Renewable hydrogen and ammonia in North Africa

*The **Global Forum on Sustainable Energy (GFSE)** is a neutral multi-stakeholder platform, which is facilitating international dialogue on energy for sustainable development by taking into account the special interests and challenges of developing countries. GFSE aims at the establishment of a sustainable world energy system from a social, economic and environmental perspective.*

GFSE contributes to both international discourse and information dissemination on sustainable energy. The multi-stakeholder platform plays a crucial role in facilitating sustainable energy projects by bringing together donors, investors and project developers. Their interaction creates new opportunities and enhances existing initiatives in the field of sustainable energy.

Table of contents

Abstract

Europe needs to reduce consumption of Russian natural gas by diversifying its suppliers, reducing gas consumption and switching to other energy carriers, including renewable energy. Renewable hydrogen and its derivatives used as energy carriers and feedstocks could play a role in reducing reliance on natural gas and decarbonising the European energy system in the future. This policy brief presents an overview of current developments in the renewable ammonia and methanol sectors at the global level as well the renewable hydrogen sector in North Africa. It describes ongoing cooperation agreements between the European Union and North African countries, hydrogen strategies, the current status of renewable electricity generation and projects under development. It also presents needs for green skills in the renewable hydrogen sector.

Author: Leonardo Barreto Gómez, GFSE Secretariat

Introduction

Hydrogen is an energy vector that can facilitate transport of renewable energy over long distances via pipelines and shipping. Hydrogen also serves as energy storage, which is highly important in an energy system based on renewables. Countries with an abundance of low-cost renewable electricity could become producers and exporters of renewable hydrogen. Green hydrogen trade and investment flows can create new patterns of trade interdependence between countries and a new geopolitical landscape.[1]

Renewable hydrogen is being promoted in North Africa. Some countries have developed national hydrogen strategies and several projects are being developed. The region has substantial renewable energy sources that could be exploited. On the other hand, there are barriers to development of renewable hydrogen projects that need to be addressed.

At the same time, the countries in the region are heavily reliant on inefficient, polluting electricity generation sources and some of them rely on substantial imports of natural gas. They require renewable electricity sources. Green hydrogen production would compete with development of renewable electricity generation for domestic use.

This policy brief presents an overview of the ammonia and methanol global markets and an overview of renewable hydrogen in four North African countries (Algeria, Egypt, Morocco and Tunisia). These countries could export green hydrogen and derivatives to the EU. They have developed hydrogen strategies and are starting to develop projects for green hydrogen or ammonia production.

Ammonia

Ammonia is an inorganic compound of nitrogen and hydrogen with the formula NH_3.[2] The production of ammonia takes place by mixing nitrogen from the air with hydrogen. Ammonia stays in liquid form at room temperature and low pressure (~10 bar).

Ammonia is used as a raw material for nitrogen fertilizer production, the largest fertiliser group. A number of other applications for ammonia exist such as refrigeration, mining, pharmaceuticals, water treatment, plastics and fibres, etc. About 70% of ammonia is used for fertilisers, while the remainder is used for other industrial applications at the global level.

Ammonia is currently made mainly from fossil fuels (natural gas and coal). There is potential to replace fossil-based ammonia with renewable ammonia based on renewable hydrogen from electrolysis in the long term.

The global industrial production of ammonia in 2021 was 235 million tonnes. Ammonia production currently relies heavily on fossil fuels and only a small fraction is produced through other technologies. Over 72% of ammonia production is via natural gas-based steam methane reforming

[1] IRENA (2022), Geopolitics of the Energy Transformation: The Hydrogen Factor, International Renewable Energy Agency, Abu Dhabi. https://www.irena.org/publications/2022/Jan/Geopolitics-of-the-Energy-Transformation-Hydrogen

[2] Wikipedia, 2023: Ammonia. https://en.wikipedia.org/wiki/Ammonia#cite_note-15

(SMR), leading to 170 bcm of natural gas demand. 26% of ammonia is produced via coal gasification, leading to 75 Mtce of coal demand.[3] 1% is produced using fuel oil and naphtha and the remainder is produced using electricity.

Energy source	Percent of global ammonia production (%) in 2020
Natural gas SMR	72%
Coal gasification	26%
Oil	1%
Electricity	1%

Source: IEA, 2022: Ammonia technology roadmap. Paris, France.

The most common ammonia production method is the Haber-Bosch process, which uses high amounts of energy due to its high operating pressure and temperature, and results in high GHG emissions. The process operates at temperatures in the range of 400–500°C and pressures in the range of 150–300 bar. When ammonia is produced using natural gas through the Haber-Bosch process, approximately 60% of the natural gas is used as raw material, while the remainder is employed to power the synthesis process.[4]

Ammonia production from fossil fuels releases a highly concentrated CO_2 stream (> 98% vol.) that could be combined with hydrogen from electrolysis to produce chemical commodities, such as carbon monoxide, ethanol, formic acid, and ethylene.[5]

Ammonia production is currently one of the main uses of hydrogen. In order to produce a ton of ammonia approximately 178 kg of hydrogen are required. Ammonia production currently accounts for around 45% of global hydrogen demand, or around 33 million tonnes (Mt) of hydrogen in 2020.[6] The total global hydrogen consumption amounted in 2020 to 90 Mt H_2. The main uses of hydrogen, including ammonia production, at the global level can be seen in the table below:

	Mt H_2 in 2020
Refineries	40
Chemical production (including ammonia production)	45 (including 33 Mt H_2 used for NH_3 production)
Direct reduced iron (DRI) process for steelmaking	5
Transport sector (3)	< 0,02
Other uses (2)	n.a.
Total	90 (1)

[3] IEA, 2021: Ammonia Technology Roadmap. Towards more sustainable nitrogen fertiliser production. https://iea.blob.core.windows.net/assets/6ee41bb9-8e81-4b64-8701-2acc064ff6e4/AmmoniaTechnologyRoadmap.pdf

[4] https://www.fertilizerseurope.com/fertilizers-in-europe/how-fertilizers-are-made/

[5] O´Neil, C., 2023: Opportunity for Chemicals and Fuels From Carbon Dioxide: Researchers Assess Roadblocks for Industrial Deployment of CO2 Electrolysis. https://www.nrel.gov/news/program/2023/researchers-assess-roadblocks-for-industrial-deployment-of-co2-electrolysis.html

[6] IRENA and AEA (2022), *Innovation Outlook: Renewable Ammonia*, International Renewable Energy Agency, Abu Dhabi, Ammonia Energy Association, Brooklyn.

Source: IEA, 2021: Global Hydrogen Review 2021. https://iea.blob.core.windows.net/assets/5bd46d7b-906a-4429-abda-e9c507a62341/GlobalHydrogenReview2021.pdf
Notes:

1. "This includes more than 70 Mt H_2 used as pure hydrogen and less than 20 Mt H_2 mixed with carbon-containing gases in methanol production and steel manufacturing. It excludes around 30 Mt H_2 present in residual gases from industrial processes used for heat and electricity generation: as this use is linked to the inherent presence of hydrogen in these residual streams – rather than to any hydrogen requirement – these gases are not considered here as a hydrogen demand."
2. "Others" refers to small volumes in industrial applications, grid injection and electricity generation.
3. In the transport sector, annual hydrogen demand is less than 20 kt H_2 – just 0.02% of total hydrogen demand

The IEA expects global hydrogen demand to increase to approx. 152.3 Mt H2 by 2030 in the net zero scenario. New applications are expected to increase substantially but traditional uses such as refining (using 37 Mt H2/year) and ammonia production (using approx. 34.5 Mt H2/year) are expected to remain at similar absolute levels as today.

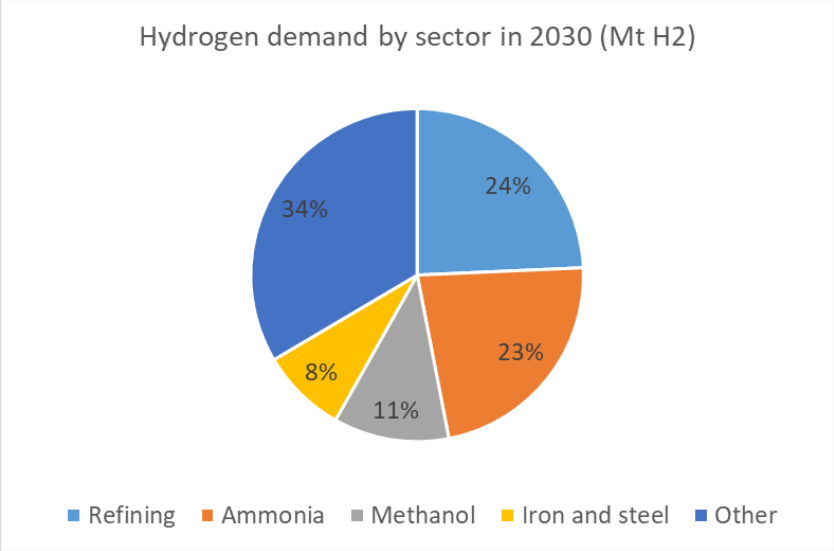

Figure 1: Hydrogen demand by sector in 2030 in the net zero scenario by the International Energy Agency (IEA). Source: International Energy Agency, 2023. Hydrogen. Overview. Paris, France. https://www.iea.org/energy-system/low-emission-fuels/hydrogen

The main uses of ammonia at the global level are as follows:

	2022
Urea	55%
Ammonium nitrate	15%
Other fertilisers	15%
Other uses (i.a. textiles, refrigerants, NOx abatement, explosives)	15%

Ammonia is the largest CO_2 emitter in the chemical industry and together with cement, steel and ethylene production, one of the main four industrial processes that need decarbonisation. Global direct emissions from ammonia production currently amount to 450 Mt CO_2. Indirect CO_2 emissions are around 170 Mt CO_2 per year and stem from electricity generation and the chemical reactions resulting from the application of urea-based fertilisers.

	CO_2 emissions (tonne CO_2/tonne NH3)
Steam methane reforming of natural gas	1.6
Coal	4.0
Naphtha/Heavy fuel oil	2.5-3.4
SMR of natural gas with CCS	0.24-0.64
Electrolysis from renewable electricity	0.1 -0.9

There is a significant increase in global demand for ammonia to meet current agricultural, chemical, and mining requirements. According to IRENA, worldwide production of ammonia was 183 million tonnes (Mt) in 2020. It is expected for existing markets for ammonia to increase demand to 223 Mt by 2030 and reach 333 Mt by 2050 in a 1.5°C scenario. This steady rise in demand is driven primarily by population growth, with ammonia demand for fertiliser applications projected to grow from 156 Mt in 2020 to 267 Mt in 2050.[7]

The fertilizer industry, for example, can reduce its carbon emissions and decarbonise food production through investments, public funding, and coherent legislative framework. Supply chain decarbonisation is possible but it needs to be complemented by improved nutrient use efficiency, given that approx. 50% of the fertiliser is released to the environment. CO2-neutral value chains for current ammonia markets are being pursued. There are already some commitments by manufacturers to reduce CO_2 emissions by 2050.

One possibility for decarbonisation of the ammonia supply chain is the use of green hydrogen. 36 GJ of electricity per tonne of ammonia are required for the production process, based on an efficiency of 64% on a lower heating value basis for the electrolyser. 95% of the electricity is used for hydrogen production. The remaining 5% is used to power the air separation unit for nitrogen production and the Haber-Bosch synthesis units. The cost of renewable ammonia depends to a large extent on the cost of renewable hydrogen, which represents approximately 90% of the production cost of renewable ammonia.

In 2024, there are only 4 renewable nitrogen fertiliser projects in operation in Norway, Spain, the Netherlands and Kenya. Three additional renewable nitrogen fertiliser projects in Australia, the United States and Namibia are expected to be commissioned in 2024.[8] The largest commercial plant

[7] IRENA and AEA (2022), Innovation Outlook: Renewable Ammonia, International Renewable Energy Agency, Abu Dhabi, Ammonia Energy Association, Brooklyn.

[8] Paul, C., 2024. Global Green Fertiliser Tracker. Greening nitrogen fertiliser production. Agora Industry. 6 June 2024. https://www.agora-industry.org/fileadmin/Projekte/2024/2024-09_IND_Fertiliser_Tracker/2024-06-06_Presentation_Global_Green_Fertiliser_Tracker.pdf

was built by Yara, a nitrogen fertilizer manufacturer from Norway.[9] It has a capacity of 20,000 tonnes/year.

Transport of ammonia

Ammonia can be liquefied either by increasing the pressure to ten atmospheres at room temperature or by cooling it down to −33 °C under 1 atmosphere. This means that ammonia can be stored in an inexpensive container and transported by ship. Thus, it can be transported more easily than liquefied hydrogen. Ships that transport ammonia are proven technology. They transport ammonia and, in some cases, other chemicals.

Ammonia can be used as a hydrogen carrier. It is easier to handle and transport than hydrogen. However, in order to release hydrogen from ammonia, a significant energy input is required. Therefore, energy losses can be significant. Ammonia loses some of its cost advantage when it has to be converted back to hydrogen for specific applications.

Trade

Ammonia is traded around the world, with global exports equating to about 10% of total production. Urea, its most common derivative, is traded even more widely, at just under 30% of its production. The table below presents the main exporting countries of ammonia in 2021. The main exporting countries are Trinidad and Tobago, the Russian Federation, Saudi Arabia, Indonesia and Canada.

Exporting country	**Exports in 2021 (Mt NH3)[10]**
Russian Federation	4,42
Trinidad and Tobago	3,18
Saudi Arabia	2,91
Indonesia	1,79
Canada	1,20
Malaysia	0,52
Egypt, Arab Rep.	0,46
Netherlands	0,34
Germany	0,34
Australia	0,34
United States	0,32

Notes: exports are gross exports.

Source: World Integrated Trade Solution (2023). Ammonia; anhydrous exports by country in 2021. https://wits.worldbank.org/trade/comtrade/en/country/ALL/year/2021/tradeflow/Exports/partner/WLD/product/281410#

Prices

[9] Yara opens renewable hydrogen plant: “A major milestone” | Yara International

[10] Source: World Integrated Trade Solution (2023). Ammonia; anhydrous exports by country in 2021. https://wits.worldbank.org/trade/comtrade/en/country/ALL/year/2021/tradeflow/Exports/partner/WLD/product/281410#

Platts' Ammonia Price Chart shows monthly averages of daily assessments for grey, blue and green ammonia across a range of geographies and delivery options.[11]

	Monthly average price, April 2024 (USD/metric tonne) Delivered to Northern Europe CFR
Grey ammonia	475.71
Blue ammonia	520.23
Green ammonia from Middle East	1010.38

Notes: 1) "In a contract specifying that a sale is cost and freight (CFR), the seller is required to arrange for the carriage of goods by sea to a port of destination and provide the buyer with the documents necessary to obtain them from the carrier".[12]

Ammonia production in the EU has become less competitive after the gas price crisis. As a consequence, several companies have reduced capacities to produce ammonia. The EU will need to import more ammonia from other countries in the future. North Africa can be a supplier of green ammonia to Europe.

Methanol

Methanol is a versatile organic chemical used in the manufacture of many products. In the chemical industry, it is used, in particular, as an input to the production of formaldehyde (used for production of polymers), formic acid and acetic acid (used e.g. for vinegar production). As a primary alcohol, methanol is a basic feedstock for petrochemicals and products. These include construction materials, polyester fibres, plastic materials, paints, and fuels.[13]

Methanol can be converted to hydrocarbons, for instance through the methanol to olefins (MtO) and the methanol to propylene (MtP) processes. Propylene is one of the key building blocks of petrochemicals used as a feedstock for a variety of polymer and chemical intermediates, and many other chemicals used as substitutes for non-plastic materials (e.g., paper, steel, and wood).[14] Methanol is also used to produce Methyl-tert-butylether (MTBE). MTBE is mainly used as an additive in gasoline.[15]

Today, methanol is one of the most-produced organic chemicals. The global demand for methanol is around 100 million tons per year. IRENA is projecting that global methanol production could increase

[11] Edwardes-Evans, H., Perez, M., 2023: Interactive: Ammonia price chart. https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/energy-transition/051023-interactive-ammonia-price-chart-natural-gas-feedstock-europe-usgc-black-sea

[12] Barone, 2022: What Is Cost and Freight (CFR) in Foreign Trade Contracts? https://www.investopedia.com/terms/c/cfr.asp

[13] Atlantic methanol, 2024: https://www.atlanticmethanol.com/about-methanol.html

[14] M. Khanmohammadi, Sh. Amani, A. Bagheri Garmarudi, A. Niaei, Methanol-to-propylene process: Perspective of the most important catalysts and their behavior, Chinese Journal of Catalysis, Volume 37, Issue 3, 2016, Pages 325-339, ISSN 1872-2067, https://doi.org/10.1016/S1872-2067(15)61031-2. (https://www.sciencedirect.com/science/article/pii/S1872206715610312)

[15] AirLiquide, 2024: Methanol. https://engineering.airliquide.com/technologies/methanol

from 100 Mt currently to 500 Mt in 2050. This increase would have to be met by renewable methanol in the long term. [16]

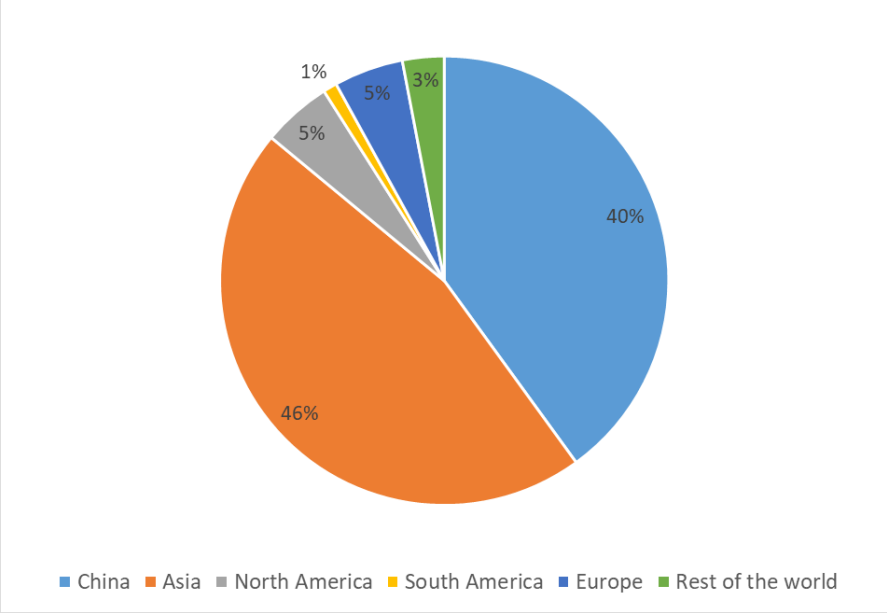

Figure 2. Methanol demand by region in 2020. Source: Methanol Market Services Asia. https://www.methanolmsa.com/market-basics/methanol/

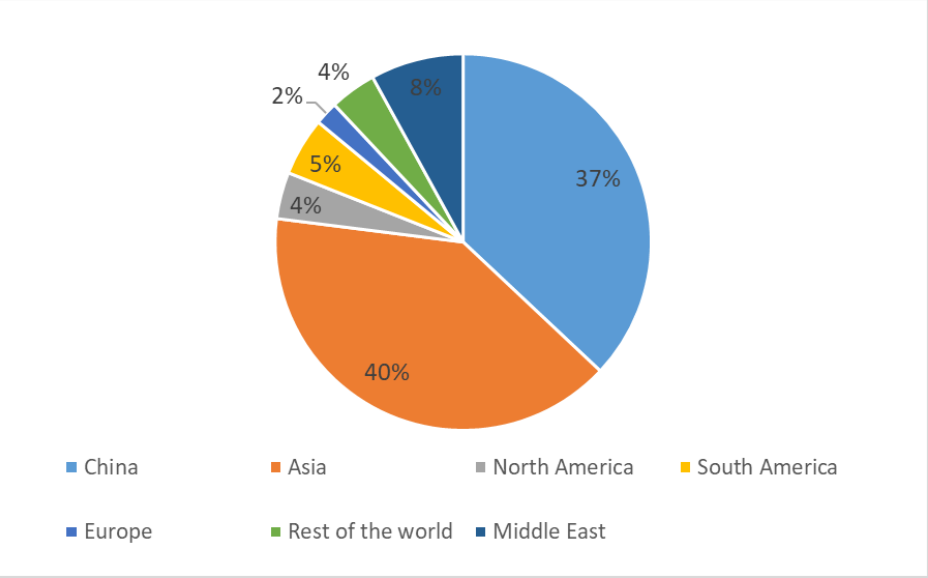

Figure 3: Methanol supply by region in 2020. Source: Methanol Market Services Asia. https://www.methanolmsa.com/market-basics/methanol/

[16] IRENA and the Methanol Institute, 2021: Innovation outlook. Renewable methanol. International Renewable Energy Agency (IRENA) and the Methanol Institute. https://www.irena.org/publications/2021/Jan/Innovation-Outlook-Renewable-Methanol

The current uses of methanol at the global level are depicted in the figure below. Formaldehyde, methanol-to-olefines (MtO), MTBE and gasoline blending are the main uses of methanol today. Formaldehyde is used to manufacture building materials and numerous household products. Olefins are used as in the manufacture of different products like plastic, detergents, rubber and food packaging.

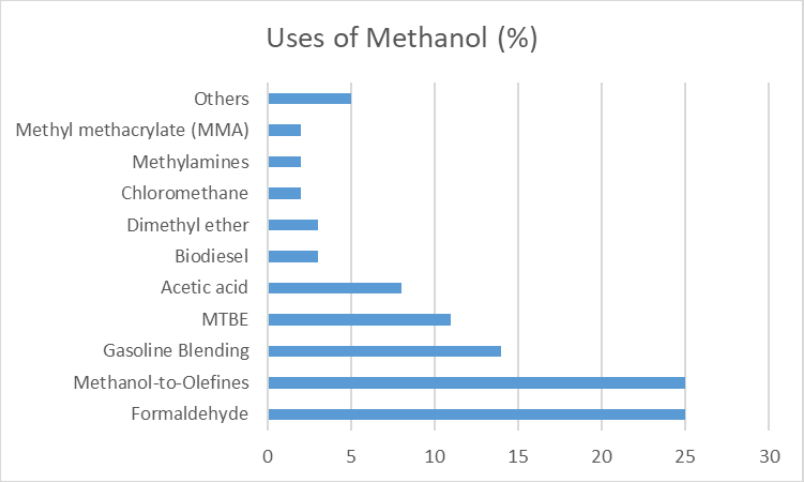

Figure 4: Uses of methanol. Source: IRENA AND METHANOL INSTITUTE (2021), Innovation Outlook: Renewable Methanol, International Renewable Energy Agency, Abu Dhabi.

The conventional production method involves natural gas or coal. This process is so energy-intensive that it is only economically viable in large-scale plants and based on cheap gas or coal. Coal gasification is a well-proven technology. However, methanol can be produced from renewable hydrogen, which reduces greenhouse gas emissions significantly. Besides ammonia, green methanol is also considered as a substitute fuel for maritime fuel applications. Additionally, it can be added to conventional liquid fuels.[17]

The low carbon intensity of renewable methanol is attractive. Renewable methanol can be produced from feedstocks with significant avoided emissions such as waste streams (e.g. landfill gas, anaerobic digester gas, and biomass).[18] It can also be produced from renewable electricity and captured CO_2.

Liquid methanol is made from synthesis gas, a mix of hydrogen, carbon dioxide and carbon monoxide. For green methanol a source of CO_2 is needed. Green methanol is produced by combining

[17] Thyssenkrup, 2024: The Revolution of Green Methanol. https://www.thyssenkrupp.com/en/stories/sustainability-and-climate-protection/the-revolution-of-green-methanol

[18] Edlund, D., Lim, D., 2021: The Renewable Methanol Pathway to Green Hydrogen. Element 1 Corp. https://www.methanol.org/wp-content/uploads/2020/04/Renewable-methanol-to-Green-Hydrogen-final-1.pdf

biogenic or captured CO_2 with renewable hydrogen.[19] This route has the largest potential to produce renewable methanol.

Green methanol will be an important feedstock for green chemicals. It can also be used for energy storage, blended with gasoline or diesel or as a maritime fuel. The high energy density of methanol in comparison to liquefied hydrogen, makes it a good alternative for long-distance transportation.

Interest in renewable methanol is being driven by the need to substantially reduce CO_2 emissions. In particular, hard-to-abate sectors that are difficult to electrify, such as shipping, require alternatives to decarbonise their operations. Shipping was responsible for the emission of around 2% percent of global energy-related CO_2 emissions (approx. 706 Mt CO_2) in 2022.[20] Due to the increase in global trade and the demand for maritime shipping, the sector's carbon footprint could increase substantially. The sector also emits substantial amounts of other harmful air pollutants such as sulphur and nitrogen oxides and particulate matter. Ships using methanol as a fuel can significantly reduce emissions of pollutants such as SO_X, NO_X, and Particulate Matter.

Shipping has been constrained by the need to find clean alternative fuels, and green methanol is one alternative. Methanol emits much less CO_2 than heavy fuel oil (HFO). 1.4 kg CO_2 per kilogram of methanol are emitted when methanol is burnt, which is much lower than the 3.1 kg CO_2 per kilogram emitted when burning fuel oil. In comparison, methanol from natural gas emits approximately 2.05 kg CO_2 per kg of methanol.

Green methanol has some advantages over other low-carbon fuels. It is liquid at room temperature and does not require pressurized or cryogenic tanks. Methanol has a higher volumetric energy density than other alternative shipping fuels such as ammonia, and hydrogen.[21] However, methanol has only half of the energy content of HFO. This means that the ships must carry more fuel onboard or refuel more often.[22]

The capacity of individual renewable methanol plants is currently in the range of 5,000-10,000 metric tons of methanol per year. However, it is expected to rise to 50,000-250,000 metric tons per year in the long term.[23]

Currently the main barrier for the uptake of green methanol is its higher cost compared to fossil fuel-based alternatives. Green methanol costs can range from $800-1,600/ton compared to $100-250/ton for fossil-based methanol.[24] The costs of green methanol are mainly determined by the costs of electricity and CO_2.

---

[19] Air Liquide, for example, offers a technology for the conversion of CO_2 to methanol. The technology is commercially available at any scale.

[20] IEA, 2023: International Shipping. International Energy Agency. Paris, France. https://www.iea.org/energy-system/transport/international-shipping

[21] Methanol Institute (May 2023), Marine Methanol: Future-Proof Shipping Fuel. https://www.methanol.org/wp-content/uploads/2023/05/Marine_Methanol_Report_Methanol_Institute_May_2023.pdf

[22] MAN energy solutions. Methanol-fueled ships: Testing of an ME-LGIM engine in Korea. https://www.man-es.com/discover/methanol-fueled-ships

[23] The Methanol Institute. https://www.methanol.org/renewable/

[24] JCDREAM, 2023. Green Methanol 2023. https://jcdream.org/wp-content/uploads/CHARGE-Green-Methanol-White-Paper.pdf

Fossil-based methanol plant in the coast of Equatorial Guinea

There is a fossil-based methanol plant in the coast of Equatorial Guinea in Africa. This plant owned by the Atlantic Methanol Production Company (AMPCO) has a production capacity of about 1 million tonnes/year and exports methanol via ship to Europe and the U.S.[25] Ampco has storage capacity of 900,000 barrels and exports its methanol via three dedicated 300,000 tonne carriers. The company also produces liquefied petroleum gas (LPG), building materials, chemicals, fuel additives and solvents.[26]

Fossil-based Methanex plant in Port Damietta (Egypt)

Today, there is only one methanol production facility in Egypt. The Methanex Egypt facility in Damietta has a production capacity of up to 1.3 million tons of fossil gas-based methanol per year, primarily supplying domestic and European markets.[27] In 2018 Egypt produced one million tons of methanol.

South Africa

A total of 140 000 tons per year of methanol is consumed in South Africa. The methanol is produced from natural gas and SASOL is the sole producer. Methanol traded amounts to 11.5% of domestic production.[28]

Green hydrogen in North Africa

Algeria

Algeria is an oil and gas exporter that could use its renewable energy potential to produce renewable hydrogen and derivatives. Algeria has a network of natural gas pipelines to Europe (the Medgaz pipeline to Spain and the TransMed pipeline to Italy) and transport capacities for LNG. Algeria was Italy's largest gas supplier in 2022 and 2023. The cooperation agreement signed in 2022 extended the volume of gas trade to 20 bcm/year and this volume is foreseen to be increased further to 36 bcm in the future. Algeria also supplies natural gas to France (through the MedGaz pipeline) and Tunisia (the latter through the Trans-Tunisian Gas Pipeline).[29]

[25] https://www.atlanticmethanol.com/home.html
[26] African Business, 2014: Equatorial Guinea: Industrial Capacity. https://african.business/2014/02/economy/equatorial-guinea-industrial-capacity
[27] https://www.methanex.com/about-us/global-locations/egypt/
[28] https://mediafra.admiralcloud.com/customer_609/40f9175f-bf73-43cf-83ff-a87d4875da6b?response-content-disposition=inline%3B%20filename%3D%2203_Zama%20Duma_The%20case%20of%20green%20methanol%20in%20South%20Africa.pdf%22&Expires=1708020599&Key-Pair-Id=K3XAA2YI8CUDC&Signature=nFp1~CBGpcln-Cp-lfgUyHlARrVlmrervW1aX5TBRMcKujSEbTkR6Jdi9DkibGkGTjwwHHkdH38u8WDtAP5dU7q9mx3J2c3y2rCpunV1lidsRCNtErf17HnRqyRk2J1zMY~pH~miInMW0lKfRmEzbY4XMYee88CdBt7ZxMo8Xm3miejT17pFI2bePANl3krMgUDMSVrcxCPZIAkrhkqNRC0KwBCHB56DzzUO3QyLL30~s2ttlHoAoYHpksX7U9Z6ci5trqQYXMXNKF4EKBTopCLql4nfD4A8KoKfZlwJxRvQRh-CcIAfIWvFdPSL68e1pzKnS7W52SrRAE9dVou2JQ__
[29] Nhede, N. 2023. Top 5 Destinations for Algeria's Pipeline Gas. Energy capital&Power. 26 September 2023. https://energycapitalpower.com/top-5-destinations-for-algerias-pipeline-gas/

Algeria´s natural gas infrastructure and its proximity to Europe can be used to transport hydrogen to Europe. In addition, the existing production and consumption of hydrogen from natural gas for domestic industrial use could be replaced by green hydrogen in the long term.[30]

Algeria is also a producer and exporter of ammonia and fertilizers. The company FERTIAL has a production capacity of 1 million tons of ammonia/year, to cover domestic needs and exports. Part of this output is used to produce nitrogen and phosphate fertilizers to cover a large part of the needs of Algerian agriculture. FERTIAL also exports part of its ammonia and fertilizer production to various foreign markets, mainly to Europe.[31]

Cooperation between Algeria and the EU

Algeria and the EU signed a Memorandum of Understanding (MoU) on a strategic partnership in the field of energy in Algiers in 2013. The partnership is aimed at developing and strengthening energy relations while respecting the balance of interests between the two parties.

At the high-level political dialogue on energy in October 2023, the two sides agreed to work on methane emissions and hydrogen by facilitating and promoting pilot industrial projects, and through the organisation of workshops that will bring together European and Algerian public and private stakeholders. They will explore the possibility to establish a cooperation agreement on hydrogen in order to identify concrete actions and projects. They also plan to extend their cooperation in the exploration, production and use of rare materials, which are used in the manufacturing of renewable energy and storage technologies.[32]

Electricity generation

Electricity generation in Algeria is almost entirely (approx. 99%) from natural gas. The share of renewable electricity (mainly wind and solar PV) in 2021 was very low. Nonetheless, Algeria aims to reach a renewable energy capacity of 15,000 MW and produce 27% of its electricity from renewable resources by 2035. The RES potentials in the country are substantial but their development would require substantial investments.

In order to achieve its targets, Algeria has been launching tenders for solar PV power plants in the past few years. The national oil company Sonatrach launched a tender for the deployment of 1 GW of solar photovoltaic plants in December 2021. In July 2023, Algeria's power utility Sonelgaz selected bidders for a 2 GW solar PV tender. The selected bidders are expected to develop solar PV projects in 11 locations and must source at least 35% of the construction components in Algeria.[33] Algeria aims at reaching 15,000 MW by 2035.

[30] Internatinal PtX hub, 2022: PtX Hub in Algeria. Leveraging existing infrastructure and vantage points to build up PtX potential. https://ptx-hub.org/algeria/
[31] FERTIAL, 2024. https://www.fertial-dz.com/.

[32] European Commission, 2023: Joint press statement: EU – Algeria high-level energy dialogue. https://energy.ec.europa.eu/news/joint-press-statement-eu-algeria-high-level-energy-dialogue-2023-10-05_en
[33] Energy Capital&Power, 2023: Algeria Powers Ahead with Sustainable Energy Initiatives. October, 2023. https://energycapitalpower.com/algeria-renewable-energy-capacity-2035/

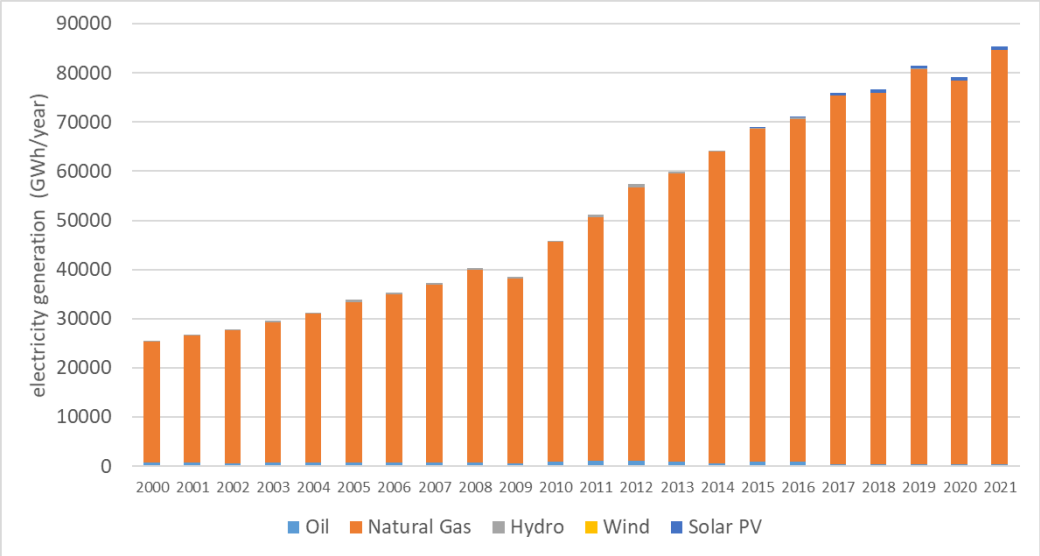

Figure 5: Electricity generation in Algeria (2000-2021) in GWh/year. Source: International Energy Agency, 2024: Algeria. Energy Mix. Paris, France. https://www.iea.org/countries/algeria/energy-mix

Clean hydrogen strategy

In this context, a national hydrogen strategy was published in 2023.[34] The strategic objectives are as follows:[35]

1. Accelerating the energy transition and reducing carbon footprint;
2. Reducing the domestic consumption of natural gas;
3. Creating an ecosystem for hydrogen development;
4. Establishing centres of excellence for research, development and training;
5. A gradual increase of domestic uses of hydrogen and its derivatives
6. Creating a hydrogen production and export centre

The goal is to export 0.9-1.2 Mt of so-called clean hydrogen to the EU by 2040. The roadmap foresees three phases of development for the hydrogen sector in Algeria, as follows:

- 2023-30: An initial demonstration phase through short-term pilot projects
- 2030-40: large-scale deployment and market creation
- 2040-50 (competitive market): industrialization and export

Until 2025, the country intends to adapt the regulatory and institutional framework for green hydrogen.

The strategy includes a component on “Development of human capital” with the following activities:

- Preparing skills and adapting training to the needs of the industry.

[34] RÉPUBLIQUE ALGÉRIENNE DÉMOCRATIQUE ET POPULAIRE, MINISTÈRE DE L'ÉNERGIE ET DES MINES 2023. Stratégie Nationale de Développement de l'Hydrogène en Algérie. September, 2023. https://www.energy.gov.dz/Media/galerie/doc_strategie_nationale_hydrogene_v.fr_(sept.2023)_65b65e6f0b8eb.pdf

[35] Collins, L., 2023: Algeria aims to supply Europe with 10% of its clean hydrogen needs by 2040 in new national H2 roadmap. Hydrogen Insight. https://www.hydrogeninsight.com/policy/algeria-aims-to-supply-europe-with-10-of-its-clean-hydrogen-needs-by-2040-in-new-national-h2-roadmap/2-1-1426265

- Creation of specialized courses and training.
- Expand national research programs.
- International scientific and technological cooperation

Cooperation between Germany and Algeria

Germany is an important trading partner for Algeria. Imports from Algeria to Germany mainly comprise crude oil and gas as well as petrochemicals. There is a "Joint Economic Commission" agreed in 2011, and in 2015 an energy partnership was created. Germany and Algeria have established a hydrogen task force to work together on green hydrogen production. Germany will support Algeria with know-how and technical expertise. As part of the agreement, the German government will provide financing for the construction of a 50 MW green hydrogen pilot plant by the national oil company Sonatrach in Arzew.[36]

Germany could import hydrogen from Algeria through the SouthH2 corridor. The SouthH2 Corridor project is a 3 300 km dedicated hydrogen pipeline corridor led by the TSOs: Snam, TAG, GCA and bayernets.[37] The corridor connects North Africa, Italy, Austria and Germany, to supply renewable hydrogen produced in North Africa to demand clusters in Italy (e.g. Augusta, Taranto and northern Italy), Austria (e.g. Styria, Vienna and Linz) and Southern German States (e.g. Bavaria). The SouthH2 Corridor appears as “Hydrogen Corridor Italy - Austria – Germany” in the 6th list of energy Projects of Common Interest (PCIs) and Projects of Mutual Interest (PMIs) adopted by the European Commission in November 2023.

Germany envisages the conversion and expansion of the existing gas pipeline corridor for renewable hydrogen, from Algeria via Tunisia, Italy and Austria to southern Germany.

"Hydrogen Import Alliance Austria" (HIAA)

The "Hydrogen Import Alliance Austria" (HIAA) is a platform founded by eight Austrian industrial groups and energy companies to facilitate large-volume imports of hydrogen as of 2030. Members of the platform are Verbund, Amag, Gas Connect Austria, LAT Nitrogen, OMV, RHI Magnesita, Voestalpine and Wiener Stadtwerke. The gas storage operator RAG Austria and the pipeline company TAG are not members of the HIAA but are involved in its work.[38] The SouthH2 corridor is the main route considered by the HIAA for green hydrogen imports.

Cooperation between ENI and the Algerian national oil company Sonatrach

The Italian oil group ENI signed an agreement with the Algerian national oil company Sonatrach in 2023. The agreement foresees exporting green or blue hydrogen to Europe through a new gas pipeline to be built between Algeria and Italy, with a capacity of 8 to 10 billion cubic metres/year to transport natural gas, ammonia and hydrogen.[39] This pipeline (Galsi project) is expected to have a length of 837 km (565 km offshore and 272 km onshore).

[36] Polly, M., 2024: Germany agrees to support the production of green hydrogen in Algeria and its export to Europe. Hydrogeninsight. https://www.hydrogeninsight.com/policy/germany-agrees-to-support-the-production-of-green-hydrogen-in-algeria-and-its-export-to-europe/2-1-1596471
[37] SouthH2 Corridor, 2022. https://www.south2corridor.net/south2
[38] Hydrogen Import Alliance Austria, 2024. https://www.hiaa.eu/.
[39] Leite, M., 2023: ALGERIA AND ITALY SIGN AN AGREEMENT ON HYDROGEN. Hydrogen Today. https://hydrogentoday.info/en/algeria-italy-hydrogen/

Projects

The national oil company Sonatrach and Hecate Energy Global Renewables (HGR Energy) signed a memorandum of understanding (MoU) to cooperate on renewable energy and green hydrogen production projects. [40]

Egypt

The EU and Egypt have an Association Agreement since 2004. It creates a free-trade area between the EU and Egypt by removing tariffs on industrial products and facilitating trade of agricultural products. The EU is Egypt's biggest trading partner, covering 24.5% of Egypt's trade volume in 2020.

At COP27, the EU and Egypt established a strategic partnership on renewable hydrogen. The implementation of the partnership will be led by the EU-Egypt Hydrogen Coordination Group. The partnership is a key building block in the EU-Mediterranean Renewable Hydrogen Partnership. Imports of green hydrogen from Egypt are part of the EU strategy to diversify energy sources and suppliers and advance decarbonisation. This cooperation may be extended regionally, upon consultation between the sides. The EU and Egypt also agreed to continue their cooperation on renewable electricity.[41],[42]

Electricity generation

As part of its contribution to the Paris Agreement, Egypt is implementing an energy diversification strategy based on an ambitious renewable energy programme. Egypt has been expanding its renewable electricity capacity in the past few years. In 2021 there were 6226 MW installed. The share of renewable electricity the same year was 14.2%. This electricity comes mainly from, hydropower, wind and solar PV.

[40] Renewables Now, 2024: Sonatrach, Hecate Energy to explore renewables, green H2 in Algeria. https://renewablesnow.com/news/sonatrach-hecate-energy-to-explore-renewables-green-h2-in-algeria-856287/

[41] European Commission, 2022: COP27: EU and Egypt step up cooperation on the clean energy transition. 16 November 2022. https://neighbourhood-enlargement.ec.europa.eu/news/cop27-eu-and-egypt-step-cooperation-clean-energy-transition-2022-11-16_en

[42] European Commission, 2022. Joint Statement on the EU-Egypt Renewable Hydrogen Partnership. 9 November 2022https://ec.europa.eu/commission/presscorner/detail/en/statement_22_6646

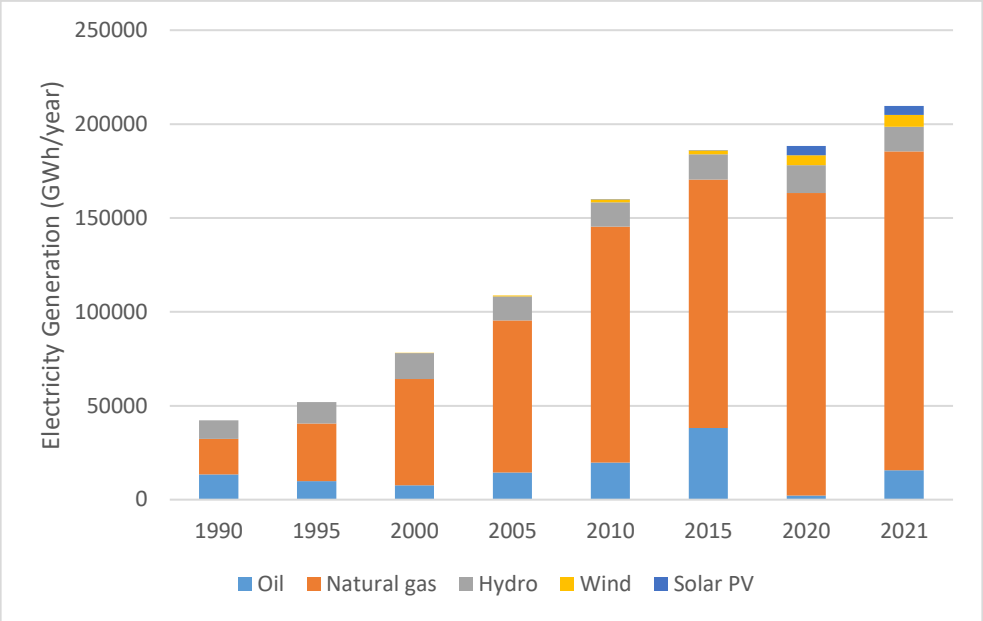

Figure 6: Electricity Generation in Egypt (1990-2021). Source: IEA: https://www.iea.org/countries/egypt

Egypt has the goal to increase the share of electricity from renewable sources to 42% by 2035.[43]

Technology	Share of electricity generation in 2035 (%)
Concentrated Solar Power (CSP)	4%
Solar PV	22%
Wind	14%
Hydro	2%
Total	42%

Low-carbon hydrogen strategy

In November 2022, the Ministry of Petroleum and Mineral Resources announced Egypt's low-carbon hydrogen strategy. The strategy aims at making Egypt one of the leading countries in low-carbon hydrogen. The goal is to secure a 5-8 percent share of the global commercial market for renewable hydrogen. The strategy was introduced during the Conference of the Parties of the UNFCCC (COP27).[44] Targets of the strategy are as follows:

- Increasing the rates of renewable energy production for Egypt.
- Maximizing the utilization of the site of the Suez Canal and the surrounding seaports
- Attracting direct investments

[43] New and renewable energy authority, 2022: Renewable Energy Targets http://nrea.gov.eg/test/en/About/Strategy

[44] Dokso, 2023: Egypt´s hydrogen strategy shapes future of sustainable energy. H2 energy news. https://energynews.biz/egypts-hydrogen-strategy-shapes-future-of-sustainable-energy/#:~:text=The%20low%2Dcarbon%20hydrogen%20strategy,hydrogen%20production%20and%20renewable%20energy

- Providing job opportunities in the various operational sectors for the production of hydrogen and its derivatives.
- Clean energy to reduce carbon emissions.[45]

Egypt already uses hydrogen from natural gas in several industries. Hydrogen is produced locally from steam methane reforming without Carbon Capture and Storage (CCS) using locally produced natural gas. The table below shows hydrogen consumption in different sectors in the year 2021.

Sector	Consumption of hydrogen in 2021 (Tonnes H2)
Ammonia	756 000
Steel	643 540
Refineries	300 000
Methanol	125 000
Total consumption	1 824 540

Source: Habib, A., Ouki, M., 2021: Egypt´s Low carbon development prospects. The Oxford Institute for Energy Studies. https://www.oxfordenergy.org/publications/egypts-low-carbon-hydrogen-development-prospects/

On 30th of January 2024, Egypt's President signed Law No.2 of 2024 on incentives for projects producing green hydrogen through electrolysis and its derivatives. The law foresees tax breaks ranging from 33 percent to 55 percent to boost local green hydrogen production. Incentives also include exemptions of VAT for equipment, raw materials and transport for projects that produce green hydrogen and its derivatives. Exports of green hydrogen projects will not be subject to VAT. In addition, projects also enjoy regulatory privileges such as the one single license for the project under the Investment Law. The objective is to attract green hydrogen production projects to the country.[46]

The Law encompasses, among others, plants that produce green hydrogen and its derivatives, water desalination projects dedicating 95% of its production to produce green hydrogen and its derivatives and solar power plants, which dedicate 95% of its electricity production to green hydrogen production and water desalination as well as storage, transmission and distribution of green hydrogen produced in Egypt. In order to be eligible, the project must have a minimum of 20% local contents.

In 2021, Egypt produced 4 million tons of ammonia (US Geological Survey, 2023)[47] mainly for the

[45] Green hydrogen organisation, 2023: GH2 counry portal Egypt. https://gh2.org/countries/egypt
[46] Salah., F., Salama, H., 2024. Egypt Releases New Law for Green Hydrogen Incentives. Riad&Riad Law Firm. https://riad-riad.com/egypt-releases-new-law-for-green-hydrogen-incentives/

[47] USGS, 2023: 2021 annual tables. US Geological Survey.

production of fertilisers. It is also the seventh largest exporter. The study conducted by the UNIDO about green hydrogen in Egypt concluded that ammonia is the most promising sector for green hydrogen use.[48] The study identified some potential offtakers of green ammonia:

- Alexfert Fertilizer / Abu Qeir Fertilizer, Location: Alexandria
- SEMADCO, Location: Al Adbeya port
- MOPCO company, Location: Damietta
- East Port Said industrial zone, Location: East Port Said

Today, there is only one methanol production facility in Egypt. The Methanex Egypt facility in Damietta has a production capacity of up to 1.3 million tonnes of gas-based methanol per year, primarily supplying domestic and European markets.[49] In 2018 Egypt produced one million tons of methanol. Methanol is used as a feedstock in several industries.

Methanol production represents an opportunity for use of green hydrogen. E-Methanol can be produced from renewable hydrogen and CO_2 capture. Methanol can also be used as a hydrogen carrier. Methanol has a much higher volumetric energy density than compressed and liquefied hydrogen and is much easier to store and transport.

Methanol can be used as a fuel for deep-sea shipping. Studies have highlighted methanol and ammonia as promising options for deep-sea shipping. E-methanol can offer reductions in GHG and air pollutant emissions. The fuel is also less harmful to the environment than ammonia or heavy fuel oil. Thanks to similar properties to marine diesel, existing infrastructure can continue to be used with only minor modifications in some cases. In addition, its rapid solubility in seawater means that in the event of accidents or leaks, the risks to marine ecosystems are much less serious than with heavy fuel oil or ammonia, for example.[50]

Projects

Some renewable hydrogen projects under development in Egypt are briefly described below:

Project Ra

In December 2022, DAI Infrastruktur signed a MoU with the Suez Canal Economic Zone for development of green maritime fuels projects. Project Ra plans to produce 1.6 million tonnes per year of ammonia. In April 2023, 780 km² of land was allocated to DAI by Egypt's Ministry of Electricity and Renewable Energy to develop three new renewable electricity projects– two wind parks and a solar PV park, all to be connected to the national grid.

[48] UNIDO, 2023: Assessment of low carbon hydrogen production, demand, business models and value chain in Egypt. Global Programm Hydrogen in Industry. United Nations Industrial Development Organisation. Vienna, Austria. https://www.unido.org/sites/default/files/files/2023-06/Low-Carbon-Hydrogen-Assessments-in-Egypt-Highlights-UNIDO.pdf

[49] https://www.methanex.com/about-us/global-locations/egypt/

[50] Diesener, S., Schur, P., 2023: Methanol als Schiffstreibstoff. NABU. https://www.nabu.de/umwelt-und-ressourcen/verkehr/schifffahrt/33080.html

Presumably, the electrolysers will be connected to Egypt's national grid and then Power Purchase Agreements (PPAs) will be used to prove that the hydrogen produce is renewable, similarly to other hydrogen production projects in the Suez Canal Economic Zone.

ACWA Power project

ACWA Power, a large water desalination company, and The Sovereign Fund of Egypt (TSFE), the Suez Canal Economic Zone (SCZone), the Egyptian Electricity Transmission Company (EETC), and the New and Renewable Energy Authority (NREA) have signed a framework agreement for a renewable ammonia project in the Suez Canal. The first phase of the project aims at producing 600,000 tonnes-per-year renewable ammonia, entailing an investment of more than $4 billion. A second phase would raise production capacity to 2 million tonnes renewable ammonia per year.[51]

Fertiglobe

Fertiglobe, a strategic partnership between the Abu Dhabi National Oil Companiy (ADNOC) and OCI, is the largest producer of nitrogen fertilizers in the MENA region. Fertiglobe has completed a first shipment of renewable ammonia that was produced in Egypt to India. The ammonia was used for the production of near-zero emissions synthetic soda ash, an ingredient of laundry powder. The company is also pursuing a green hydrogen project in partnership with Scatec, Orascom Construction, the Egyptian Electricity Transmission Company, and the Sovereign Fund of Egypt. The project will produce up to 15,000 tonnes per year of green hydrogen, as feedstock to produce up to 90,000 tonnes per year of renewable ammonia in the Suez Canal Economic Zone in Egypt.[52]

Fertiglobe was also the winner of the first H2Global pilot auction for renewable ammonia, funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK), at a contract price of 1000 EUR/ton. 273 MW of renewable electricity generation will be built to power Egypt Green Hydrogen, the supplier of renewable hydrogen for Fertiglobe. The supply of renewable ammonia for the German market will start at about 19,500 tons of ammonia in 2027 and rise up to a total of 397,000 tons cumulatively by 2033. [53]

Scatec green methanol project in Egypt

The renewable energy developer Scatec ASA and the Alexandria National Refining and Petrochemical Company (ANRPC) have signed a joint development agreement for a green methanol project in Port Damietta (Egypt).[54]

The initial production capacity of the project is set at 40,000 tons of green methanol per year, with the possibility of expansion to 200,000 tons per year. Under the signed agreement, renewable energy power plants, including solar and wind power plants, with a capacity of at least 40 MW and 120 MW

[51] Njovu, G., 2023: Headway in ACWA Power's renewable ammonia projects. https://www.ammoniaenergy.org/articles/headway-in-acwa-powers-renewable-ammonia-projects/
[52] Rahman, F., 2023: Fertiglobe makes first shipment of renewable ammonia from Egypt plant. https://www.thenationalnews.com/business/energy/2023/11/20/fertiglobe-makes-first-shipment-of-renewable-ammonia-from-egypt-plant/
[53] H2Global Stiftung, 2024. News. Results of the pilot auction - Lot 1. https://www.h2-global.org/news
[54] Shumkov, I., 2023: Scatec, ANRPC to co-develop USD-450m green methanol plant in Egypt. Renewables now. https://renewablesnow.com/news/scatec-anrpc-to-co-develop-usd-450m-green-methanol-plant-in-egypt-823429/?utm_term=Autofeed&utm_medium=Social&utm_source=Twitter#Echobox=1684548015

respectively, are planned. In addition, a green hydrogen production plant with a capacity of 60 MW, a seawater desalination plant and green methanol production and storage stations are foreseen.

Morocco

Morocco has the status of a privileged partner country of the EU. The EU and Morocco signed an Association Agreement in the year 2000. In 2022, the EU and Morocco signed the EU-Morocco Green Partnership. This is a bilateral framework to enhance dialogue and cooperation on climate action, and to make progress towards a low-carbon and green economies.[55] The partnership has potential for increasing energy interdependence between the two parties, specifically relying on the large potential for renewable energy in Morocco. The partnership also aims at developing cooperation with other international actors to encourage a stronger commitment to achieving the goals of the Paris Agreement.[56]

Electricity generation

Electricity generation in Morocco is mainly based on coal and natural gas. Renewable energy currently accounts for 19% of Morocco's electricity production. However, the country has an ambitious energy transition plan. Morocco's goal is producing 52% of its electricity from renewables by 2030. It aims to add approximately 3.6 GW of new solar and wind capacity. Between 2021 and 2023, the country added about 203 MW of additional capacity from renewable energy sources.

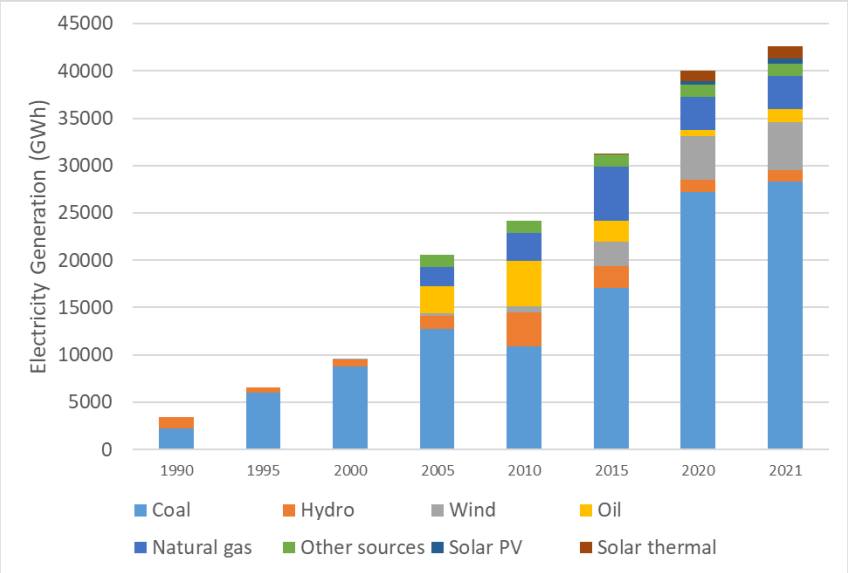

Figure 7: Electricity generation in Morocco. Source: IEA, 2024. https://www.iea.org/countries/morocco

[55] European Commission, 2022: EU climate cooperation with Africa. https://climate.ec.europa.eu/eu-action/international-action-climate-change/eu-engagement-climate-action-non-eu-countries/eu-climate-cooperation-africa_en#country-specific-partnerships

[56] European Commission, 2022: The EU and Morocco launch the first Green Partnership on energy, climate and the environment ahead of COP 27. https://neighbourhood-enlargement.ec.europa.eu/news/eu-and-morocco-launch-first-green-partnership-energy-climate-and-environment-ahead-cop-27-2022-10-18_en

The largest plant under construction is the Noor Ouarzazate complex. It consists of four power plants each using different renewable technologies as follows: Noor I (160 MW), Noor II (200 MW), Noor III (150 MW), and the planned Noor IV (72 MW).[57],[58]

Green hydrogen strategy and roadmap

Morocco has issued a green hydrogen strategy and a national roadmap.[59] Among others, the strategy includes the following measures:

- The development of a national hydrogen market, inviting operators and investors to use clean energy based on green hydrogen;
- Ensuring the necessary financing for the development of hydrogen and associated production activities by strengthening international cooperation;
- The creation of a Moroccan and regional research and development (R&D) pole and to propose a set of pilot projects;
- The implementation of measures for the local industrial integration of the hydrogen sector through the training of the workforce;
- The creation of favourable conditions for the export of hydrogen and its derivatives, with priority given to its export to Europe.

The strategy also supports the local production of ammonia to reduce the amount of imports. So far, Morocco has mainly relied on imported ammonia to cover its needs.

Morocco has a large phosphate resource base and a significant role in global fertiliser production.[60] It holds 75 percent of global phosphate reserves.[61] The OCP Group (OCP S.A.), owned by the Moroccan Government and the Banque Populaire du Maroc, has about 31% global market share in fertilizers.[62] OCP is the world's largest producer of phosphate and phosphate-based products and it is one of the largest fertilizer and chemicals companies in the world. OCP Group has four mining sites and two industrial complexes in Morocco.[63] However, the OCP group operates in five continents. It includes Phosboucraa, located in Boucraa (Southern Region in Morocco) a company that mines, processes and markets phosphate rock, OCP North America and OCP Africa, which is involved in sustainable agriculture.

[57] Anouar, 2022: Morocco Has Invested $5.2 Billion in Solar Energy Projects. https://www.moroccoworldnews.com/2022/08/350593/morocco-has-invested-5-2-billion-in-solar-energy-projects

[58] Kasraouli, 2021: Morocco's Ouarzazate Noor Solar Plant Supplies 2 Million Moroccans with Electricity. https://www.moroccoworldnews.com/2021/02/335886/moroccos-ouarzazate-noor-solar-plant-supplies-2-million-moroccans-with-electricity

[59] Ministere de la transition energetique et du developpement durable , 2021. HYDROGÈNE VERT VECTEUR DE TRANSITION ÉNERGÉTIQUE ET DE CROISSANCE DURABLE. https://www.mem.gov.ma/Pages/actualite.aspx?act=278

[60] Phosphate is the natural source of phosphorous, an element that provides a quarter of all the nutrients that plants need for their growth and development (Source; OCO Group, 2024, What is phosphate? https://www.ocpgroup.ma/what-is-phosphate).

[61] United Nations, 2023: All about the NDCs. https://www.un.org/en/climatechange/all-about-ndcs

[62] https://www.ocpgroup.ma/ocp-group

[63] https://web.archive.org/web/20170106012533/http://www.syitc.com/events/ocp-group-major-business-opportunities/

Fertiliser use is key to increasing food production yields, particularly in the Maghreb. Morocco relies on imports of fossil gas-based ammonia for its fertiliser production. Thus, the OCP group is interested in diversifying the production sites for ammonia from natural gas towards other countries in Africa with large natural gas reserves, thus avoiding transport costs. OCP is currently involved in developing projects to produce ammonia from natural gas in Nigeria, Ghana and Ethiopia.

The OCP group is interested in replacing imported fossil-based ammonia by green ammonia. The OCP Group will build a new ammonia production facility near Tarfaya. The plant will be powered by 3.8 GW of wind and solar energy, with desalinated water to be used for electrolysis. The plant aims at producing 200,000 tonnes per year of renewable ammonia from 2026, and 3 million tonnes per year from 2032.[64] It has an estimated investment cost of 7 billion USD.[65] In the long term. Morocco will need to replace part of its imported grey ammonia by green ammonia from domestic renewable energy sources. Domestic production of green ammonia could contribute to make its fertilizer industry more sustainable and mitigate the risks posed by volatile natural gas prices. It can also open opportunities for exports of green ammonia to other regions. However, green ammonia is still expensive.

Morocco can become a supplier of green ammonia to the EU. One of the priorities for the EU to reduce carbon emissions in the agriculture sector is transitioning fertiliser production from ammonia produced from grey hydrogen to ammonia from green hydrogen. The EU will need to incentivise both domestic and foreign producers to decarbonise production of ammonia, for instance through the introduction of green labels, in order to facilitate market creation for green ammonia.

HEVO Ammonia Morocco project

In July 2021 Morocco's Ministry of Energy, Mines and Environment launched the HEVO Ammonia Morocco project, with estimated investments of $850 million. The facility is expected to produce 183,000 tons of green ammonia by 2026. Fusion Fuel plans to supply the technology to produce the 31,000 tons/year of green hydrogen needed for the project. The ammonia produced in this plant is expected to be exported to Europe.

AMUN project

Another project that is being developed is the AMUN project, being developed by CWP Global. The project will be located close to Tan Tan. Three phases are planned. The first two phases have both 3 GW of solar and 3 GW of wind. They should reach a combined ammonia production of 2 to 2.5 million tonnes per year. The third phase is still in early development. [66]

Gaia Energy project

China Energy has signed an MoU with Ajlan Bros, a company based in Saudi Arabia, and Gaia Energy (based in Morocco) to build a plant for green ammonia production with a capacity of approx. 1.4

[64] Atchison, Julian, 2022: Green ammonia in Morocco: an update. January 27, 2022. https://www.ammoniaenergy.org/articles/green-ammonia-in-morocco-an-update/

[65] Eljechtimi, A., 2023: Morocco's OCP plans $7 billion green ammonia plant to avert supply problems. https://www.reuters.com/sustainability/climate-energy/moroccos-ocp-plans-7-mln-green-ammonia-plant-avert-supply-problems-2023-06-20/

[66] Rouwenhorst, K., 2023: Gigawatt-scale renewable ammonia in Northwest Africa. https://www.ammoniaenergy.org/articles/gigawatt-scale-renewable-ammonia-in-northwest-africa/

million tonnes/year. The project plans to install 4 GW of wind power and 2 GW of solar PV for green hydrogen production. The green ammonia is expected to be used both domestically and for exports.[67]

Pilot Power-to-Liquids (PtL) plant

A pilot PtL plant is being constructed in Morocco, initiated by the International PtX Hub. It will provide test labs for professionals working in the Power-to-Liquid value chain. The plant will produce either e-kerosene (Fischer-Tropsch based Sustainable Aviation Fuel) or e-methanol via Polymer Electrolyte Membrane (PEM) electrolysis and CO_2 input.[68]

When developing hydrogen production based on electrolysis in North Africa, it has to be taken into account that water scarcity is a significant problem and has led to local conflicts. Current electrolysers are operated with highly purified water. It is necessary to treat and deionise impure water for electrolysers. This increases the operation and maintenance costs.

Tunisia

The privileged partnership between Tunisia and the European Union (EU) was established in 2012. In 2023, the European Union and Tunisia agreed to work together on a comprehensive partnership package.[69] The package has four pillars:

- Macro-financial support and further assistance
- Strengthening economic and trade ties
- Green energy transition
- People-to-people contacts
- Migration

The package comprises a sustainable energy partnership aimed at creating a framework for trade in renewables, and integration with the EU electricity market. It includes a Memorandum of Understanding on renewable energy production, establishing a roadmap on a green energy transition and the finalisation of negotiations on the ELMED submarine interconnector between Italy and Tunisia.[70] The pillar "People-to-people contacts" included €10 million for technical and vocational training in 2023.

[67] Atchison, 2023. China energy foreign investments in ammonia. May 17, 2023. https://www.ammoniaenergy.org/articles/china-energy-foreign-investments-in-ammonia/

[68] Schöttler, 2023: Power-to-Liquid pilot plant to increase market readiness and capacities in Morocco. International PtX Hub. https://ptx-hub.org/power-to-liquid-pilot-plant-to-increase-market-readiness-and-capacities-in-morocco/

[69] European Commission, 2023: European Commission and Tunisia Joint Statement. 11 June 2023 https://ec.europa.eu/commission/presscorner/detail/en/statement_23_3202

[70] European Commission, 2023: EU comprehensive partnership package with Tunisia. 11 June 2023. https://ec.europa.eu/commission/presscorner/detail/en/FS_23_3205

In December 2023, the EU and Tunisia agreed on a €150 million program is designed to support the Tunisian government's efforts to boost the economy, notably by improving public finance management and the business and investment climate.[71]

Electricity generation

Electricity generation in Tunisia comes mainly from natural gas. Renewables supplied approximately 4.3% of the electricity generation in 2021. Domestic natural gas production meets about 53% of the total demand for natural gas. The remaining 47% is imported, mainly from Algeria. Tunisia receives natural gas as a royalty on the Algerian Transmed gas pipeline, which is a 2,475 km natural gas pipeline that exports Algerian natural gas to Italy.[72]

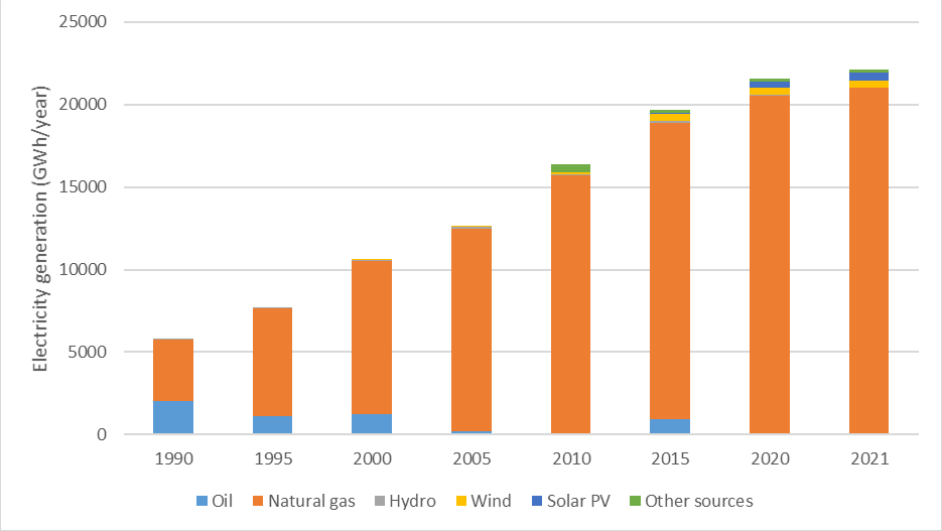

Figure 8: Electricity generation in Tunisia (1990-2021). Source: IEA, 2024. https://www.iea.org/countries/tunisia

State-owned national electricity and gas utility company STEG owns 92.1% of the installed electricity generation capacity. Tunisia imports electricity from Algeria and Libya.

In 2021, Tunisia had achieved only 400 MW of renewable electricity capacity, with the largest contribution from wind power and smaller amounts from solar PV and hydropower. Tunisia has a renewable electricity target of 35 percent by 2030. The target requires a renewable capacity addition of approximately 4 GW until 2030. This translates into an annual capacity addition of at least 500 MW/year.[73]

[71] European Commission, 2023: L'Union européenne et la Tunisie conviennent d'un programme de 150 millions d'euros. https://neighbourhood-enlargement.ec.europa.eu/news/lunion-europeenne-et-la-tunisie-conviennent-dun-programme-de-150-millions-deuros-2023-12-20_en

[72] International Trade Administration, 2024: Tunisia - Country Commercial Guide. Electrical Power Systems and Renewable Energy. 15.4.2024. https://www.trade.gov/country-commercial-guides/tunisia-electrical-power-systems-and-renewable-energy#:~:text=Tunisia's%20power%20sector%20is%20well,19%2C520%20gigawatt%20hours%20in%202022.

[73] REGLObal, 2023: Greening Energy Mix: Investments focus on increasing renewables in Tunisia https://reglobal.org/greening-energy-mix-investments-focus-on-increasing-renewables-in-tunisia/

As part of the National Renewable Energy Development Plan, in January 2023, the Tunisian Ministry of Industry, Mines and Energy launched three new calls for tenders for solar PV and wind power projects with a total capacity of up to 1,700 MW (1,100 MW of solar PV capacity and 600 MW of wind power capacity). The first component of the tender involves eight separate solar PV projects of up to 100 MW each, for a total of 800 MW. The second component of the tender includes eight wind power projects. For the period 2022-2025, the maximum allowed installed capacity of a single project is 75 MW. The third part of the tender includes two concessionary Solar PV projects.[74]

The development of the first privately financed solar PV project with a capacity of 100 MW located in Tunisia's Kairouan governorate was launched in September 2023.[75]

Tunisia offers incentives to attract foreign investors in the renewable energy sector, including tax exemptions, waivers for customs duties, accelerated depreciation, and repatriation of profits for non-resident companies.[76]

Hydrogen roadmap

In 2019, the Tunisian government published its "Hydrogen Roadmap". The document highlights the current energy context in Tunisia, including the country's high dependence on imported fossil fuels and the need to increase the share of renewable energies in the energy mix. It also identifies the main challenges facing the development of a hydrogen economy in Tunisia, such as the lack of infrastructure and the high cost of production.

The objectives of the roadmap include increasing the share of renewable energies in the energy mix and creating new economic opportunities in the hydrogen sector.

The roadmap identifies four strategic axes for the development of a hydrogen economy in Tunisia:

- Development of renewable energies: The roadmap emphasizes the importance of developing renewable energies, particularly solar and wind power, to generate electricity and produce hydrogen.
- Implementation of hydrogen infrastructure: The roadmap outlines the need to build out hydrogen infrastructure, including production facilities, storage facilities, and distribution networks.
- Promotion of hydrogen-powered vehicles: The roadmap encourages the adoption of hydrogen-powered vehicles to reduce dependence on fossil fuels and decrease emissions.

[74] Positiv´energy, 2023: Tunisia: Call for tenders for 1.7 GW of renewable energy. April 20 2023. .https://positivenergy.tn/2023/04/20/tunisia-call-for-tenders-for-1-7-gw-of-renewable-energy/
[75] AfDB, 2023: Tunisia: AfDB, AMEA Power, IFC and SEFA launch first large-scale privately-financed solar project. African Development Bank (AfDB). 26 September 2023. https://www.afdb.org/en/news-and-events/press-releases/tunisia-afdb-amea-power-ifc-and-sefa-launch-first-large-scale-privately-financed-solar-project-64588
[76] Jenayah, A., 2023: Unlocking Solar and Wind Potential: Streamlining Authorization for Foreign Investors in Tunisia's Renewable Energy Sector. LegalcommunityMENA, https://legalcommunitymena.com/unlocking-solar-and-wind-potential-streamlining-authorization-for-foreign-investors-in-tunisias-renewable-energy-sector/#_ftn4

- Development of a hydrogen industry: The roadmap highlights the potential for Tunisia to become a hub for the production and export of hydrogen and hydrogen-related products, such as fuel cells and electrolysers.

The roadmap includes action plans for each of the strategic axes, including specific goals, timelines, and responsibilities. These action plans cover a range of topics, such as the development of renewable energy projects and the construction of hydrogen infrastructure.

However, Tunisia needs support in particular regarding financing issues, setting up hydrogen value chains and developing specialist expertise.

National strategy for green hydrogen and derivatives

The National Strategy for the Development of Green Hydrogen and its Derivatives in Tunisia was published in September 2023.[77] The target is to produce 320,000 tonnes of green hydrogen by 2030. This requires an electrolyser capacity of about 3.8 GW and about 5 GW of renewable electricity. By 2050, Tunisia intends to produce 8.3 Mt of green hydrogen, including approx. 6 Mt for export by pipeline and 2.3 Mt both for the local market and export as derivatives. This would require an electrolyser capacity of about 86.8 GW and about 100 GW of renewable electricity. These targets are very ambitious.

According to the strategy, the development of green hydrogen for local markets can be considered a priority for:

- Ammonia and methanol for the period 2025 - 2035
- Methanol for bunkering local ships as of 2030, but this could be accelerated by international bunkering
- Hydrogen for the refinery, as soon as the refinery is rehabilitated. The rehabilitation will probably take place in 2030. However, the estimated quantities of green hydrogen are low (20 kt/year)

The strategy proposes connecting the production centers for green hydrogen in the south of the country and the demand centers for the local and export markets. The strategy also proposes to use existing natural gas infrastructure to the extent possible.

According to the strategy, a new dedicated gas pipeline would be needed to collect the green hydrogen produced in the south of the country and transport it to the north of the country to be exported to Italy.

The strategy does not suggest blending hydrogen into the existing natural gas grid since it requires technical adjustments and introduce additional costs.

[77] MIME, 2024. STRATÉGIE NATIONALE POUR LE DÉVELOPPEMENT DE L'HYDROGÈNE VERT ET SES DÉRIVÉS EN TUNISIE. Synthèse - Mai 2024. Ministère de l'Industrie, des Mines et de l'Energie (MIME). https://www.energiemines.gov.tn/fileadmin/docs-u1/Re%CC%81sume%CC%81_stratei%CC%80gie_nationale_MIME-WEB.pdf

A supportive regulatory framework, which is essential to attract private investments in the hydrogen sector, is being developed.

Ammonia

Ammonia is used directly as a fertilizer (agricultural ammonium nitrate) or for the production of fertilizers by the Groupe chimique Tunisien (CGT). At present, there is no domestic production of ammonia. Tunisia relies on imports. Demand for ammonia in Tunisia could increase in the future if fertilizer production is increased again.

The phosphate industry represents 4 percent of GDP and 15 percent of exports of Tunisia. In 2023, the government announced an initiative to prioritize phosphate production by the Compagnie des phosphates de Gafsa (CPG), the state-owned phosphate company. The country seeks to take advantage of increases in fertilizer prices by increasing the exports of phosphate and phosphate fertilizers. The latter are produced by a subsidiary of CPG, the Groupe chimique Tunisien (GCT). [78]

The Gafsa Basin accounts for more than 90 percent of Tunisia's phosphate rock production. However, other large phosphate rock deposits exist (for example in Sra Ouertane) but they have not been exploited yet.

The European Commission has classified phosphate rock as one of 20 critical raw materials.[79] Phosphate rock is identified as non-substitutable and of high economic importance, highlighting the need of securing supply. Tunisia's strategic advantage as a phosphate-rich country offers a gateway to European markets. However, in the future, the Groupe chimique Tunisien (CGT) must decrease the carbon footprint of its phosphate fertilizers, in order to be able to reduce custom duties under the European Carbon Border Adjustment Mechanism (CBAM).

Projects

The following projects are examples of the set of projects currently under development in Tunisia and should provide a blueprint for large-scale green hydrogen and ammonia production projects in Tunisia.

<u>H2-Notos</u>

TE H2, a joint venture between TotalEnergies and EREN Groupe, and VERBUND, Austrian largest electricity company, have signed a Memorandum of Understanding with the Republic of Tunisia to explore the implementation of a large-scale green hydrogen project called "H2 Notos" for export via pipelines to Central Europe.

H2 Notos plans to produce green hydrogen using electrolysers powered by large onshore wind and solar projects and supplied with desalinated water. The project is expected to produce around 200,000 tons of green hydrogen per year in the initial phase, with the potential to increase production in

[78] Yahyaoui, A., 2023: Shaping a New Future for Tunisia's Phosphate. https://resourcegovernance.org/articles/shaping-new-future-tunisias-phosphate

[79] European Commission, 2023: Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing a framework for ensuring a secure and sustainable supply of critical raw materials and amending Regulations (EU) 168/2013, (EU) 2018/858, 2018/1724 and (EU) 2019/1020 COM/2023/160 final. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52023PC0160

southern Tunisia to 1 million tons per year. The project will have access to the European market via the "SoutH2 Corridor", a hydrogen pipeline project connecting North Africa with Italy, Austria and Germany, which is expected to be operational around 2030.[80]

The SouthH2 Corridor project is a 3,300 km long hydrogen pipeline connecting North Africa, Italy, Austria and Germany. Led by transmission system operators, each of which has submitted a project of common interest to the European Commission, it aims to deliver competitive renewable hydrogen to Europe. More than 70% of the corridor consists of reused infrastructure, which is supplemented with new sections of pipeline as required. The corridor enjoys political support as well as strong support from companies involved in the production (about 2.5 million tons per year) and consumption of hydrogen along the entire corridor.

In May 2024, Austria, Germany and Italy signed a Joint Declaration to develop the south hydrogen import corridor connecting the three countries.[81] The southern corridor is expected to play an important role in supplying the southern German states (e.g. Bavaria), Austria and Italy.

HyDeploy: This is a European Union-funded project focused on developing and demonstrating innovative hydrogen production and storage technologies in Tunisia. The project involves several partners from Europe and Tunisia and aims to demonstrate the feasibility of using hydrogen as a clean energy carrier in the country.

HYPERION: This is another EU-funded project aimed at developing and testing advanced hydrogen production technologies in Tunisia. The project focuses on the use of renewable energy sources, such as solar and wind power, to produce hydrogen through electrolysis.

Sfax Green Hydrogen: This is a project aimed at producing green hydrogen from renewable energy sources in the city of Sfax.

ACWA Power

ACWA Power, a private water desalination company, has signed an agreement with the Tunisian government to produce up to 600,000 tons/year of green hydrogen for exports towards Europe. In the first phase, the company plans to install 4 GW of renewable electricity and 2 GW of electrolyser

[80] Verbund, 2024: Grüner Wasserstoff: TE H2 geht eine Zusammenarbeit mit VERBUND für ein Großprojekt in Tunesien ein. 28 May 2024. Paris and Tunis. https://www.verbund.com/de-at/ueber-verbund/news-presse/presse/2024/05/28/te-h2-zusammenarbeit-verbund#!/1/undefined/1/undefined/%7B%22sitepath%22%3A%22f7fce78b-6810-49fa-b663-54ba31acfdae%22%2C%22database%22%3A%22web%22%2C%22language%22%3A%22de%22%2C%22token%22%3A%22gj2kx4dds7ljcp914bp5u%22%2C%22folder%22%3A%22celum%22%2C%22page%22%3A0%2C%22isMobile%22%3Afalse%7D/undefined

[81] Landini, F., Amante, A., Wacket, M., 2024: Italy, Germany, Austria sign cooperation deal on southern hydrogen link. May 30, 2024. https://www.reuters.com/sustainability/climate-energy/italy-germany-austria-sign-cooperation-deal-southern-hydrogen-link-2024-05-30/

capacity, as well as battery storage facilities, to produce 200,000 tons/year of green hydrogen. The company plans to export the green hydrogen through the SouthH2 Corridor.[82]

Skills for green hydrogen

Education and training are essential for the development of skills of the workforce in the hydrogen field. However, there is a lack of specific hydrogen education and training programs. There is also a lack of trained teachers and trainers as well as of available equipment for practical training and education.

Specific hydrogen expertise is not available at a sufficient scale. Companies in the hydrogen sector generally have difficulties finding people with hydrogen experience. Engineers and technicians are in demand, in particular chemical and electric engineers as well as gas industry technicians. The development of hydrogen infrastructure is conducted by the existing engineering consultancy sector. Most hydrogen teams in large engineering consultancies are staff with experience in other energy sectors (predominantly oil and gas).

The European hydrogen skills initiative has identified professional roles where there is an urgent need for qualified staff such as: [83]

- Hydrogen production specialist
- Hydrogen storage specialist
- Fuel cell specialist
- Electrochemical engineer
- Maintenance technicians
- Process engineers for manufacturing hydrogen
- Production technicians

In contrast, the demand for plant and machine operators is low.

In terms of skills, the following have been identified as prioritary:

- safety and risks aspects of hydrogen projects
- hydrogen production, transport, storage
- green hydrogen value chain

[82] Arab News, 2024. ACWA Power signs deal for major green hydrogen project in Tunisia. June 4 2024. https://www.arabnews.com/node/2521256/business-economy

[83] Green Skills for Hydrogen, 2023: European Hydrogen Skills Strategy. https://greenskillsforhydrogen.eu/wp-content/uploads/2023/10/Green-Skills-for-Hydrogen-European-Hydrogen-Skills-Strategy-last-update-24102023.pdf

"Production" and "hazards" are the most frequently mentioned skills by the industry. "Hazards" is a cross-cutting skill across the green hydrogen value chain. Basic hydrogen awareness is also necessary to avoid misconceptions among technical workers.

In addition, specialist fabrication skills will be required for the construction of hydrogen pipelines, once they start to be deployed.

Furthermore, the use of hydrogen in manufacturing industries will require workers to be trained to handle it safely and avoid any leakages. Currently, there are limited training opportunities and resources to provide hydrogen knowledge and training to the existing workforce.

Professionals in the hydrogen sector typically hold a Master's degree in a relevant discipline such as chemical or mechanical engineering but specialisation on hydrogen is still rare. As it stands, on-the-job training and practical training courses are the main means to provide training to the staff of companies in the hydrogen sector. However, the number of programmes on fuel cells and hydrogen in higher education is increasing rapidly.

There are some occupations where a person may require reskilling and upskilling, but the principles of the role are similar to the roles in other industries. For example: [84]

- Procurement
- Legal
- Health and Safety

In addition, digital skills will be increasingly needed, for example:

- remote monitoring of hydrogen production,
- smart metering,
- other automated processes

[84] Edwards, L., 2023: Reskilling Talent for Hydrogen Renewable Energy Jobs. NERFIRCROFT. August 2023. https://www.nesfircroft.com/resources/blog/reskilling-talent-for-hydrogen-renewable-energy-jobs/

Hydrogen educational programmes at the Institut Français du Pétrole & Energies Nouvelles (IFPEN)

The engineering graduate programme of the Institut Français du Pétrole & Energies Nouvelles (IFPEN) has integrated hydrogen skills into existing programmes. It also provides short modules with a focus on fuel cell modelling, salt cavity storage, hydrogen energy system modelling and lifecycle analyses (European Commission, 2021).[85]

The IFPEN has also developed New Advanced-Master program "Hydrogen Project and Engineering". The program covers the entire hydrogen value chain and has been accredited by the Conférence des grandes écoles (CGE). It is aimed at persons with an engineering degree or equivalent (4 or 5 years of higher education). The program covers challenges facing hydrogen, as well as its role in the energy transition. Hydrogen production technologies, hydrogen transport, storage and distribution. The curriculum also covers regulation, safety and environmental issues as well as the economics of hydrogen, uses the transport and industrial sectors and project management. The program has received the support of several industrial companies (Air Liquide, Axens, Elogen, Engie, France Hydrogène, GRTgaz, H2V, Lhyfe, Saipem and Volvo). [86]

Some possible measures to develop skills in the hydrogen sector are as follows:

1. Skills needs assessments
2. Mapping of available trainings
3. Develop modular trainings
4. Develop skills passports displaying an individual worker's current qualifications
5. Develop a set of hydrogen micro-credentials that address immediate training needs.[87]
6. Put in place relevant national standards for the certification of technicians in the renewable hydrogen sector[88]
7. Make equipment for practical training available (e.g. fuel cells, electrolysers, storage etc.)
8. Encourage the mobility of learners and trainers to enhance access to training and facilitate experience exchange
9. Development of micro-credentials for gas industry workers, mechanical fitters and electricians[89]

[85] Iain Weir, Jolanta Beinarovica, Kayleigh Nelson, Joginder Fagura and Mark Morrison, Optimat Ltd. March 2023. Mapping the current and forecasted hydrogen skills landscape. https://www.climatexchange.org.uk/publications/mapping-the-current-and-forecasted-hydrogen-skills-landscape/

[86] IFP School, 2024: New Advanced-Master program "Hydrogen Project and Engineering". https://www.ifp-school.com/en/node/1899

[87] Swinburne University of technology, 2022: Hydrogen Skills Roadmap. An analysis of the skills and training needs to support a future hydrogen economy. Victorian Hydrogen Hub.

[88] Energy Skills Queensland, 2020: Interim Research Report: Hydrogen Industry - Job Roles, Skills, Qualifications and Experience. Energy Skills Queensland https://energyskillsqld.com.au/wp-content/uploads/2020/10/Interim-Research-Report-Hydrogen-Industry.pdf

[89] Micro-credentials are evidence of the learning outcomes that a learner has achieved as part of a less extensive learning unit. They must comply with quality assurance standards. BMBWF, 2024. Micro-credentials. https://www.bmbwf.gv.at/Themen/HS-Uni/Europ%C3%A4ischer-Hochschulraum/Die-Themen-des-Europ%C3%A4ischen-

10. Cooperation between European universities and vocational training institutions and partners in other regions
11. Cooperation between industry, governments and vocational education and training institutions to develop hydrogen-specific education and training

The Bavarian-Tunisian technology and innovation hub for green hydrogen

The German region of Bavaria has set up the Bavarian-Tunisian technology and innovation hub for green hydrogen as a cooperation between the Bavarian State Ministry of the Environment and Consumer Protection, the Ministry of Industry, Mines and Energy (MIME) of Tunisia and the Ecole Nationale d'Ingenieurs de Tunis (ENIT).[90] The hub promotes dialogue between Tunisian and Bavarian stakeholders and enables exchange between universities. A training with focus on hydrogen and leadership and a mentoring programme promotes Tunisian women, who work in the renewable hydrogen sector.

The UNIDO with the support of the Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK) is working on the development of training for the Tunisian green hydrogen stakeholders. [91] The UNIDO has developed a developed a methodology to assess skills for green hydrogen over the entire value chain to support the development of interventions to build capacity on vocational, educational and/or training programs.

Conclusions

This policy brief has presented an overview of renewable hydrogen in four North African countries (Algeria, Egypt, Morocco and Tunisia). These countries could export green hydrogen and derivatives to the EU. They have adopted clean or green hydrogen strategies and are developing projects for green hydrogen or green ammonia production.

Renewable hydrogen can also be used as a feedstock by the North African industry to produce green products with higher value-added than raw materials such as green steel, green fertilizers and cement for domestic consumption or exports to the European Union.

Cooperation between North Africa and the EU on renewable energy can become a building block for a broader cooperation on trade, security, technology, climate and environmental policy, thus strengthening the EU's external relations towards Africa as strategic partner. A sound cooperation requires development of trade relationships, substantial investments, opening of markets and recognition of North African countries as equal partners.

Green ammonia and methanol production provide opportunities for the use of hydrogen. They can be used in existing industries such as fertilizer and chemicals production. Green methanol can also be

Hochschulraums/Microcred.html#:~:text=%E2%80%9EMicrocredentials%20sind%20Nachweise%20%C3%BCber%20die,weniger%20umfangreichen%20Lerneinheit%20erzielt%20hat.

[90] GIZ, 2023: Green Hydrogen – High on the Tunisian Agenda. https://www.giz.de/en/downloads/giz2022-en-bavaria-tunisia.pdf

[91] UNIDO, 2024: Global Programme Hydrogen in Industry. https://hydrogen.unido.org/skills

used as a fuel for maritime transport, which is a hard-to-decarbonise sector. Ammonia and methanol are also easier to transport than hydrogen. Ammonia stays in liquid form at room temperature and low pressure (~10 bar). Methanol is a colourless liquid that is soluble in water and biodegradable. Ships for transport of ammonia and methanol are proven technology.

Ammonia is currently made mainly from fossil fuels (natural gas and coal). About 70% of ammonia is used for fertilisers, while the remainder is used for other industrial applications at the global level (e.g. textiles, refrigerants, NO_X abatement). Ammonia is the largest CO_2 emitter in the chemical industry and needs decarbonisation. Green hydrogen is a possibility for decarbonisation of the ammonia supply chain. Some projects to produce green ammonia are already being developed in Morocco and Egypt. Ammonia production is considered one of the main uses of green hydrogen in the medium term.

Today, methanol is one of the most produced organic chemicals. The global demand for methanol is around 100 million tons per year. The conventional production of methanol involves natural gas or coal. However, methanol can be produced from renewable hydrogen, which reduces greenhouse gas emissions significantly. Interest in renewable methanol is being driven by the need to mitigate CO_2 emissions. In particular, the shipping sector requires alternatives to decarbonise their operations, but green methanol can also be used to produce petrochemicals.

Currently the main barrier for the uptake of green methanol is its higher cost compared to fossil fuel-based alternatives. Green methanol costs can range from $800-1,600/ton compared to $100-250/ton for fossil-based methanol.[92]

The green hydrogen strategy of Morocco aims at preparing for the export of green hydrogen and derivatives but also supports the local production of ammonia to reduce the amount of imports. Morocco has a large phosphate resource base and a significant role in global fertiliser production. Morocco relies on imports of fossil gas-based ammonia for its fertiliser. In the medium-term, it could reduce its dependence through renewable ammonia.

Egypt's low-carbon hydrogen strategy aims at exports but also utilising green hydrogen for domestic industrial uses in the ammonia, steel, refining and methanol production sectors currently using domestic grey hydrogen and at maximizing the utilization of the site of the Suez Canal and the surrounding seaports. Ammonia has been identified as the most promising sector for domestic green hydrogen use in Egypt.

In January 2024, Egypt issued a law (Law No.2 of 2024) on incentives for projects producing green hydrogen through electrolysis and its derivatives. The law foresees tax breaks ranging from 33 percent to 55 percent to boost local green hydrogen production. Incentives also include exemptions of VAT for equipment, raw materials and transport for projects that produce green hydrogen and its derivatives. Exports of green hydrogen projects will not be subject to VAT.

The Tunisian green hydrogen strategy was issued in September 2023. The strategy is mainly oriented towards exports but also considers the development of green hydrogen for local ammonia and methanol production in the medium term. After 2030, the strategy considers the use of methanol as a fuel for ships as well as hydrogen for the refinery, if the refinery is rehabilitated. According to the

[92] JCDREAM, 2023. Green Methanol 2023. https://jcdream.org/wp-content/uploads/CHARGE-Green-Methanol-White-Paper.pdf

strategy, a new dedicated gas pipeline would be needed to collect the green hydrogen produced in the south of the country and transport it to the north of the country to be exported to Italy. The strategy does not suggest blending hydrogen into the existing natural gas grid since it requires technical adjustments and introduce additional costs.

Algeria published a national hydrogen strategy in 2023. The goal is to export 0.9-1.2 Mt of so-called clean hydrogen to the EU by 2040. Clean hydrogen includes both green and blue hydrogen. The Italian oil group ENI signed an agreement with the Algerian national oil company Sonatrach in 2023. The agreement foresees exporting green or blue hydrogen to Europe through a new gas pipeline to be built between Algeria and Italy, with a capacity of 8 to 10 billion cubic metres/year to transport natural gas, ammonia and hydrogen.[93] This pipeline (Galsi project) is expected to have a length of 837 km (565 km offshore and 272 km onshore).

Green hydrogen from Algeria and Tunisia could be imported in the long run through the SoutH2 Corridor. The South Corridor is a 3 300 km dedicated hydrogen pipeline corridor led by the TSOs: Snam, TAG, GCA and bayernets.[94] The corridor connects North Africa, Italy, Austria and Germany, to supply renewable hydrogen produced in North Africa to demand clusters in Italy (e.g. Augusta, Taranto and northern Italy), Austria (e.g. Styria, Vienna and Linz) and Southern German States (e.g. Bavaria).

Support to hydrogen projects in North African countries is available through the global gateway, the European Investment Bank and some mechanisms from the Member States such as H2Global. The EU has also recently launched a pilot mechanism to support the market development of hydrogen and connect demand and supply. Projects from North African countries can use the pilot mechanism to find off takers in the EU and connect with financial institutions. [95]

The development of green hydrogen production capacities in North Africa requires the rapid development of renewable electricity potentials. A careful balance should be cast between electricity generation capacity to meet domestic electricity demand and capacity to produce hydrogen from renewable electricity. Affordable electricity to meet domestic demand is required to ensure the economic and social development of the countries.

Just transition would require EU countries to support not only investment projects to export green hydrogen but also to implement cooperation packages, for example supporting renewable energy for domestic consumption and energy efficiency.

Another barrier for the development of hydrogen projects in North Africa is that specific hydrogen expertise is not available at sufficient scale. Companies in the hydrogen sector generally have difficulties finding people with hydrogen experience. Engineers and technicians are in demand, in particular chemical and electric engineers, as well as gas industry technicians. Skill needs assessments are required.

Another challenge is the lack of infrastructure to transport hydrogen or hydrogen derivatives (e.g. ammonia, methanol). Transport infrastructure would have to be developed. This includes developing

[93] Leite, M., 2023: ALGERIA AND ITALY SIGN AN AGREEMENT ON HYDROGEN. Hydrogen Today. https://hydrogentoday.info/en/algeria-italy-hydrogen/
[94] SoutH2 Corridor, 2022. https://www.south2corridor.net/south2
[95] European Commission, 2024: Pilot mechanism to support the market development of hydrogen. https://energy.ec.europa.eu/topics/energy-systems-integration/hydrogen/european-hydrogen-bank/pilot-mechanism-support-market-development-hydrogen_en

pipelines for hydrogen transport for instance the southH2 corridor as well as maritime transport of ammonia and methanol.

Lack of investment frameworks is another barrier. There is a need to increase financial resources for technical assistance to promote project development for production and use of green hydrogen, for instance through scaling up funding for project preparation facilities.[96]

[96] Energy Sector Management Assistance Program (ESMAP); Organisation for Economic Co-operation and Development (OECD); Global Infrastructure Facility; Hydrogen Council. 2024. Scaling Hydrogen Financing for Development. ESMAP Paper. © Washington, DC: World Bank. http://hdl.handle.net/10986/41125 License: CC BY 3.0 IGO.

*The **Global Forum on Sustainable Energy (GFSE)** is a neutral multi-stakeholder platform, which is facilitating international dialogue on energy for sustainable development by taking into accounts the special interests and challenges of developing countries. GFSE aims at the establishment of a sustainable world energy system from a social, economic and environmental perspective.*

GFSE contributes to both international discourse and information dissemination on sustainable energy. The multi-stakeholder platform plays a crucial role in facilitating sustainable energy projects by bringing

Imprint

Author: Leonardo Barreto Gómez

Published and produced by: Global Forum on Sustainable Energy,
c.o. Österreichische Energieagentur – Austrian Energy Agency
Mariahilfer Straße 136, A-1150 Vienna

E-Mail: gfse@energyagency.at

Internet: http://www.gfse.at