ports • Egyptian National gas Holding company	Cooperation agreement to conduct feasibility studies for green hydrogen projects and build a 500 MW project for export to Europe	• 500 MW of electrolysers (700 MW of wind and 800 MW of solar)	• 2,000 jobs while being constructed and over 500 permanent jobs once it becomes operational, along with other indirect jobs.	(Finance, 2022)

	Parties	Scope of Work	Investment & Production	Comments	Reference
5	• SCZone • TSFE • NREA • EETC • Maersk International	MoU to develop green fuel for marine bunkering in the Suez Canal Economic Zone	N/A		(Offshore Energy, 2023)
6	• AMEA POWER • SCZone • TSFE • EETC • NREA	MoU to produce green ammonia for export	• 390,000 tons of green ammonia over two phases		(AMEA Power, 2022)
7	• H2-Industries • SCZone	MoU to build a waste-to-hydrogen plant	• 300,000 tons of green hydrogen • $3-4 billion		(Enterprise Ventures, 2022), (the National News, 2022) (SCzone, 2022)
8	• Electricite de France (EDF) • SCZone • Sovereign Wealth Fund of Egypt • EETC • NREA • Zero-Waste (Sawaf family)	MoU to produce green ammonia for marine bunkering	• 350,000 tons of green ammonia • 650 MW solar and wind	Production to begin for phases 1 and 2 in 2026, and 2030, respectively.	(EDF Renewables, 2022)
9	• SCZone • TSFE • EETC • NREA • Abu Dhabi Future Energy Company (Masdar), • Hassan Allam Utilities Company	• MoU to develop two hydrogen plants in the Suez Canal Zone, and on the Mediterranean • Green hydrogen for local market • Green ammonia for export	• 4 GW • 480,000 tons of green hydrogen • 2.3 million tons of green ammonia	Production to begin for the Suez Canal Zone plant in 2026	(Zawya Projects, 2022)
10	• BP • NREA • EETC • SCZone • TSFE	MoU to conduct a feasibility study for a green hydrogen export hub in Egypt	N/A		(BP, 2022)

	Parties	Scope of Work	Investment & Production	Comments	Reference
11	• Taqa Power • Voltalia • SCZone • TSFE • EETC	MoU to produce green hydrogen	• 1 GW electrolysis capacity • 2.7 gigawatts of solar-and-wind power • 150,000 t of green hydrogen	Project to start initially with 100 MW and ramp up to 1 GW.	(TAQA Arabia, 2022)
12	• Egyptian Natural Gas Holding Company (EGAS) • EEHC • Eni	MoU to collaborate in studying the feasibility of green and blue hydrogen in Egypt	N/A		(Egypt Ministry of Petroleum, 2023)
13	• GE • EEHC • Hassan Allam Construction • PGESCO	Strategic cooperation agreement to study the feasibility of co-firing hydrogen with natural gas for electricity production	N/A	Operated GE's gas turbine on hydrogen blended fuel during COP 27.	(General Electric, 2022)
14	• SCZone • TSFE • EETC • NREA • ACWA Power	MoU to study the feasibility of green hydrogen production	No information available	ACWA is building a $1.5 billion project in Egypt, the largest wind power project in the middle east	(Egypt Oil and Gas, 2022)
15	• SCZone • TSFE • EETC • NREA • China Energy (China Energy Engineering Corporation)	MoU to produce green hydrogen to export green ammonia to Europe	• 140,000 tons of green hydrogen • $5.1 Billion	Construction to begin in May 2023	(ESI AFRICA, 2023)
16	• SCZone • TSFE • EETC • NREA • DAI Global company	MoU to study the feasibility of green ammonia production	2 million tons of green ammonia		(DAI Infrastruktur , 2023)
17	• SCZone • TSFE • EETC • NREA • OCIOR Energy	MoU to study the feasibility of green ammonia production potentially for export to Europe	1.1 million tons of green ammonia in two phases	• Phase 1, 2027, 0.1 million tons of green ammonia • Phase 2, 2030, 1 million tons of green ammonia	(Ocior, n.d.)

	Parties	Scope of Work	Investment & Production	Comments	Reference
18	• SCZone • TSFE • EETC • NREA • Chemical Industries Holding Company	MoU for a feasibility study on green ammonia production	No information available	Chemical Industries Holding Company currently operates multiple grey ammonia plants in Egypt	(Ahram Online, 2022)
19	• ReNew Power • ELSEWEDY ELECTRIC • SCZone • TSFE • EETC • NREA	Framework Agreement to develop a green hydrogen plant	220,000 tons of green hydrogen in two phases	• Final Investment Decision (FID) for the project 12-16 months from November 2022 • Phase 1, 2026, 20,000 tons of green hydrogen • Phase 2, 200,000 tons of green hydrogen	(ElSEWEDY ELECTRIC, 2022)
20	• Globeleq • SCZone • TSFE • EETC • NREA	MoU to develop a green hydrogen plant for ammonia fertilizers	• 3.6 GW of electrolysis capacity • 9 GW of solar PV and wind power generation	• Project to be conducted in 3 phases • Phase 1, 100 MW electrolysis capacity for green ammonia fertilizers	(GLOBELEQ, 2022)
21	• Alfanar (Saudi) • SCZone • TSFE • EETC • NREA	MoU to develop a green hydrogen plant for ammonia fertilizers and other hydrogen uses locally and internationally	• $3.5 billion • 500,000 tons of green ammonia • 100,000 tons of green hydrogen		(Reuters, 2022)
22	• Fortescue Future Industries (FFI) • SCZone • TSFE • EETC • NREA	MoU to study and develop a green hydrogen plant for export to Germany	• 7.6 GW • 330,000 tons of green hydrogen	Project to be completed over multiple stages, from 2027 to 2030.	(Daily News Egypt, 2022)
23	• Total Eren • Enara Capital • SCZone • TSFE • EETC • NREA	MoU to build a green ammonia plant	1.1 million tons of green ammonia after all stages	• Gradual production increase from 300,000 tons of ammonia to 1.5 m tons • Production to begin in 2025	(Enterprise, 2022)

	Parties	Scope of Work	Investment & Production	Comments	Reference
24	• Actis • SCZone • TSFE • EETC • NREA	MoU for green hydrogen development	No information available	Actis has invested in renewable energy projects in Egypt through Lekela Power's 250 MW West Bakr wind farm	(Actis, 2022)
25	• Egyptian Natural Gas Holding Company (EGAS) • Toyota Tshusho	Conduct feasibility studies //for blue ammonia production using carbon capture, use and storage (CCUS)	No information available		(Argus Media group, 2022)
26	• DNV • PETROJET	MoU to provide PETROJET with technical expertise	N/A	PETROJET aims to be a green hydrogen EPC contractor	(DNV, 2023)
27	• Ministry of Petroleum & Mineral Resources • Ministry of Electricity and Renewable Energy • EU Commission - European Green Deal	MoU for cooperation on production, usage, investment, and trading of green hydrogen and its derivatives	N/A		(European Commission, 2022)
28	• Ministry of Petroleum & Mineral Resources • EU Commission for Energy • Ministry of Energy of Israel	MoU to encourage public sector to shift to green hydrogen usage and production	N/A		(European Commission, 2022)
29	• Ministry of Petroleum & Mineral Resources • Ministry of Electricity and Renewable Energy • Ministry of International Cooperation • German Federal Ministry for Economic Affairs and Climate Action • German Federal Ministry for Economic Cooperation and Development	Declaration of intent for cooperation on green hydrogen and LNG trade	N/A		(German Federal Ministry for Economic Cooperation and Development, 2022)

A2 Interview questions

Table 7: Interview questions

General information
Date: Stakeholder and name interviewee: Type of stakeholder (public/governmental, private, NGO, finance or other): Interviewer:
Topic ambitions, opportunities, and challenges
1. What ambitions does your organization have regarding the development of green hydrogen? 2. Elaborating on the ambition, which opportunities are visible for your organization as well as the country regarding green hydrogen? 3. Which (general) challenges are visible in realizing the stated ambitions
Topic activities
4. Which activities and/or projects are currently present to stimulate the development of green hydrogen? What works and what does not work in these activities and/or projects? 5. Does the organization respond enough to the potential of green hydrogen? In case of no, what is needed to do so?
Topic structures and policies
6. Which structures are currently in place that support or stimulate the development of green hydrogen? What is going well in these structures? And what could go better? 7. Are there policies and/ or regulations/laws in place to stimulate green hydrogen? In case yes, which? In case no, what is the reason behind this? 8. Are there resources (capacity, incentives, funding etc.) present to stimulate green hydrogen? In case yes, which and in case no, what is lacking?
Topic stakeholders
9. Which stakeholders are important in developing a sustainable green hydrogen market? (e.g., is the field clear or not clear) 10. Which companies (incl. Dutch affiliated companies) are active when it comes to green hydrogen? 11. Which organizations need to be more active when it comes to green hydrogen? Explain why so.
Topic solutions and changes
12. Are there solutions available that are also have been proven to work? In case yes, can you explain and elaborate. 13. Which changes are important to develop the green hydrogen market in the future?
Topic role involved parties

14. What role do you see for the government in the future regarding green hydrogen? - In case of a private company: What role do you see for private companies? - In case of industry: What role do you see for the industry? - In case of NGO: What role do you see for the NGO? - In case of the Netherlands: What role do you see for the Netherlands?
Topic opportunities and risks
15. Which opportunities are visible to realize a sustainable green hydrogen market in the future (focus on support, expertise, or solutions)? 16. What are the risks for Egypt as well as the Netherlands in realizing a sustainable green hydrogen market?

A3 Transformation model and market phase determination

Market phase determination

First, we discuss the market phase analysis. To determine the phase the market is operating in, the interview answers were categorized under the different market phases per party in Table 8

Table 8: Market loop table was used to identify current market phase of Egyptian hydrogen market

	Governmental bodies					NGO's	Banks		Project developers		
	EEHC	Ministry of petroleum	NREA	SCZone	TSFE	GIZ	EBRD	IFC	Fertiglobe	Inifinite Energy	Med Partners
Loop 1	1,50	2,75	1,50	1,75	2,50	1,75	2,25	1,75	1,50	1,50	1,50
Loop 2	1,67	2,67	2,50	3,00	2,33	2,00	1,67	1,00	1,33	1,67	1,50
Loop 3	2,50	2,50	2,00	2,50	2,50	1,00	2,50		2,00	2,33	2,00
Loop 4		2,00	1,50	2,67	2,20	1,25	2,40		1,50	1,00	1,67
Totaal	1,78	2,43	1,80	2,42	2,36	1,54	2,21	1,11	1,54	1,62	1,64

Insufficient information	1	1,5	2	2,5	3	3,5	4
(empty box)	Inception phase		Competitive advantage phase		Pre-competitive and collaboration phase		Institutionalization phase

Table 8 illustrates the market phase in which the different stakeholders are operating in governmental bodies, NGO's, banks, and project developers. A higher number, or green color, presents a more developed market phase. Two important conclusions can be drawn from this analysis:

- The *overall* market phase of the Egyptian hydrogen market is in between the competitive advantage phase (2) and the pre-competitive and collaboration phase (3). Considering the technological state of hydrogen technology, this means the market is quite developed.

- However, a significant difference is found between the market phase of governmental bodies in comparison to project developers. The *government* is almost in the pre-competitive and collaboration phase (3), while the *project developers* are between the inception phase (1) and the competitive advantage phase (2). This indicates that significant Government to Government (G2G) involvement is not anticipated in the process of establishing procedures and legal frameworks. This is partly due to the existing presence of parties like EBRD, GIZ and IFC, who already fulfill such a role. The relatively low market phase for project developers also highlights a potential focus point for collaboration, which is further explained in chapter 4.2

A4 Long list of potential collaboration opportunities

Strengthen ministries and/or regulations and policies

1. Assist in formulating selection criteria for project developers.
2. Aid NREA in establishing a transparent land allocation process.
3. Contribute to the formulation of regulations for brine discharge.
4. Safeguard Egypt's dedicated renewable energy production.
5. Facilitate government with the implementation of the green hydrogen project incentives and in the lessons learned.
6. Assist the government in establishing a dedicated hydrogen authority.
7. Devise a comprehensive monitoring and evaluation strategy for hydrogen-related activities.
8. Review and refine the procedure for project allocation.

Knowledge transfer

9. Knowledge transfer on the newest developments on regulations/green hydrogen requirements in the EU
10. Share insights on the newest and latest development on pricing mechanisms and subsidy schemes in EU
11. Facilitate knowledge transfer regarding green fuel bunkering (for example between port authorities and SCZone).
12. Promote government-to-government knowledge transfer on hydrogen pipelines versus electricity grid congestion.
13. Strengthen knowledge transfer to the Egyptian government, possibly collaborating with GIZ, EBRD, and TSFE.
    - Provide expertise on green hydrogen.
    - Emphasize the importance of asset privatization.

Awareness

14. Drive energy transition and water conservation awareness through citizen-focused campaigns.
15. Raise awareness about Egypt's potential role in hydrogen export among government, citizens, and the EU.
16. increase awareness about EU initiatives such as HyXchange and H2Global.

Stimulate offtake in the European Union

17. Foster an investment-friendly environment for off-takers, complementing Egyptian incentives. For example, by a country’s participation in H2Global.

Networking

18. Introduce companies to Egypt, including off-takers, technology providers, storage experts, desalination firms, and project developers.

- Assist project developers in forging connections.
- Organize networking events to link project developers with off-take partners.
- Coordinate networking events between the government and supply chain technology providers.

19. Establish a project developer branch organization.
20. Aid project developers in forming a branch organization with a cohesive green hydrogen strategy.

Synergies with other themes

21. Explore the relationship between agriculture, green hydrogen, and desalination, particularly in light of planned TSFE desalination projects. Focus on developing regulations for brine discharge.

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