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Hydrogen Fact Sheet – North African Countries

Morocco | Algeria | Tunisia | Egypt | Mauritania

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1 Conclusions

All the North African countries in scope (Morocco, Algeria, Tunisia, Egypt and Mauretania) see the option of exporting green hydrogen or derivatives based on RES-E. However, their **current electricity systems** show high specific CO_2-emissions due to high shares of coal or natural gas-fired electricity generation. The uptake of wind and solar power, which are the most relevant RES-E sources due to low costs, has hardly started. Only single digit shares of RES-E can be observed in most countries, whereas Morocco shows higher shares based on hydro power.

- ➔ This situation highlights the importance of defining criteria for RES-E input for hydrogen production. This is especially important for grid integrated electrolysis plants. However, production of green hydrogen can also be a chance to accelerate the uptake of RES-E within those countries.

Most of the countries have not published detailed **hydrogen strategies** up to date. Morocco published its hydrogen strategy late 2021. Currently, studies mainly on transport options and costs are being prepared, first projects are being planned and first MoU have been signed. This early stage of the hydrogen economy indicates that no significant hydrogen imports to the EU can be expected before 2030.

The question of **transport towards the EU** is still an open one and could develop into a hen and egg problem. Investing into hydrogen production without physical export infrastructure in place is of high risk. Retrofitting existing pipelines to Spain and Italy could be the cheapest and quickest option. Shipping can be an option for trading derivatives such as e-fuels. However, there are several issues that need to be addressed in the case of pipeline transport of hydrogen:

- ➔ It is not clear how the existing business case of exporting natural gas (mainly from Algeria towards Spain and Italy) can be streamlined with an increasing export of hydrogen. Blending hydrogen with natural gas could be an option, but this would lower the value of hydrogen and does not deliver pure hydrogen to EU as needed by industries. Adding additional pipelines will increase the transport costs. However, converting one of the existing pipelines towards Spain/Italy into a hydrogen pipeline could be a feasible option to get started.
- ➔ Investors will only invest into export pipelines for hydrogen if further distribution within the European grid is secured. The European Network Development Plan for Gas could be the adequate instrument to show concrete plans to make physical imports of hydrogen from Northern Africa possible in the future.

Combining the unsolved transport issues and domestic demand for **ammonia** (e.g. Morocco), green ammonia production and export could be of major interest for the exporting country for the near future and could help to decarbonise their industry. However, this could lead to possible conflicts:

- ➔ Extracting hydrogen from ammonia in Europe (hence using ammonia only as a “carrier” for hydrogen) will increase the costs for hydrogen in the destination country.
- ➔ Using ammonia directly will be direct competition to the European ammonia industry.

Most of the North African countries studied show **high water stress and socio-economic inequalities and conflicts**.

- ➔ Therefore, sustainability criteria are not only needed for the electricity input but also to make sure hydrogen production is in line with sustainability goals.

No strategies for producing and exporting **blue hydrogen** exist in northern African countries. Algeria as the largest exporter of natural gas within the region established CCS projects in the past, however.

- ➔ If the export of blue hydrogen could be a business case and could be the entrance to the hydrogen economy for Algeria is yet to be seen.

2 Convergence & Divergence with the EU & comparing the countries

2.1 Morocco

Strengths	Weaknesses
Electricity	
• Large, low cost PV and Wind potentials within the country also close to coast (that enables water supply via sea water desalination)	• Little uptake of RES-E based on PV or Wind so far • High specific GHG emissions from electricity generation due to coal-based power plants
Transport	
• Existing pipeline infrastructure towards Spain, however, Morocco is only a transit country to date. • Existing ammonia import infrastructure can be used for green ammonia exports	
Convergence & Divergence with EU hydrogen strategy	
• Political and economic as well as the hydrogen strategy clearly focus on green hydrogen • Own interest in hydrogen production due to domestic ammonia demand	• Possible interest in exporting ammonia which might conflict with interests of the European ammonia industry.
Water	
• So far low density of sea water desalination plants which indicates low ecological stress due to brine disposal	• Areas with high water stress coincide with good PV and Wind resources
Socioeconomics	
• Green hydrogen could be building block for decarbonising domestic fertilizer industry	• The distribution of income within the population is very unequal which could indicate that only few people will benefit from hydrogen, especially if it is mostly an export industry
Hydrogen Strategy & Economy	
• Hydrogen Strategy published • Some of the lowest costs because of short transport distance to EU and existing pipelines • First hydrogen projects in planning • Fertilizer production could be the show case for sustainable domestic use of hydrogen and production of climate neutral products • Exiting R&D facilities such as IRESEN • Work starting already on the regulatory basis for green hydrogen (GOs, certification etc.)	• No hydrogen projects to date
political	
• Existing energy and hydrogen collaborations with Germany • Compared to other countries in the region, the quality of regulation is higher	• Open issues with Western Sahara (unsettled conflicts on territory) • Low environmental performance

2.2 Algeria

Strengths	Weaknesses
Electricity	
• Large, low costs potentials for PV and Wind	• Little uptake of RES-E so far • High specific GHG emissions from electricity generation which is based on natural gas
Transport	
• Existing natural-gas pipeline infrastructure towards Italy and Spain.	• Potential conflict between established natural gas business model and green hydrogen exports if gas pipeline infrastructure is to be used
Convergence & Divergence with EU hydrogen strategy	
• New Ministry on Energy Transformation has been established with focus on green hydrogen.	• No hydrogen strategy in place • Low-cost domestic natural gas and experience in CCS-technology could lead to an interest in exporting blue hydrogen if business case and transport options exist.
Water	
	• High water stress in densely populated coastal areas with possible future competition for water from sea water desalination
Socioeconomics	
• Skilled work force in the hydrocarbon field. • Green hydrogen could be building block for decarbonising domestic fertilizer and petrol industry.	• The distribution of income within the population is very unequal which could indicate that only few people will benefit from hydrogen exports
Hydrogen Strategy & Economy	
• Existing companies with know how in the gas industry. • First hydrogen projects in planning • Some of the lowest costs because of short transport distance to EU and existing pipelines that could be retrofitted.	• No existing hydrogen projects to date • Below average standards in terms of investment climate, corruption and environmental performance resulting in high WACC and reducing supply costs for hydrogen.
political	
• High political interest in green hydrogen as diversification strategy moving on from natural gas	• Regulatory quality very low • Low political stability • Low corruption control and environmental performance

2.3 Tunisia

Strengths	Weaknesses
Electricity	
• Large, low costs potentials for PV and Wind	• Little uptake of RES-E so far • High specific GHG emissions from electricity generation based on natural gas.
Transport	
• Existing pipeline infrastructure towards Italy, however, Tunisia is only a transit country.	• Strong dependence on Algeria for transport infrastructure
Convergence & Divergence with EU hydrogen strategy	
	• No hydrogen strategy in place
Water	
• Productive water management plans in place	• High water stress in Northern Tunisia
Socioeconomics	
Green hydrogen could be building block for decarbonising domestic fertilizer industry	The distribution of income within the population is very unequal which could indicate that only few people will benefit from hydrogen, especially if it is only developed as an export industry
Hydrogen Strategy & Economy	
• First hydrogen projects in planning • Memorandum of Understanding for Hydrogen Cooperation with Germany • High interest in exporting hydrogen or derived products to Italy / EU	• No existing hydrogen projects to date
political	
• Compared to other countries in the region, corruption is lower and regulatory quality higher. • High political interest in green hydrogen • Existing trade cooperation with the EU	• Indicators show low political stability, there is a high political uncertainty now.

2.4 Egypt

Strengths	Weaknesses
Electricity	
• Large, low cost PV and Wind potentials within the country and along the Nile river • Strong economic growth; established renewables support schemes with many RES-E projects in the project pipeline • Favourable locations for standalone hybrid PV and wind systems along the Golf of Suez	• Currently low RES-E share • Strong projected increase in electricity demand and plans to include coal-fired generation in national energy strategy
Transport	
• Potential benefits for development of secondary hydrogen transport infrastructure services, making use of the location along future trade routes through the Suez Canal • Existing ammonia import infrastructure can be used for green ammonia exports	• No pipeline connection to connect to European demand centres
Convergence & Divergence with EU hydrogen strategy	
• Political focus on green hydrogen and hydrogen-derived products • Own interest in hydrogen production due to domestic ammonia demand	• Vast RES-E resources, established refining industry and waste land resources might favour the case of producing e-fuels rather than hydrogen • Given the level of available RES-E resources, the ambitions for the decarbonization of the domestic electricity system are very low
Water	
• The Nile River can provide water to make attractive inland sites for hydrogen production feasible	• Existing and strongly increasing problems with fresh water supply and water conflicts on the Nile River • already strong focus on seawater desalination increases need for environmental regulation of brine disposal
Socioeconomics	
• Green hydrogen could be building block for decarbonising domestic fertilizer industry	• The distribution of income within the population is very unequal which could indicate that only few people will benefit from hydrogen, especially if it is only developed as an export industry
Hydrogen Strategy & Economy	
• Fertilizer production could be the show case for sustainable domestic use of hydrogen and production of climate neutral products; also, substantial domestic hydrogen demand could be substituted by green hydrogen to reduce industrial CO2 emissions	• No hydrogen projects to date • Potential conflict between established fossil fuel exports business model providing both crude and refined products and green hydrogen exports; same could be true for green vs. grey ammonia • Strong economic involvement of the military especially in infrastructure
political	

Strengths	Weaknesses
	• Important infrastructure is owned and operated by the military, this might be a problem for international funding agencies and for the involvement of private companies. • Low regulatory quality and political stability

2.5 Mauritania

Strengths	Weaknesses
Electricity	
• Large, low cost PV/Wind hybrid potentials within the country and close to coast (water supply)	• Access to energy/electricity is still very limited for the population, about 50% have access to electricity • Little uptake of RES-E based on PV or Wind so far
Transport	
	• Long distance to EU compared to other northern African countries. • Shipping will be the only option • No existing ammonia terminals
Convergence & Divergence with EU hydrogen strategy	
• High potential for economic development and electrification of areas	• Due to the need to ship to EU, derivatives will be in focus. In the case of ammonia, conflicts with the European ammonia industry might arise.
Water	
• Low water stress in southern Mauretania • So far low density of sea water desalination plants and unpopulated coastlines with low competition for water.	• Most other regions suffer from high water stress
Socioeconomics	
	• The distribution of income within the population is very unequal which could indicate that only few people will benefit from hydrogen exports • Slavery is still an issue
Hydrogen Strategy & Economy	
• First MoU regarding a 30GW hydrogen project	• No existing hydrogen projects to date • Lack of access to capital and high WACC
political	
• Political focus is on green hydrogen • High potential for economic development and electrification of areas	• Weak regulatory environment • Low human rights standards • Limited chance for Mauretania to take part in the hydrogen value chain for economic participation

2.6 Comparing the countries

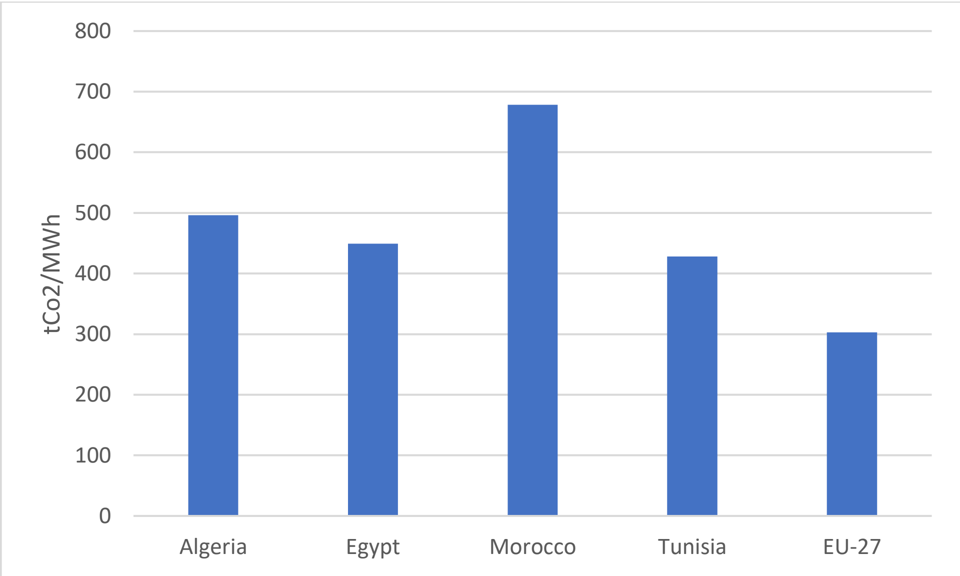
In the following sections we compare the countries studied based on various data sets.

2.6.1 Current CO_2-emissions of electricity generation

The current specific CO_2-intensity of electricity generation is shown in Figure 2-1**Fehler! Verweisquelle konnte nicht gefunden werden.**. All countries studied in northern Africa show higher CO_2-intensity than EU-27 average. Especially coal-based electricity generation in Morocco leads to high specific CO_2-emissions within the grid.

The data shows that producing hydrogen via electrolysis using electricity from the grid will lead to significantly higher CO_2-emissions in all countries studied compared to the European situation. This indicates the importance of additional RES-E generation within those countries. This would make sure that CO_2-emissions are not increasing due to increased generation of electricity by fossil power plants in order to cover additional demand caused by hydrogen production.

Figure 2-1: Specific CO_2-intesity of electricity generation [2017]

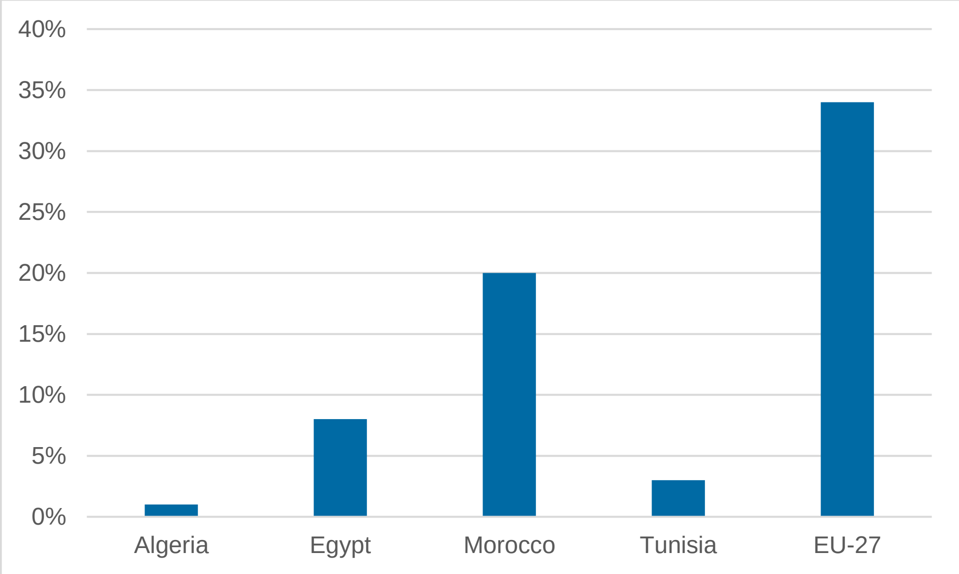


Source: IEA (2020): IEA CO2 Emissions from Fuel Combustion Statistics. https://doi.org/10.1787/co2-data-en Data for Mauretania is not available.

2.6.2 Current RES-E shares

The current RES-E share in electricity generation is shown in Figure 2-2. In line with the high CO_2-intensity of the countries studied, the RES-E share appear to be lower than EU-27 average. Especially Algeria and Tunisia have low RES-E shares. Morocco's share of about 20% is mainly based on hydropower. This shows that the uptake of RES-E has just started. Especially PV and Wind power plants are very rare and not many wind or PV projects can serve as a best practice project for future hydrogen production projects.

Figure 2-2: RES-E share of electricity generation

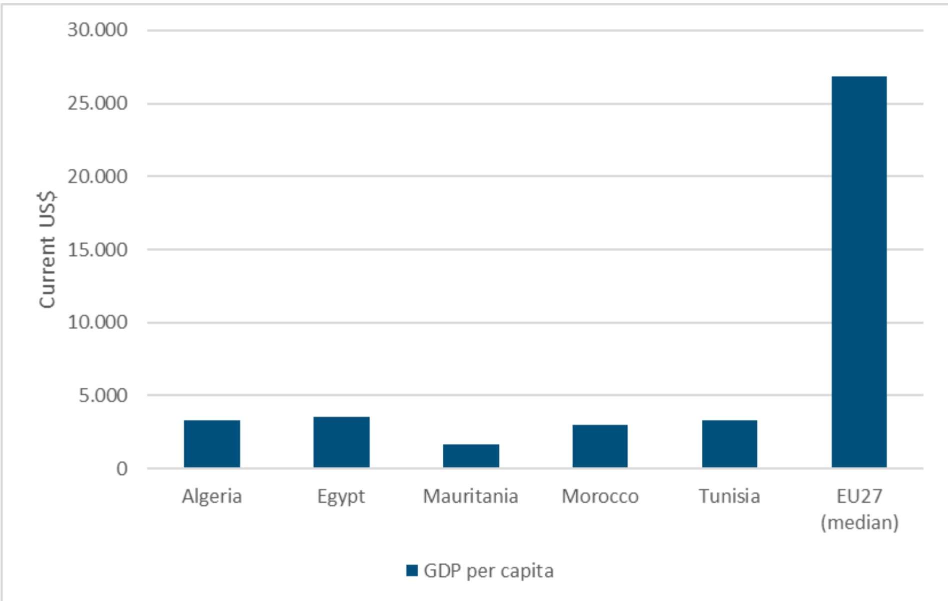


Source: IRENA (2020): Renewable Energy Statistics; Data for Mauretania is not available. Data for EU-27 [2019] from https://ec.europa.eu/eurostat/de/web/energy/data/shares

2.6.3 Comparing socio-economic and political indicators

All countries under consideration display levels of socio-economic development well below the European level (for the median EU country, per capita GDP is slightly above US$ 25.000 per year). Most countries display per capita GDP of US$ 3.000 to 3.500. Mauretania, the poorest country within the countries under consideration, has a GDP per capita of less than US$ 1.700 per year. See Figure 2-3**Fehler! Verweisquelle konnte nicht gefunden werden.** for a breakdown by country.

Figure 2-3: Per capita GDP

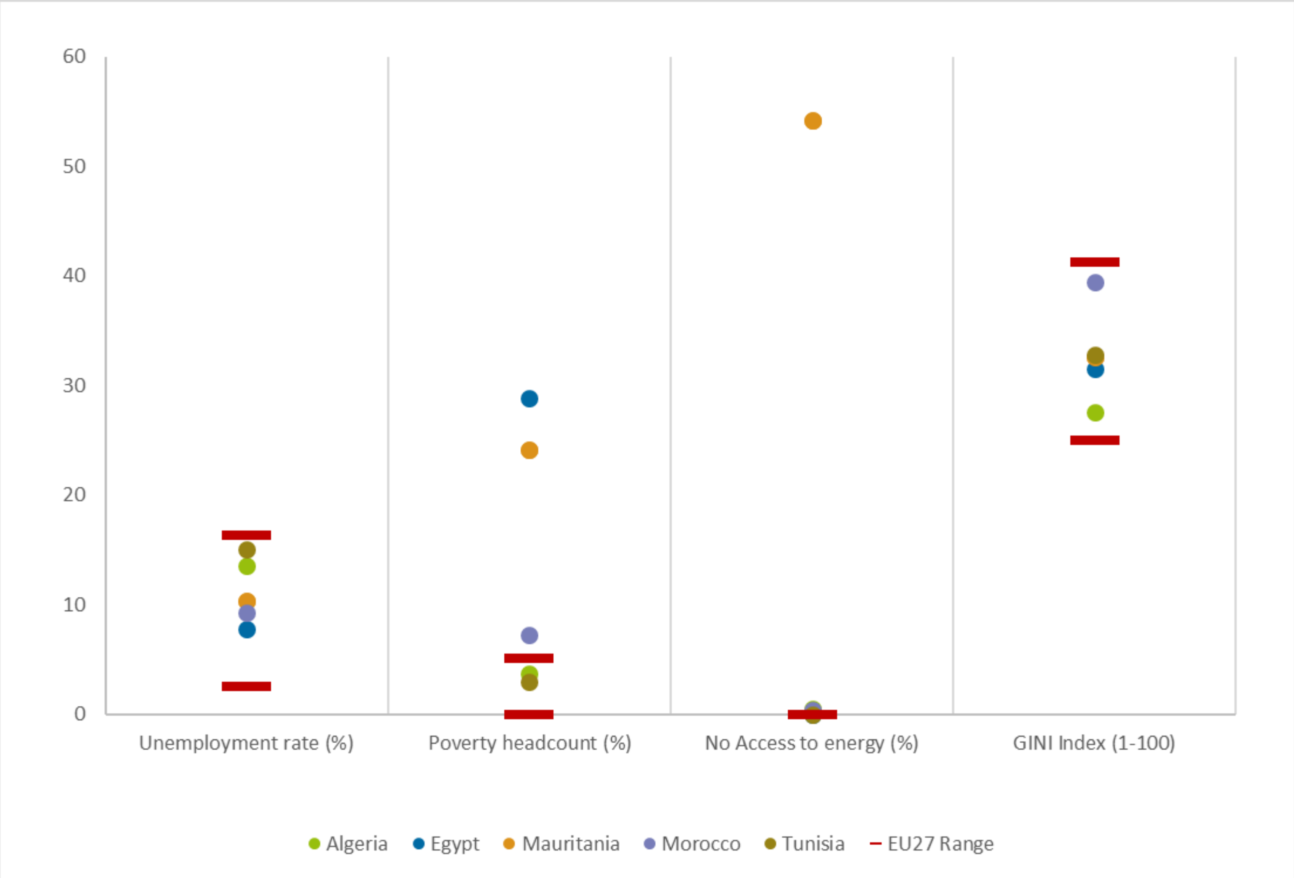


Source: World Bank: World Development Indicators (2021)

In the following, we focus on country-specific aspects related to socio-economic development and governance. We rely on data from the World Bank's World Development Indicators Database to compare the unemployment rate, poverty headcount ratio at US$ 3.20 per day, the Gini index and energy access of the countries in scope (see Figure 2-4). This allows for a rough understanding of the economic situation in the respective countries and offers an idea of the main challenges for a green hydrogen strategy.

Good governance is key to ensure low-cost and reliable supply of green hydrogen and to prevent negative side-effects for sustainable development. We thus also compare different relevant governance indicators: these include regulatory quality, political stability, control of corruption and environmental performance in Figure 2-5 also taken from the same source. In both figures, the range of den EU-27 Member-states is indicated by the red. All indicators are described in detail in section 4 in the appendix.

Figure 2-4: Comparing the countries - unemployment rate, poverty headcount, GINI index and access to energy



Source: Own compilation based on World Bank data and data from EU Stat

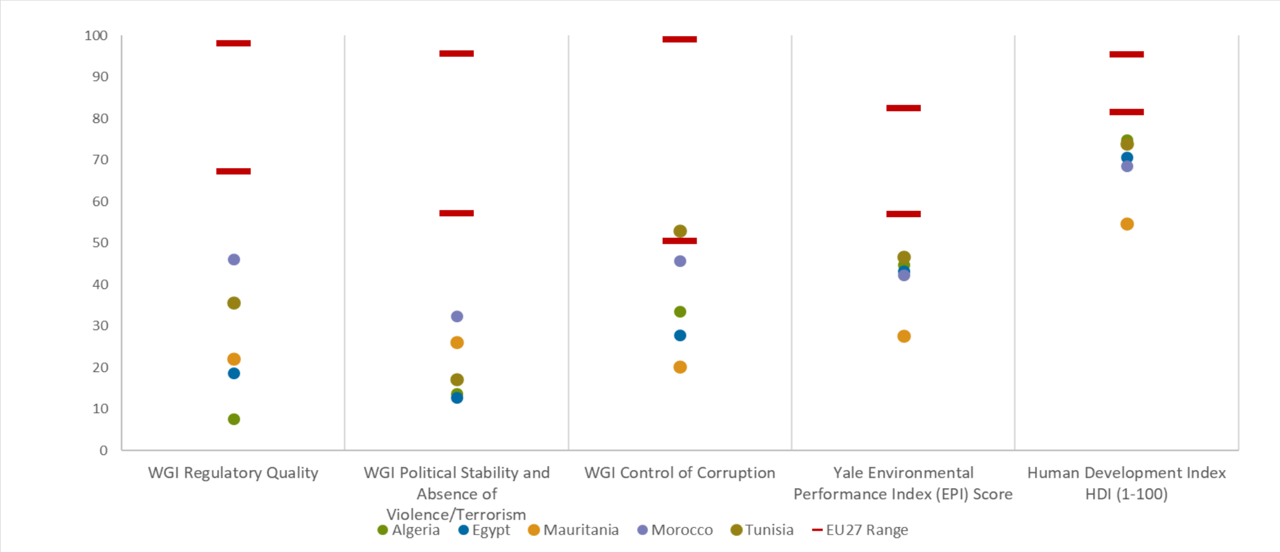
The poverty headcount is especially high in Mauretania and Egypt.

Economic inequality as measured by the Gini index lies within the range of European countries and is most pronounced in Morocco and least severe in Algeria.

Access to energy to most inhabitants is given in all countries except for Mauretania.

The following diagram shows economic, regulatory, and environmental indicators for the EU and the countries in scope.

Figure 2-5: Economic, regulatory, environmental and human development Indicators and HDI



Source: Own compilation based on World Bank data and Yale University

Especially the regulatory quality and control of corruption show a wide range within the countries in scope. Both could have a significant effect on the WACC for hydrogen projects which will either lead to higher supply costs or to a reduced number of projects being developed within the country.

Morocco and Tunisia show better scores compared to the other countries for most indicators. However, political stability is an issue for Tunisia.

Compared to European Member states, especially Algeria, Egypt and Mauretania fall behind in regulatory quality.

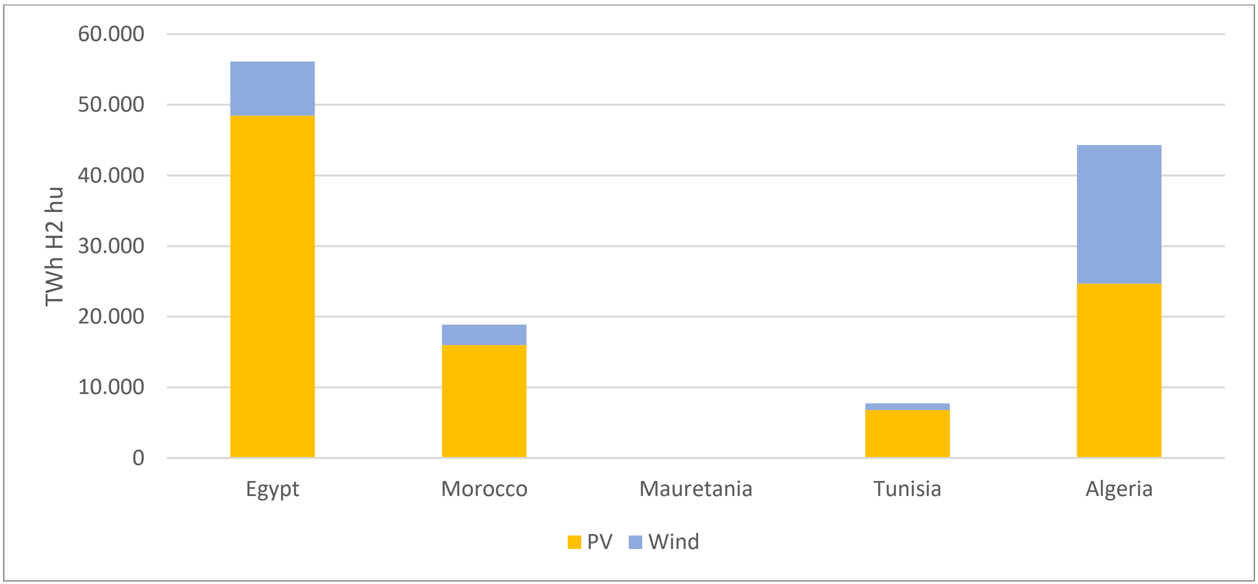
All countries under consideration are well below the EU average for the Environmental Performance index. This could indicate challenges to ensure that green hydrogen production risks adverse impacts on other aspects of environmental sustainability, such as land and water, countermining decarbonizing the fossil fuel intensive national energy systems.

With regard to the human development index, all countries are well below the EU range. This is particularly true for Mauretania.

2.6.4 H_2 production potentials

The production potentials shown in Figure 2-6 are exclusively based on solar irradiation and wind speeds. They do not consider other constraints like access to water and do not account for technological, socio-economic or ecological factors. Some of these constraints are considered in Figure 2-7.

Figure 2-6: Theoretical yearly production potential for gaseous hydrogen by country



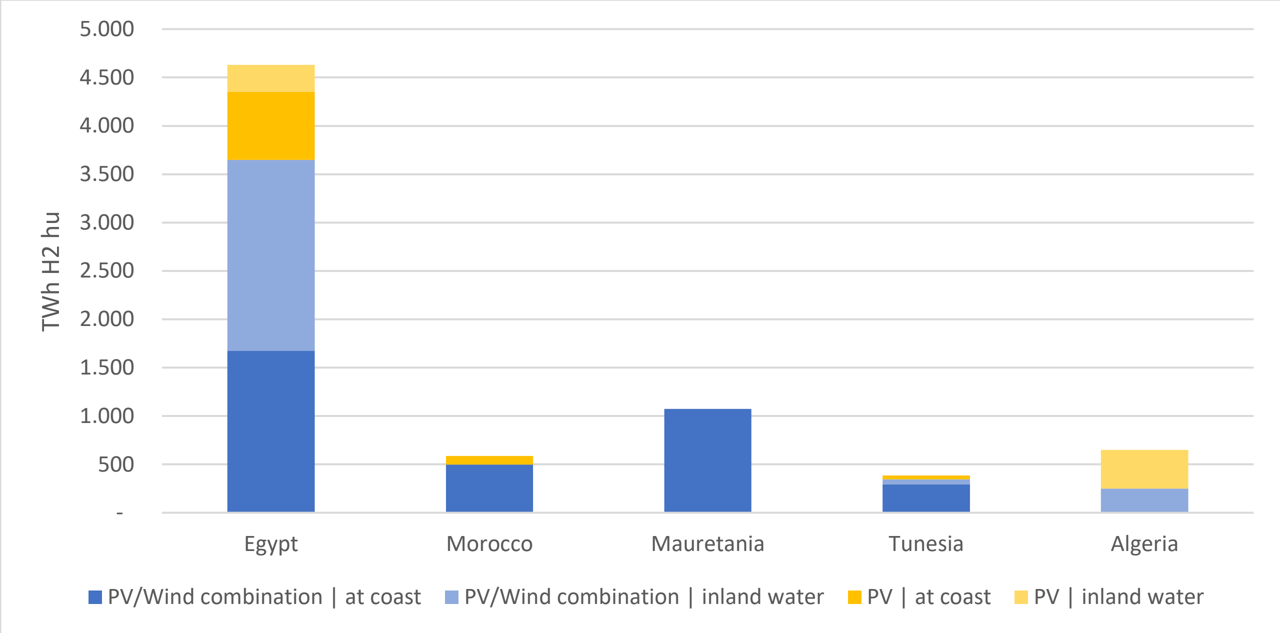
Note: Data on Mauretania is not available from this source.

Source: Own figure based on data from Brändle et al. 2020.

- ➔ Egypt and Algeria show very high potentials compared to Morocco and Tunisia.
- ➔ Potentials are mostly based on PV. However, Algeria also shows high shares of Wind potentials.

Figure 2-7 shows the annual production potential reported for gaseous hydrogen production by thee PtX Atlas from Fraunhofer Institute. While both sources estimate wind speeds and solar irradiation for RES-E production, values in the PtX Atlas are much lower compared to the theoretical production potentials reported in Figure 2-6. In contrast to Figure 2-6, the figures reported by PtX Atlas also take into account distance to infrastructure, cities and the coast (please see https://devkopsys.de/ptx-atlas/#methodik for detailed information). The main driver that reduces the potential areas for hydrogen production is however, the limitation to areas that are reported to have low water stress by the World Resource Institute. Only areas with low water stress levels are eligible to be considered for hydrogen production within the GIS analysis of the PtX Atlas. Also other competing uses are taken into account as well as distance to possible export infrastructure. This explains the difference in magnitude between the theoretical potential (Figure 2-6) and an export potential (Figure 2-7).

Figure 2-7: annual potential for producing gaseous hydrogen



Source: PTX Atlas Fraunhofer https://maps.iee.fraunhofer.de/ptx-atlas/

→ Very high production potentials in Egypt are due to the use of large inland RES-E potentials along the Nile-River. However, along the Nile-River population density and agricultural use is very high which might reduce this enormous potential when looking into specific sites.

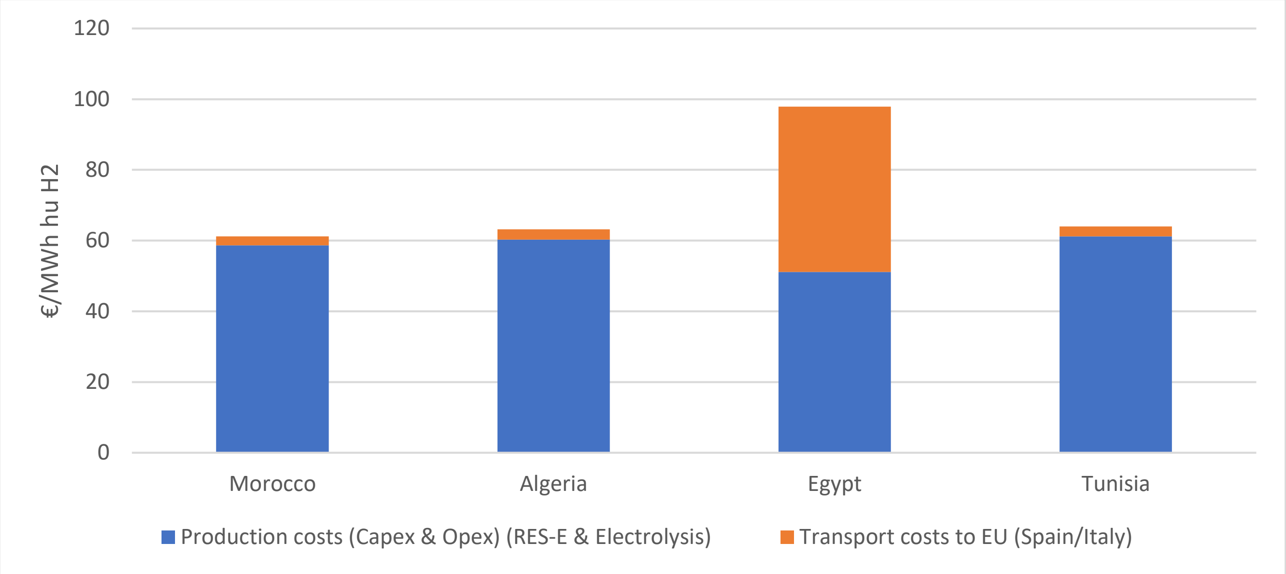
→ The production potentials could increase if sea water desalination plants are eligible as a water source.

→ Compared to the raw RES-E generation potentials, wind power plays a major role for producing hydrogen based on the methodology of the PtX Atlas. Wind power is mostly used in combination with PV generation. One reason is to achieve high full load hours of RES-E generation and hence high full load hours of the capital-intensive electrolysis.

2.6.5 Supply costs for hydrogen

Figure 2-8 shows the total supply costs for gaseous hydrogen from different North African countries to Spain or Italy in 2030 based on data from Brändle et al. 2020.

Figure 2-8: Total supply costs of gaseous hydrogen incl. transport to Spain/Italy in 2030



Source: Brändle et al. 2020 ; Comparable data for Mauretania is not available. Transport is assumed to take place in retrofitted natural gas pipelines except for Egypt where shipping of liquified hydrogen is assumed. CAPEX costs are assumed to be along the "optimistic" scenario.

Hydrogen production costs are reported to be in the same range for the selected countries. However, values will vary due to firstly, different WACC in those countries (the source assumes for all countries 8%) and secondly market prices that will not only take into account production costs at best locations.

The supply costs vary however especially due to the transport costs. Egypt is assumed not to be able to transport hydrogen via pipelines and therefore shipping costs (incl. liquification etc.) build up to be a substantial part of the supply costs.

Due to those costs it is unlikely that Egypt will export liquified hydrogen competing with countries that are connected to the EU via pipelines. Instead, ammonia or methanol or even efuels could be an option.

3 Detailed Information – Country Factsheets

3.1 Morocco

Political and economic environment (please refer to appendix 0 for description of indicators)	
Investment climate	
WGI Regulatory Quality 2019	46,15 (scale 0-100)
WGI Political Stability and Absence of Violence/Terrorism	32,38 (scale 0-100)
Socio-economic context	
GDP per capita (current US$) Unemployment rate [1]	3.009 9,3 % (2016) of population
Poverty headcount ratio at $3.20 [2]	7,3 % (2013) of population
Access to energy [% of pop. 2019]	99,6 %
GINI Index	39,5, Rank 63/159
Sustainability governance	
Yale Environmental Performance Index Rank (EPI)	42,3, Rank 100/180
Corruption	
WGI Control of Corruption	45,67 (scale 0-100)
Trade	
Main export partners[3] [% of trade volume €]	• Spain (22,6%) • France (19,4%) • Italy (4,3%)
Main export goods [% of trade volume €]	• Cars (11,9%) • Insulated Wire (11,4%) • Mixed mineral or chemical fertilizers (8,22%)
Trade agreements[4]	• There are free trade agreements with USA, Egypt, Jordan, Tunisia, Turkey, and the United Arab Emirates (UAE). • The EU and Morocco established a Free Trade Area as part of the EU-Morocco Association Agreement, signed in 1996, which entered into force on 1 March 2000. Trade in industrial products is entirely liberalised, while market opening for agricultural products is also substantial. • Negotiations for a Deep and Comprehensive Free Trade Area (DCFTA) with the EU started in 2013. A Sustainability Impact Assessment carried out by an independent contractor accompanied the launch of negotiations. The last negotiating round was held in April 2014, after which negotiations were put on hold at Morocco's request.
Hydrogen strategy and economy	

[1] https://data.worldbank.org/indicator/SL.UEM.TOTL.NE.ZS?name_desc=false
[2] https://data.worldbank.org/indicator/SI.POV.NAHC?name_desc=false
[3] https://oec.world/en
[4] Whole text cited from: https://ec.europa.eu/trade/policy/countries-and-regions/countries/morocco/

Existing hydrogen strategy	• Green Hydrogen Strategy published in Aug. 2021 by the Energy Ministry (short version[5]) (long version[6]) • The MAR/GER Energy Partnership Secretariat (PAREMA) supported the elaboration of the strategy.
Existing bilateral hydrogen agreements	• Germany and Morocco signed an agreement for a hydrogen alliance in 2020 that includes two hydrogen projects (>100MW), technical cooperation and further cooperation in research and development.[7] • A MoU was signed between Morocco and Portugal in February 2021 (direct outcome: HEVO green ammonia project)
Existing projects[8] (incl. Blue hydrogen)	None in the IEA Database 2020
Planned projects [up to 2030] [9] (incl. Blue hydrogen)	Green ammonia • ? MW | Starting 2025 | HEVO; CCC; Fusion Fuel; Vitol • 1 MW | starting Date not documented | IRESEN; Fraunhofer IMWS • 3-5 MW | starting 2021 | OCP pilot in Jorf Lasfar Green hydrogen • 100 MW | Starting 2024 | MASEN with KfW
support schemes or funding facilities for clean hydrogen	• None to date • Morocco aims to work on GOs for electricity to have the framework ready for grid integrated hydrogen production
Potential branches for domestic hydrogen demand	• Fertilizer production: Based on ammonia and local phosphate reserves Morocco is a major producer of fertilizer. Morocco imports more than one million tonnes[10] of ammonia per year[11]. This import could be substituted by domestic ammonia production based on green hydrogen. Main player is OCP Group which is mostly state owned. The hydrogen strategy expects ~3 to 7 TWh of domestic hydrogen demand in the industry sector for 2030.
Hydrogen Exports in strategy [TWh per year]	2030: 10.3 to 21.7 TWh 2040: 45.9 to 91.8 TWh 2050: 114.7 to 229.5 TWh
Main hydrogen production technology in focus[12]	Green hydrogen based on Wind power and PV. Combined Wind/PV-Plants also find excellent sites in Morocco. The hydrogen strategy is exclusively dedicated to green hydrogen.

[5] https://www.mem.gov.ma/pages/actualite.aspx?act=278

[6] https://www.mem.gov.ma/Lists/Lst_rapports/Attachments/36/Feuille%20de%20route%20de%20hydrog%C3%A8ne%20vert.pdf

[7] https://ghorfa.de/de/bundesregierung-unterzeichnet-wasserstoff-abkommen-mit-marokko/

[8] IEA Hydrogen Project Database

[9] IEA Hydrogen Project Database

[10] Eichhammer, Wolfgang; Oberle, Stella; Haendel, Michael; Boie, Inga; Gnann, Till; Wietschel, Martin; Lux, Benjamin (2019): Study on the opportunities of "Power-to-X" in Morocco. 10 Hypotheses for discussion. Fraunhofer Institut für System- und Innovationsforschung (Fraunhofer ISI). Karlsruhe, zuletzt geprüft am 20.01.2021.

[11] To produce this amount of ammonia using the green hydrogen route, about 2,5 GW of electrolysis capacity would be needed. This assumes 4.000 full load hours, a heating value of 5,2 kWh/kg of ammonia and losses of about 52% from electricity to ammonia.

[12] The locations with high potentials can be drawn from the maps in the following chapter showing the PV and Wind energy potential.

Secondary hydrogen production technology in focus	Morocco does not exploit domestic natural gas. Hence, there is no focus on blue hydrogen.
Primary focus of export substance	• Because of domestic demand for ammonia this might be the focus in a first phase. This is also indicated in the hydrogen strategy which stresses that shipping of ammonia will be the first substance to be exported starting around 2030. • Exporting pure hydrogen will depend on availability of transport infrastructure into the EU, especially pipelines. The Hydrogen Strategy expects hydrogen exports via pipeline from 2035 onwards.
Estimated costs of hydrogen production & transport to Spain [€/MWh] [13]	<table><tr><th>Year</th><th>2025</th><th>2030</th><th>2040</th><th>2050</th></tr><tr><td>€/MWh (H2 Hu) retrofitted pipeline</td><td>66</td><td>57</td><td>42</td><td>30</td></tr><tr><td>€/MWh (H2 Hu) new high cost pipeline</td><td>75</td><td>67</td><td>52</td><td>40</td></tr></table>
Production potential [TWh] [14]	• Hydrogen: ~ 586 TWh (mainly PV/Wind hybrid at coast; compressed) • FT-liquids: ~ 374 TWh (mainly PV/Wind hybrid at coast) • Methanol: ~ 378 TWh (mainly PV/Wind hybrid at coast) • Methan: ~384 TWh (mainly PV/Wind hybrid at coast; liquid)
Transportation to Europe in hydrogen strategy	• Natural gas pipeline runs from Algeria to Spain through Morocco. By the end of 2021 current contracts will expire and the Moroccan part of the pipeline can be used by Morocco. • Ammonia shipping could also be in focus, as port is infrastructure available (e.g. Port Jorf Lasfar). Tanger could also be a relevant port for hydrogen or ammonia exports.
Key actors	• Institute Research Energy Solar And Energy Nouvelles (IRESEN): Research Institute • Moroccan Ministry of Energy, Mines and Sustainable Development (MEMDD) • Moroccan Agency for Sustainable Energy (MASEN) • National Office for Electricity and Water (ONEE): grid operator. • Energy Investment Company (SIE) • OCP Group: a state-owned phosphate rock miner, phosphoric acid manufacturer and phosphate fertilizer producer • National Commission for Green H_2
Main existing conflicts that could also be an issue for hydrogen production [15]	

[13] Own calculations based on potential-weighted average production costs for optimistic cost case and low temperature electrolysis from: Supply Costs for Low-Carbon Hydrogen. Institute of Energy Economics at the University of Cologne (EWI). Köln. Online verfügbar unter https://www.ewi.uni-koeln.de/cms/wp-content/uploads/2021/03/EWI_WP_20-04_Estimating_long-term_global_supply_costs_for_low-carbon_Schoenfisch_Braendle_Schulte-1.pdf, zuletzt geprüft am 03.09.2021.

[14] https://maps.iee.fraunhofer.de/ptx-atlas/

[15] Main source is the Environmental Justice Atlas: https://ejatlas.org/

Water conflicts	• Social mobilizations for the democratization of access to water in response to increased privatization activities within the water sector (e.g., in the city of Casablanca) • Persistent protests against silver mining activities (Imider Silver Mine) causing severe water pollution and local groundwater depletion • Protests against the development of a Tamalout Dam (Central Morocco) due to associated land expropriations of local villagers nearby	
Water stress	• Morocco shows high water stress especially in populated and economic areas. • Water stress and water competition cannot be defined on a country wide level. I should be analysed on project level. • focus should be on salt water desalination.	
Land conflicts	• Large-scale mobilizations against offshore oil/gas exploitation and industrial fishing activities on Western Sahara territories considered illegal due to lack of consent from the local population (Saharawi indigenous people) • Geopolitically motivated mobilizations against several wind power projects in Western Sahara areas; projects are considered as reinforcing the illegal occupation by the Moroccan state and its exploitation of local resources • Accusations of 'green grabbing' and complaints against the CSP complex *Noor I* concerning the use of local resources (land, water) for green energy generation • *Soulaliyate women's movement* as a nationwide grassroots mobilization demanding for equal rights and shares for women when their collective land is privatized	
Socio-economic	• Since 1980s: wide process of economic liberalization, privatization and deregulation particularly in the urban public transport sector, water and electricity supply, sanitation and waste management • Strikes concerning inhumane working conditions and lacking access to socio-economic benefits of cobalt mining activities in the Atlas Mountains • Controversial large-scale evictions and relocations of local populations for urban development projects (e.g., in Casablanca, Rabat)	
Other	• Local protests and concerns about environmental impacts of large-scale sand mining at the north-western coast	
existing CCS projects in case of blue hydrogen	None	
Existing and future energy system & decarbonisation strategy	2018	2030
Total gross electricity production (net imports)[16] [TWh]	36 (-0.1)	Not available

[16] IEA (2021): Electricity Information Statistics. https://doi.org/10.1787/elect-data-en

RES share in gross electricity generation[17] [%]	20%	~30 %[18]
CO_2 intensity of gross electricity generation [gCO_2/kWh, 2017][19]	679	No available
Largest fossil fuel-based electricity generation (share in total generation)]	Coal (60%)	Fossil Gas 23%[20] Rest (25%) probably coal[21] However, due to long-term PPAs, coal might play an even bigger role.
CO_2 emissions from electricity production (from other energy industry own use, manufacturing industries and construction) [$MtCO_2$, 2017][22]	23 (0,8)	Only total emission targets[23]
Goals decarbonisation for 2030 (NDC discussion)	Unconditional target: 91% above 2010 (excl. LULUCF) Conditional target: 40% above 2010 (excl. LULUCF)[24]	

3.2 Algeria

Political and economic environment (please refer to appendix 0 for description of indicators)	
Investment climate indicators	
WGI Regulatory Quality 2019	7,69 (scale 0-100)
WGI Political Stability and Absence of Violence/Terrorism	13,81 (scale 0-100)
Socio-economic context	
GDP per capita (current US$)	3.310
Unemployment rate [% of pop.] [25]	13,6 % (2017)
Poverty headcount ratio at $3.20 [26]	3,7 % (2011)
Access to energy [% of pop. 2019]	99,5 %
GINI Index	27,6, Rank 148/159
Sustainability governance indicators	
Yale Environmental Performance Index Rank (EPI)	44,8, Rank 84/180
Corruption indicators	
WGI Control of Corruption	33,49 (scale 0-100)
Trade	

17 IRENA (2020): Renewable Energy Statistics
18 There is a goal set of 52% if renewables within the electricity sector that relates to capacity. From this value about 30% of renewable electricity generation can be assumed. Source: Government of Morocco (2016): UNFCCC -Morocco’s Nationally Determined Contribution
19 Calculated as CO_2 emissions from electricity and heat production divided by gross electricity generation.
20 Hamane (2016): A Snapshot of Morocco’s Power Sector
21 https://climateactiontracker.org/countries/morocco/current-policy-projections/
22 IEA (2020): IEA CO_2 Emissions from Fuel Combustion Statistics. https://doi.org/10.1787/co2-data-en
23 https://climateactiontracker.org/climate-target-update-tracker/morocco/
24 https://climateactiontracker.org/countries/morocco/pledges-and-targets/
25 https://data.worldbank.org/indicator/SL.UEM.TOTL.NE.ZS?name_desc=false
26 https://data.worldbank.org/indicator/SI.POV.NAHC?name_desc=false

Main export partners [% of trade volume €]	• Italy (13,2 %) • France (12,8 %) • Spain (11,9 %)
Main export goods [% of trade volume €]	Hydrocarbons are most relevant • Crude Petroleum (41,7 %) • Petroleum Gas (32,7 %) • Refined Petroleum (18,9 %)
Trade agreements[27]	• The Free Trade Area (FTA) of the EU-Algeria Association Agreement grants preferential treatment for Algerian exports to the EU. • Algeria is member of OPEC
Hydrogen strategy and economy	
Existing hydrogen strategy	• None to date The new Algerian Government declares development of a national H_2 strategy as priority. Also, there is a new ministry for energy transition and renewable energies which is part of a strategy to diversify export of fossil hydrocarbon. On 28th November 2021 a committee was charged with the development of Algeria's hydrogen strategy.[28] Algeria hopes to sell hydrogen instead of natural gas to Spain and Italy starting 2030, using the same pipelines.[29]
Existing bilateral hydrogen agreements	• MoU was signed on 14th December 2021 between Eni and Sonatrach to aim for a strategic energy transition, also concerning hydrogen, among others[30]
Existing projects[31] (incl. Blue hydrogen)	• None to date However, CCS has been practiced in Algeria already for increased extraction of natural gas fields.
Planned projects [up to 2030] [32] (incl. Blue hydrogen)	• Feasibility study | Sonatrach (state owned) & ENI (Italy) | green hydrogen[33]
support schemes or funding facilities for clean hydrogen	None to date
Potential branches for domestic hydrogen demand	• Chemical and petrol industry • Fertilizer Production
Exporting potential in strategy [TWh per year]	No strategy to date
Main Hydrogen production technology in focus	No strategy to date Ambitions of the Ministry of Energy Transition and Research show a focus on green hydrogen. However, prices for blue hydrogen can be very low (due to domestic natural gas).

27 Whole text cited from: https://ec.europa.eu/trade/policy/countries-and-regions/countries/algeria/
28 https://www.abbc.org.uk/2022/01/new-energy-algeria-focus-q4-2021/ & https://www.arabnews.com/node/1970821/middle-east
29 https://www.arabnews.com/node/1970821/middle-east
30 https://www.eni.com/en-IT/media/press-release/2021/12/eni-sonatrach-expand-their-strategic-partnership-algeria.html
31 IEA Hydrogen Project Database
32 IEA Hydrogen Project Database
33 https://www.reuters.com/business/energy/eni-teaming-up-with-sonatrach-production-hydrogen-algeria-2021-07-07/

<table>
<tr><td>Secondary hydrogen production technology in focus</td><td>No strategy to date</td></tr>
<tr><td>Primary focus of export substance</td><td>No strategy to date</td></tr>
<tr><td>Estimated costs of hydrogen production [€/MWh] [34] and transport to Spain</td><td>
<table>
<tr><th>Year</th><th>2025</th><th>2030</th><th>2040</th><th>2050</th></tr>
<tr><td>€/MWh (H2 Hu) retrofitted pipeline</td><td>73</td><td>63</td><td>47</td><td>34</td></tr>
<tr><td>€/MWh (H2 Hu) new high cost pipeline</td><td>84</td><td>74</td><td>58</td><td>45</td></tr>
</table>
</td></tr>
<tr><td>Production potential [TWh] based on PTX Atlas[35]</td><td>

Hydrogen: ~ 649 TWh (based on PV or hybrid at inland water sources; compressed)
FT-liquids: ~ 453 TWh (based on PV or hybrid at inland water sources)
Methanol: ~ 458 TWh (based on PV or hybrid at inland water sources)
Methan: ~475 TWh (mainly PV/Wind hybrid at coast; compressed)

</td></tr>
<tr><td>Transportation to Europe in hydrogen strategy</td><td>

No strategy to date
However, gas infrastructure exists with export pipelines to Spain (Almeria) and via Tunesia into Italy. In addition, Algeria has LNG Terminals and Ammonia export facilities (Arzew).
Compared to other countries in northern Africa, the natural gas pipeline System connects most of northern Algeria, which makes exports of pure hydrogen via retrofitted pipelines with low transport-costs more likely.

</td></tr>
<tr><td>Key actors</td><td>

Ministry of Energy Transition and Research: New Ministry organising the transition also towards new options for exports besides natural gas
Sonatrach: Stateowned company in the natural gas and oil business
Development-committee for hydrogen strategy made up of representatives of the Commission for Renewable Energies and Energy Efficiency, the Ministry of Energy Transition and Renewable Energies, Sonatrach and Sonelgaz[36]

</td></tr>
<tr><td colspan="2">Main existing conflicts that could also be an issue for hydrogen production</td></tr>
<tr><td>Water conflicts</td><td>

Anti-fracking uprisings against shale gas extraction in Algeria's central regions due to heavy pollution, contamination, and depletion of local water supplies, commonly used for agriculture
Increased pressures on water resources apprehended for the future due to high population growth and climate-change impacts
Instability within the water sector and supply as water funding in Algeria strongly correlates with oil prices inducing the risk of an economic water scarcity/poverty[37]

</td></tr>
</table>

[34] Own calculations based on potential-weighted average production costs for optimistic cost case and low temperature electrolysis from: Supply Costs for Low-Carbon Hydrogen. Institute of Energy Economics at the University of Cologne (EWI). Köln. Online verfügbar unter https://www.ewi.uni-koeln.de/cms/wp-content/uploads/2021/03/EWI_WP_20-04_Estimating_long-term_global_supply_costs_for_low-carbon_Schoenfisch_Braendle_Schulte-1.pdf, zuletzt geprüft am 03.09.2021.

[35] https://maps.iee.fraunhofer.de/ptx-atlas/

[36] https://www.abbc.org.uk/2022/01/new-energy-algeria-focus-q4-2021/

[37] Kherbache, N. (2020): Water policy in Algeria: limits of supply model and perspectives of water demand management (WDM). *Desalination and Water Treatment 180,* pp. 141-155.

Water stress level	• High to extremely high water stress levels in coastal areas in the North of the country • Arid conditions in large swaths of the country, especially in southern regions that form part of the Sahara Desert	
Land conflicts	None reported	
Socio-economic	• Violent protests at various oil and gas producing sites throughout the country, including Algeria's largest oil field *Hassi Messaoud*, concerning high unemployment rates and poor living conditions • Growing local discontent and protests due to economic exclusion and underdevelopment despite the high economic productivity in the nation's fossil-fuel sector • Accusations of so-called 'gas grabs': long term contracts of EU member states with Algeria guarantee a secure oil and gas supply for European countries while the Algerian population is left with high socio-environmental impacts	
Other	• High marine pollution by industrial activities (paper and packaging production) in the coastal town of *Bou Ismail*	
existing CCS projects in case of blue hydrogen	Carbon Capture and Storage from a gas processing plant at In Salah. The joint venture of BP, Statoil and Sonatrach started operation in 2004. Until the project was suspended in 2012, 3.8 $MtCO_2$ had been injected into an aquifer below the gas field.[38]	
Existing and future energy system & decarbonisation strategy	2018	2030
Total gross electricity production (net imports)[39] [TWh]	77 (-0.1)	Not available
RES share in gross electricity generation[40] [%]	1	27%
CO_2 intensity of gross electricity generation [gCO_2/kWh, 2017][41]	496	Not available
Largest fossil fuel-based electricity generation (share in total generation)]	Natural Gas (98%)	Not available
CO_2 emissions from electricity production (from other energy industry own use, manufacturing industries and construction) [$MtCO_2$, 2017][42]	38 (10, 12)	Not available
Goals decarbonisation for 2030 (NDC discussion)	Reduction of GHG emissions by 7% to 22% compared to business as usual scenario (7% GHG to be achieved with national means.) [43]	

3.3 Tunisia

Political and economic environment (please refer to appendix 0 for description of indicators)

[38] http://www.zeroco2.no/projects/in-salah, https://co2re.co/FacilityData.
[39] IEA (2021): Electricity Information Statistics. https://doi.org/10.1787/elect-data-en
[40] IRENA (2020): Renewable Energy Statistics
[41] Calculated as CO_2 emissions from electricity and heat production divided by gross electricity generation.
[42] IEA (2020): IEA CO_2 Emissions from Fuel Combustion Statistics. https://doi.org/10.1787/co2-data-en
[43] https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Algeria%20First/Algeria%20-%20INDC%20(English%20unofficial%20translation)%20September%2003,2015.pdf

• **Investment climate**	
WGI Regulatory Quality 2019	35,6 (scale 0-100)
WGI Political Stability and Absence of Violence/Terrorism	17,1 (scale 0-100)
Socio-economic context	
GDP per capita (current US$)	3.319
Unemployment rate [44]	15,1% of population
Poverty headcount ratio at $3.20 [45]	3 % of population
Access to energy [% of pop. 2019]	100
GINI Index	32,8 (2015), Rank 119/159
Sustainability governance	
Yale Environmental Performance Index Rank (EPI)	46,7, Rank 71/180
Corruption	
WGI Control of Corruption	53 (scale 0-100)
Trade	
Main export partners [% of trade volume €]	• France (29%) • Italy (16,5%) • Germany (12,6%)
Main export goods [% of trade volume €]	• Insulated Wire (12%) • Non-Knit Men's Suits (5,29%) • Crude Petroleum (3,93%)
Trade agreements[46]	• The EU and Tunisia have concluded an Association Agreement, which was signed in July 1995 and entered into force on 30 March 1998. The Agreement established a free trade area under which all two-way trade in industrial products takes place free of any trade tariffs. • Negotiations for a Deep and Comprehensive Free Trade Area (DCFTA) between the EU and Tunisia were launched in Tunis on 13 October 2015. The overall goal of the negotiations is to create new trade and investment opportunities and to better integrate Tunisia's economy into the EU single market. The DCFTA also aims to support ongoing economic reforms in Tunisia and to bring Tunisian legislation closer to that of the EU in trade-related areas
Hydrogen strategy and economy	
Existing hydrogen strategy	• None to date • But relevant study: Study on the opportunities of "Power-to-X" in Tunisia[47]

44 https://data.worldbank.org/indicator/SL.UEM.TOTL.NE.ZS?name_desc=false
45 https://data.worldbank.org/indicator/SI.POV.NAHC?name_desc=false
46 Whole text cited from: https://ec.europa.eu/trade/policy/countries-and-regions/countries/tunisia/
47 https://energypedia.info/images/0/0c/Potential_Study_PtX_in_Tunisia_2021.pdf

Existing bilateral hydrogen agreements	German-Tunisian Memorandum of Understanding (MoU) to develop the green hydrogen market in Tunisia MoU signed between Aker Clean Hydrogen and TuNur to establish a commercially viable clean hydrogen and ammonia value chain[48]
Existing projects[49] (incl. Blue hydrogen)	None in the IEA Database 2020
Planned projects [up to 2030] [50] (incl. Blue hydrogen)	• None in the IEA Database 2020 • BMZ Project "Building blocks of green hydrogen in Tunisia" German KfW will finance pilots with 20 Mio. € • TuNur is planning a H_2 pilot project in the south of Tunisia[51]
support schemes or funding facilities for clean hydrogen	None identified
Potential branches for domestic hydrogen demand	• Currently no significant hydrogen demand[52] • In the future green ammonia and methanol production could be used to replace imports
Exporting potential in strategy [TWh per year]	No strategy existing, but focus on export with ca. > 90% share on total production 2025: n.a. 2030: n.a. 2035: n.a.
Main Hydrogen production technology in focus	Mainly combined wind PV close to coast
Secondary hydrogen production technology in focus	Green hydrogen in the focus
Primary focus of export substance	Depending on the needs of importing countries
Estimated costs of hydrogen production [€/MWh] [53] and transport to Italy	Year: 2025 / 2030 / 2040 / 2050 €/MWh (H2 Hu) retrofitted pipeline: 76 / 66 / 50 / 36 €/MWh (H2 Hu) new high cost pipeline: 96 / 86 / 70 / 57
Production potential [TWh] based on PTX Atlas[54] based on PEM	• Hydrogen: ~ 385 TWh (mainly hybrid at coast; compressed) • FT-liquids: ~ 236 TWh (mainly hybrid at coast) • Methanol: ~ 238 TWh (mainly hybrid at coast) • Methan: ~249 TWh (mainly PV/Wind hybrid at coast; compressed)
Transportation to Europe in hydrogen strategy	• There is an existing pipeline for natural gas towards Italy. However, this pipeline delivers gas from Algeria to Italy and Tunisia is only transit country. Therefore, this possible export option can most likely only be used in cooperation with Algeria. • Ammonia port terminals in port of Gabès

48 https://news.cision.com/aker-clean-hydrogen/r/aker-clean-hydrogen--third-quarter-results-2021,c3438047
49 IEA Hydrogen Project Database
50 IEA Hydrogen Project Database
51 https://www.tunur.tn/project/green-hydrogen/
52 https://energypedia.info/images/0/0c/Potential_Study_PtX_in_Tunisia_2021.pdf
53 Based on https://maps.iee.fraunhofer.de/ptx-atlas/
54 https://maps.iee.fraunhofer.de/ptx-atlas/

Key actors	• Ministry of Industry, Energy and Mines • Tunisian Company of Electricity and Gas (STEG): public company • National Agency for Energy Management (ANME): regulator • TuNur: developer of hydrogen projects • National Engineers School, University of Monastir: Research on green hydrogen
Main existing conflicts that could also be an issue for hydrogen production [55]	
Water conflicts	• Tunisia is considered as quite advanced in terms of water storage, management and resource planning[56] • One of the top-ranking countries in North Africa in terms of drinking water access (close to 98%)
Water stress level	• Very arid country with high water scarcity levels • Areas least affected by water scarcity are mostly in the central, eastern and south-eastern regions of the country
Land conflicts	• Anti-fracking protests against a shale-gas fracking exploration initiative in the Ghadames Basin submitted by the multinational *Shell* • Conflicting land claims of the state and a local cooperative over agricultural land in a central oasis of the country
Socio-economic	• Local protests concerning poor working conditions and unemployment in phosphate mines in the Gafsa region, one of the country's main export sources • Heavy protests concerning unemployment and socio-economic injustices against the British oil and gas company *Petrofac* producing on the island of Kerkennah
Energy poverty	• Reliance on energy imports from Algeria • Frequent power cuts in the national energy supply system
Other?	• Protests concerning environmental impacts of phosphate industries in the Gafsa region and in the town of Gabès
existing CCS projects in case of blue hydrogen	none

Existing and future energy system & decarbonisation strategy	2018	2030
Total gross electricity production (net imports)[57] [TWh]	21 (-0.1)	Not available
RES share in gross electricity generation[58] [%]	3%	30%
CO_2 intensity of gross electricity generation [gCO_2/kWh, 2017][59]	428	Not available

55 Main source is the Environmental Justice Atlas: https://ejatlas.org/
56 Terrapon-Pfaff, Julia; Prantner, Magdolna; Zelt, Ole; Missaoui, Rafik; Ghezal, Abdelkarim; Toumi, Marwa (2021): Study on the opportunities of "Power-to-X" in Tunisia. Hg. v. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). Wuppertal Institut für Klima, Umwelt, Energie (Wuppertal Institut). Eschborn. Online verfügbar unter https://energypedia.info/images/0/0c/Potential_Study_PtX_in_Tunisia_2021.pdf, zuletzt geprüft am 01.09.2021.
57 IEA (2021): Electricity Information Statistics. https://doi.org/10.1787/elect-data-en
58 IRENA (2020): Renewable Energy Statistics
59 Calculated as CO_2 emissions from electricity and heat production divided by gross electricity generation.

Largest fossil fuel-based electricity generation (share in total generation)]	Natural Gas (95%)	Not available
CO_2 emissions from electricity production (from other energy industry own use, manufacturing industries and construction) [$MtCO_2$, 2017][60]	9 (0, 5)	Not available
Goals decarbonisation for 2030 (NDC discussion)	-41% carbon intensity compared to 2010[61]	

3.4 Mauritania

Political and economic environment (please refer to appendix 0 for description of indicators)	
Investment climate	
WGI Regulatory Quality 2019	22,12 (scale 0-100)
WGI Political Stability and Absence of Violence/Terrorism	26,19 (scale 0-100)
Socio-economic context	
GDP per capita (current US$)	1.672
Unemployment rate [62]	10,3 % (2017)
Poverty headcount ratio at $3.20 [63]	24,1 % (2014)
Access to energy [% of pop. 2019]	45,8
GINI Index	32,6 (2015), Rank 123/159
Sustainability governance	
Yale Environmental Performance Index Rank (EPI)	27,7, Rank 167/180
Corruption	
WGI Control of Corruption	20,19 (scale 0-100)
Trade	
Main export partners [% of trade volume €]	• China (32,3%), • Switzerland (12,5%), • Spain (9,3%), • Japan (9,06%)
Main export goods [% of trade volume €]	• Iron Ore (38,3%), • Non-fillet Frozen Fish (15,7%), • Gold (13,6%)
Trade agreements[64]	• The Economic Partnership Agreement (EPA) with West Africa covers goods and development cooperation. The EPA also includes the possibility to hold further negotiations on sustainable development, services, investment and other trade-related issues in the future.

60 IEA (2020): IEA CO_2 Emissions from Fuel Combustion Statistics. https://doi.org/10.1787/co2-data-en
61 https://unfccc.int/sites/default/files/resource/Synthese%20Ang%20Finalise%20Tunisia.pdf?download
62 https://data.worldbank.org/indicator/SL.UEM.TOTL.NE.ZS?name_desc=false
63 https://data.worldbank.org/indicator/SI.POV.NAHC?name_desc=false
64 Whole text cited from: https://ec.europa.eu/trade/policy/countries-and-regions/regions/west-africa/

Hydrogen strategy and economy	
Existing hydrogen strategy	In May 2021, the president, M. Mohamed Ould Cheikh El Ghazouani, has announced a road map for a green hydrogen strategy. This road map will include the legal framework and incentives for foreign investments for renewable energies and hydrogen as well as the creation of competences on the national level.
Existing bilateral hydrogen agreements	None to date
Existing projects[65] (incl. Blue hydrogen)	None to date
Planned projects [up to 2030] [66] (incl. Blue hydrogen)	• The government of Mauritania and renewable energy developer CWP Global have signed a memorandum of understanding to develop a 30 GW power-to-X project. Danish power company Ørsted, and Copenhagen's utility, Hofor, entered into an agreement that will secure green power in the framework of the wider, 1.3 GW, Green Fuels for Denmark project. • MoU was signed with Chariot on 28th September 2021 for potential 10 GW green hydrogen project[67]
support schemes or funding facilities for clean hydrogen	None to date
Potential branches for domestic hydrogen demand	• Mining • Transport • Power sector
Exporting potential in strategy [TWh per year]	2025: no data 2030: no data 2035: no data
Main Hydrogen production technology in focus	Wind and PV hybrids
Secondary hydrogen production technology in focus	No sources
Primary focus of export substance	Because of shipping distance, derivatives will likely be in focus
Estimated costs of hydrogen production [€/MWh] [68] assuming shipping of liquified hydrogen to EU	**Year**: **2050** €/MWh (H_2 Hu): 89
Production potential [TWh] based on PTX Atlas[69] based on PEM	• Hydrogen (liquid): ~ 986 TWh (mainly hybrid at coast) • FT-liquids: ~ 823 TWh (mainly hybrid at coast) • Methanol: ~ 845 TWh (mainly hybrid at coast) • Methan: ~ 846 TWh (mainly hybrid at coast)
Transportation to Europe in hydrogen strategy	• Shipping will be in Focus

65 IEA Hydrogen Project Database
66 IEA Hydrogen Project Database
67 https://www.chariotenergygroup.com/wp-content/uploads/2021/10/Green-Hydrogen-Project_Chariot-Limited.pdf
68 Based on https://maps.iee.fraunhofer.de/ptx-atlas/
69 https://maps.iee.fraunhofer.de/ptx-atlas/

Key actors	• The president, M. Mohamed Ould Cheikh El Ghazouani, has recently emphasized the opportunities arising for Mauretania from a global energy transition and called for a realignment of the country' energy strategy toward increased reliance on RE. • Energy ministry responsible, currently mainly focused on oil and gas, little consideration of RE and hydrogen. • Environment ministry is in favor of green hydrogen, but not in charge of corresponding legislation. • Societe de Production d'Electricite a partir du Gaz (SPEG)	
Main existing conflicts that could also be an issue for hydrogen production [70]		
Water conflicts	• Only 68% of the Mauritanian population have access to potable water (state year 2018), largely in urban areas[71] • Frequent and severe water shortages in rural areas inducing migration stream towards the country's cities[72]	
Water stress level	• Arid conditions in large areas of the country forming part of the Sahara Desert • Low to medium water stress levels in the more populated southern regions of the Sahel	
Land conflicts	• Conflicts over community-owned land areas sold by Mauritanian government officials to foreign agribusiness investors from Saudi Arabia and Japan	
Socio-economic	• Civic unrest and (peaceful) protests *inter alia* concerning underemployment and uneven payment patterns of operating mining companies • Slavery abolished only in 2007, but still practiced in some parts of the country (estimates suggest that about 2% of the population are enslaved)	
Energy poverty	• Large issue in Mauretania • Access to electricity in 2013 at 60% in urban areas and 5% in rural areas.	
Other?	• Heavy environmental pollution and health hazards through fishmeal factories on the coast • Industrial sea overfishing on the entire coastline	
existing CCS projects in case of blue hydrogen	None to date	
Existing and future energy system & decarbonisation strategy	current	2030
Total gross electricity production (net imports) [TWh][73]	About 1 TWh in 2015	Not available
RES share in gross electricity generation [%][74]	About 20% in 2015 Based mainly on hydro power but also first PV and Wind plants	Not available

[70] Main source is the Environmental Justice Atlas: https://ejatlas.org/
[71] https://www.afdb.org/en/news-and-events/mauritania-on-track-to-beating-drinking-water-shortages-18743
[72] https://www.afdb.org/en/news-and-events/mauritania-on-track-to-beating-drinking-water-shortages-18743
[73] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA_RRA_Mauritania_EN_2015.pdf
[74] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA_RRA_Mauritania_EN_2015.pdf

CO_2 intensity of gross electricity generation [gCO_2/kWh, 2017][75]	Not available	Not available
Largest fossil fuel-based electricity generation (share in total generation)[76]	Thermal Oil	Natural Gas
CO_2 emissions from electricity production (from other energy industry own use, manufacturing industries and construction) [$MtCO_2$, 2017][77]	Not available	Not available
General remarks concerning the energy system[78]	• Domestic gas fields such as Banda are in development and will supply natural Gas for electricity production • Hydropower is a relevant electricity source with further planned projects of >100MW • The electricity demand is driven by mining industry • The electricity grid is very limited and focusses on the coastal region • Most rural areas are not connected to the grid and only about 50% of the urban areas.	
Goals decarbonisation for 2030 (NDC discussion)	GHG reduction compared to 2010: 22%[79]	

3.5 Egypt

Political and economic environment (please refer to appendix 0 for description of indicators)	
Investment climate	
WGI Regulatory Quality 2019	18,8 (scale 0-100)
WGI Political Stability and Absence of Violence/Terrorism	12,9 (scale 0-100)
Socio-economic context	
GDP per capita (current US$)	3.547
Unemployment rate 2019 [80]	7,8 % of population
Poverty headcount ratio at $3.20 [81]	28,9 % of population
Access to energy [% of pop. 2019]	100
GINI Index	31,5 (2017), Rank 129/159
Sustainability governance	
Yale Environmental Performance Index Rank (EPI)	43,3, Rank 94/180

75 Calculated as CO_2 emissions from electricity and heat production divided by gross electricity generation.
76 https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA_RRA_Mauritania_EN_2015.pdf
77 IEA (2020): IEA CO_2 Emissions from Fuel Combustion Statistics. https://doi.org/10.1787/co2-data-en
78 https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA_RRA_Mauritania_EN_2015.pdf
79 https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Mauritania%20First/INDC%20MAURITANIA.pdf

Corruption	
WGI Control of Corruption	28 (scale 0-100)
Trade	
Main export partners [% of trade volume €]	• USA (8.8%) • UAE (6.3%) • Italy (6.3%)
Main export goods [% of trade volume €]	• Crude Petroleum (11.5%) • Refined Petroleum (9.1%) • Gold (5.6%)
Trade agreements[82]	• In June 2013, the EU and Egypt began discussing how to deepen their trade and investment relations through a Deep and Comprehensive Free Trade Area (DCFTA). A future DCFTA would aim to improve market access and the investment climate. It would also support Egyptian economic reforms. It would extend beyond the Association Agreement to include i.a. trade in services, government procurement, competition, intellectual property rights, and investments. The EU commissioned a Sustainability Impact Assessment (SIA) for a possible DCFTA with Egypt in 2014. However, the DCFTA negotiations have not yet started.
Hydrogen strategy and economy	
Existing hydrogen strategy	In preparation[83]
Existing bilateral hydrogen agreements	• Energy partnership with Denmark (Strategic Sector Cooperation (SSC) e.g. as financing vehicle (2019-2022)) • Germany (BMWi) focusses on “project based partnerships” • Egyptian-German Joint Committee on Renewable Energy, Energy Efficiency and Environmental Protection (JCEE) (2019-2023): Host High-Level Joint Committee (HLJC), a platform for high-level policy dialogue between Germany and Egypt in the energy sector[84] •
Existing projects[85] (incl. Blue hydrogen)	None in the IEA Database 2020
Planned projects [up to 2030] [86] (incl. Blue hydrogen)	None in the IEA Database 2020; feasibility studies and MoU signed with: i.a. ENI, DEME Group of the HYPORT consortium, Siemens, MAN[87], MoU for Green Ammonia production with Thyssenkrupp

82 Whole text cited from: https://ec.europa.eu/trade/policy/countries-and-regions/regions/egypt/

83 https://english.ahram.org.eg/NewsContent/3/12/416914/Business/Economy/Egypt%E2%80%99s-president-urges-establishing-integrated-st.aspx; https://english.ahram.org.eg/News/454602.aspx

84 Several ministries such as Ministry of Electricity and Renewable Energy (MoERE), as well as downstream and subordinate agencies, including the New and Renewable Energy Authority (NREA), the Egyptian Electric Utility and Consumer Protection Regulatory Agency (EgyptERA), selected electricity distribution companies (DISCOs), and many more. Five German ministries are HLJC members: Federal Ministry for Economic Cooperation and Development (BMZ), Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), Federal Ministry for Economic Affairs and Energy (BMWi), the Federal Ministry of Education and Research (BMBF) and the Federal Foreign Office (AA)

85 IEA Hydrogen Project Database

86 IEA Hydrogen Project Database

87 https://www.eni.com/en-IT/media/press-release/2021/07/cs-eni-firma-accordo-produzione-idrogeno-egitto.html, https://en.amwalalghad.com/deme-led-consortium-submits-feasibility-study-for-green-hydrogen-production-project-in-egypt/,

<table>
<tr><td></td><td>Industrial Solutions[88] further a MoU between Scatec Asa and SCZone was signed on 16th December 2021on green hydrogen, ammonia and sea-water desalination;
• 50-100 MW | planned to operate in November 2022 | Scatec, Fertiglobe, Emirati Abu Dhabi National Oil Company | green ammonia[89]</td></tr>
<tr><td>support schemes or funding facilities for clean hydrogen</td><td>None to date[90]</td></tr>
<tr><td>Potential branches for domestic hydrogen demand

Exporting potential in strategy [TWh per year]</td><td>• in the short-term, green H2 could help to decarbonize and expand fertilizer production and exports (4% of export value in 2019)

In the medium-term, developing an export oriented green H2 industry might pose opportunities but could also endanger the current business model of crude oil and petroleum products exports (comprising over 25% of total export value in 2019</td></tr>
<tr><td>Main Hydrogen production technology in focus</td><td>Not clear due to missing strategy</td></tr>
<tr><td>Secondary hydrogen production technology in focus</td><td>Not clear due to missing strategy</td></tr>
<tr><td>Primary focus of export substance</td><td>Egypt already exports ammonia which could be starting point for green ammonia exports. However, due to missing strategy no clear definition in literature to be found.</td></tr>
<tr><td>Estimated costs of hydrogen production [€/MWh] [91] and shipping to EU</td><td><table><tr><th>Year</th><th>2025</th><th>2030</th><th>2040</th><th>2050</th></tr><tr><td>€/MWh (H2 Hu) shipping of liquified H_2 to EU</td><td>109</td><td>98</td><td>78</td><td>59</td></tr></table></td></tr>
<tr><td>Production potential [TWh] based on PTX Atlas[92] based on PEM</td><td>• Hydrogen (liquid): ~ 4.333 TWh (mainly hybrid at coast)
• FT-liquids: ~ 3.693 TWh (mainly hybrid at coast)
• Methanol: ~ 3.674 TWh (mainly hybrid at coast)
• Methan: ~ 3.815 TWh (mainly hybrid at coast)</td></tr>
</table>

https://www.zawya.com/mena/en/business/story/International_companies_to_invest_in_green_hydrogen_production_in_Egypt_says_minister-SNG_217625516/ , https://www.man-es.com/company/press-releases/press-details/2021/08/12/taqa-arabia-signs-mou-with-man-energy-solutions-for-egyptian-green-hydrogen-project

88 https://www.egypttoday.com/Article/1/104392/Egypt-studies-establishment-of-factory-for-green-hydrogen-ammonia-production

89 https://www.arabnews.com/node/1987996/business-economy

90 https://renewablesnow.com/news/scatec-unveils-plans-for-more-hydrogen-to-ammonia-projects-in-egypt-765882/

91 Own calculations based on potential-weighted average production costs for optimistic cost case and low temperature electrolysis from: Supply Costs for Low-Carbon Hydrogen. Institute of Energy Economics at the University of Cologne (EWI). Köln. Online verfügbar unter https://www.ewi.uni-koeln.de/cms/wp-content/uploads/2021/03/EWI_WP_20-04_Estimating_long-term_global_supply_costs_for_low-carbon_Schoenfisch_Braendle_Schulte-1.pdf, zuletzt geprüft am 03.09.2021.

92 https://maps.iee.fraunhofer.de/ptx-atlas/

Transportation to Europe in hydrogen strategy	• LNG Terminals[93]: Active liquification terminals in Idku and Damietta in the Mediterranean Sea (9.36 bcm/y) and two idle Floating Storage and Regasification Units (FSRUs) terminals in the Golf of Suez • Ammonia Terminals[94]: Dammietta[95] and Abu Qir at the Mediterranean Sea and El Sokhna at the Gulf of Suez • There is no existing pipeline from Egypt to central Europe.
Key actors	• Supreme Energy Council (SEC): guides Egyptian energy sector strategy and policy level by regulations and directions • Ministry of Electricity and Renewable Energy (MoERE):Overall management of the Egyptian electricity sector through its subsidiary company the Egyptian Electricity Holding Company (EEHC) an in cooperation with Egyptian Electric Utility and Consumer Protection Regulatory Agency (EgyptERA) and the New and Renewable Energy Authority (NREA) • Ministry of Petroleum and Mineral Resources: entrusted with the overall management of all petroleum activities in the country, including exploration, production and distribution of oil, oil products and gas • There might be a conflict between the established fossil business model (esp. represented by the Ministry of Petroleum and Natural Resources) and the development of green hydrogen. MoERE is charged with leading the preparation of a national hydrogen strategy • Egyptian Electricity Transmission Company (EETC): TSO • Egyptian Natural Gas Holding Company (EGAS) • Egyptian armed forces' Engineering Authority • The military is an important owner and operator of infrastructure (such as Ports, parts of the electricity grid, saltwater desalination, water transport and distribution systems etc.)
Main existing conflicts that could also be an issue for hydrogen production [96]	

[93] Enriquez, Abel; Parada, Luis I. (2019): The Role of LNG in the Euro-Mediterranian Region (EMR): Regulatory and Policy Measures advancing the LNG hub development and the small scale business in the region. Enagás. https://www.gti.energy/wp-content/uploads/2019/10/20-LNG19-03April2019-Enriquez-Abel-paper.pdf

[94] Alfa Laval; Hafnia, Haldor Topsoe, Vestas; Siemens Gamesa (2020): Ammonfuel: An industrial view of ammonia as a marine fuel. https://hafniabw.com/wp-content/uploads/2020/08/Ammonfuel-Report-an-industrial-view-of-ammonia-as-a-marine-fuel.pdf

[95] https://www.cgrgroup.com/project/africa/egypt/eagrium-urea-and-ammonia-terminal-damietta-port-egypt

[96] Main source is the Environmental Justice Atlas: https://ejatlas.org/

Water conflicts	• In 2015, water supply from the Nile accounts for 98% of renewable water resources in Egypt[97] • Water supply from the Nile will likely be substantially reduced during the filling of the Grand Ethiopian Renaissance Dam (GERD) on the Blue Nile in Ethiopian, which is currently in the last completion phase and filling has already begun in 2020. • With strong population increase and rising industry demand water demand is expected to increase strongly[98] • Future of water in Egypt heavily relies on external cooperation with its neighbours and its own ability to optimally manage internal demand and use of water • Current water deficit and “virtual water” imports are expected to increase • Sea Water desalination plays an important role in Egypt’s drinking water supply strategy. 47 seawater desalination plants in the governorates of North and South Sinai, Port Said, Ismailia, Suez, Dakahlia, Kafr E-Sheikh, Beheira Matrouh, and the Red Sea are to be built through Public-Private-Partnerships (PPP) until 2025, with a total production capacity of 2.44 Million m^3 per day[99] • Groundwater pollution and environmental damages caused by hydraulic fracturing activities in the Western Desert and in the town of Fares (southern region)
Water stress level	• Population, agriculture and industry are all concentrated on the narrow strips along the Nile river and in the Nile delta area.
Land conflicts	• There might be co-benefits with agricultural land, as evaporation and shading are important issue in agriculture in Egypt • Persisting land conflicts associated with the Aswan High Dam bordering Lake Nasser where local inhabitants were expropriated of their lands for the development of the dam • Critiques of large-scale and non-compensated displacement of local populations for the development of the New Suez Canal

97 Heggy, Essam; Sharkawy, Zane; Abotalib, Abotalib Z. (2021): Egypt’s water budget deficit and suggested mitigation policies for the Grand Ethiopian Renaissance Dam filling scenarios. Environ. Res. Lett.16 (7). DOI: 10.1088/1748-9326/ac0ac9.

98 Nikiel, Catherine A.; Eltahir, Elfatih A. B. (021): Past and future trends of Egypt’s water consumption and its sources. Nat Commun 12(1). DOI: 10.1038/s41467-021-24747-9

99 https://www.afrik21.africa/en/egypt-government-to-invest-2-8-billion-for-47-desalination-plants-in-5-years/

Socio-economic	• Repressive political system: The authoritarian nature of the Sisi regime, and widespread repression in Egypt, have the potential to spark a populist backlash[100] • Gender inequality ranking it at 108 out of 162 countries • Political uprisings in Egypt left the poor in deprived communities worse off.[101] • The new social contract exchanges political and socio-economic rights for political stability. • The same unfulfilled aspirations and problems in education and employment persisted over time. • The uprisings led to a more repressive state, a highly polarised society and growth did not trickle down to the poor. • Economic crises affected the poor, esp. women and youth in urban areas. • Regional protests against multiple energy infrastructure projects (power plants, pipelines) and industrial activities (fertilizer, cement) due to negative impacts on local livelihoods (agriculture, tourism) and biodiversity • Coal-related industries – since 2013 an anti-coal movement has been formed, particularly targeting the Egyptian cement industry	
existing CCS projects in case of blue hydrogen	no	
Existing and future energy system & decarbonisation strategy	2018	2035
Total gross electricity production (net imports) [TWh]	194 (-0.1)	~420[102]
RES share in electricity generation[103] [%]	8	20% by 2022, 37% by 2035[104]
CO_2 intensity of electricity generation [gCO_2/kWh, 2017]	449	240-360[105]
Largest fossil fuel-based electricity generation (share in total generation)]	Natural Gas (80%)	Coal (34%)
CO_2 emissions from electricity production (from other energy industry own use, manufacturing	83 (15, 32)	

[100] https://gsdrc.org/publications/conflict-analysis-of-egypt/

[101] Ibrahim, Solava (2021): The dynamics of the Egyptian social contract: How the political changes affected the poor. World Development. 138. DOI: 10.1016/j.worlddev.2020.105254

[102] Based on percentages of RES-E generation given in NDC update. Ministry of Environment (2018): Egypt's first Biannual update Report on the United Nations Framework Convention on Climate Change. https://unfccc.int/sites/default/files/resource/BUR%20Egypt%20EN.pdf?download.

[103] IRENA (2020): Renewable Energy Statistics

[104] For 2022: PV: 2%, Wind: 12%, Hydro: 6%; Source: http://nrea.gov.eg/test/en/About/Strategy; for 2035: CSP: 8% (32 TWh); PV: 12% (49 TWh), Wind: 15% (61 TWh), Hydro: 3% (14 TWh). Source: Ministry of Environment (2018).

[105] Own calculations: The underlying generation mix for the ISES 2035 Scenario includes 34% of coal-fired generation and 8.8% nuclear. Assuming an average electric efficiency of 42.5% (supercritical power plant in hot climate) and a constant emission factor for the remaining natural gas and oil-fired fleet gives an emissions factor of 360gCO_2/kWh. If instead, coal is replaced by the current mix, the grid emission factor decreased to around 240gCO_2/kWh.

industries and construction) [$MtCO_2$, 2017]		
Goals decarbonisation for 2030 or 2050 (NDC discussion)	Neither the initial NDC nor the biannual update give emission targets.	

4 Appendix

Description of Indices used in fact sheets

Indicator/Index	publisher	Source	Link	Calculation
GDP per capita	World Bank	World Development Indicators	link	GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in current U.S. dollars.
Human Development Index	UNDP	Human Development Report 2020	link	The Human Development Index (HDI) is a summary measure of average achievement in key dimensions of human development: a long and healthy life, being knowledgeable and have a decent standard of living. The HDI is the geometric mean of normalized indices for each of the three dimensions.
WGI Regulatory Quality 2019	World Bank	Kaufmann, Daniel and Kraay, Aart and Mastruzzi, Massimo, The Worldwide Governance Indicators: Methodology and Analytical Issues (September 2010). World Bank Policy Research Working Paper No. 5430, Available at SSRN: https://ssrn.com/abstract =1682130	link	Percentile Rank 0 - 100, where 0 reflects the lowest, 100 the highest rank. Describes the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development. Based on e.g. price controls, discruminatory taxes, extent of market dominance, investment freedom, ease of starting a business governed by local law, reulatory burden.
WGI Political Stability and Absence of Violence/Terrorism 2019	World Bank	Kaufmann, Daniel and Kraay, Aart and Mastruzzi, Massimo, The Worldwide Governance Indicators: Methodology and Analytical Issues (September 2010). World Bank Policy Research Working Paper No. 5430, Available at SSRN: https://ssrn.com/abstract =1682130	link	Percentile Rank 0 - 100, where 0 reflects the lowest, 100 the highest rank. Perception of the likelihood of political instability and/or politically motivated violence including terrorism. This perception is based on a wide scale of indicators such as armed conflicts, violent demonstrations, social unrest, security risk rating, government stability, political terror scale, protests and riots.
Unemployment rate (% of population)	World Bank	International Labour Organization, ILOSTAT database	link	Unemployment refers to the share of the labor force that is without work but available for and seeking employment. Definitions of labor force and unemployment differ by country.

Poverty headcount ratio at $3.20 a day (% of population)	World Bank	World Bank, Global Poverty Working Group. Data are compiled from official government sources or are computed by World Bank staff using national (i.e. country–specific) poverty lines	link	Poverty headcount ratio at $3.20 a day is the percentage of the population living on less than $3.20 a day at 2011 international prices. As a result of revisions in PPP exchange rates, poverty rates for individual countries cannot be compared with poverty rates reported in earlier editions.
GINI Index	World Bank	World Bank, Development Research Group. Data are based on primary household survey data obtained from government statistical agencies and World Bank country departments	link	Gini index measures the extent to which the distribution of income among individuals or households within an economy deviates from a perfectly equal distribution. A Gini index of 0 represents perfect equality, while an index of 100 implies perfect inequality.
GINI Index Rank	Index Mundi	World Bank, Development Research Group. Data are based on primary household survey data obtained from government statistical agencies and World Bank country departments	link	Ranked by the Data published by World Bank
Access to energy (% of population) 2019	World Bank	World Bank, Sustainable Energy for All (SE4ALL) database from the SE4ALL Global Tracking Framework led jointly by the World Bank, International Energy Agency, and the Energy Sector Management Assistance Program	link	Electrification data are collected from industry, national surveys and international sources
Yale Environmental Performance Index (EPI)	Yale University	Environmental Performance Index is a registered trademark of Yale University	link	The EPI is based on 32 performance indicators across 11 issue categories (e.g. Air Quality, Waste Management, Climate Change, Biodiversity & Habitat etc.). The Index shows at national level how close each country is to set environmental policy targets.
WGI Control of Corruption 2019	World Bank	Kaufmann, Daniel and Kraay, Aart and Mastruzzi, Massimo, The Worldwide Governance Indicators: Methodology and Analytical Issues (September 2010). World Bank Policy Research Working Paper No. 5430, Available at SSRN: https://ssrn.com/abstract=1682130	link	Percentile Rank 0 - 100, where 0 reflects the lowest, 100 the highest rank. The extent to which public power is used for private gain based on individual variables such as corruption among public officials, puplic trust of politicians, corruption Index etc.

Main Export Partners & Goods	Observatory of Economic Complexity (OEC)	BACI by CEPII Research and Expertise on the World Economy	link	The database is built on the data directly reported by each country to the United Nations Statistical Division (Comtrade)