Hydrogen fact sheet – Gulf Cooperation Countries (GCC)

Saudi-Arabia | Oman | United Arab Emirates | Qatar

Kuwait | Bahrain

Freiburg/Berlin, 28.02.2022

Authors

Christoph Heinemann
David Ritter
Dr. Roman Mendelevitch
Kaya Dünzen

In cooperation with:

PtX Hub

Contact
info@oeko.de
www.oeko.de

Head Office Freiburg
P. O. Box 17 71
79017 Freiburg

Street address
Merzhauser Straße 173
79100 Freiburg
Phone +49 761 45295-0

Office Berlin
Borkumstraße 2
13189 Berlin
Phone +49 30 405085-0

Office Darmstadt
Rheinstraße 95
64295 Darmstadt
Phone +49 6151 8191-0

Supported by:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

of the Federal Republic of Germany

This publication was produced with the financial support of the European Union's Partnership Instrument and the German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU) in the context of the International Climate Initiative (IKI). The contents of this publication are the sole responsibility of adelphi and do not necessarily reflect the views of the funders.

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Conclusions

The GCC countries (Saudi Arabia, Oman, United Arab Emirates UAE, Kuwait, Qatar and Bahrain) all have investigated the option to export hydrogen or derivatives. However, there are **no specific hydrogen strategies** published, while strategies are planned or under preparation in Oman, Kuwait and UAE.

The **framework conditions for a future hydrogen economy in the GCC countries** and the export potential can be described by the following:

1. The GCC countries do have vast potentials for green as well as blue hydrogen. Green hydrogen has highest potential in countries with large available space (Saudi Arabia, Oman, UAE, Kuwait). Blue hydrogen can be produced in most countries (except for Bahrain) due to availability of domestic natural gas production.
2. Due to domestic cheap natural gas, experience in CCS technology and at least partly available infrastructure (LNG ports, pipelines) blue hydrogen can be expected to be produced at low costs.
3. Most of the GCC countries have their own refineries and chemical industry where hydrogen could be used to produce low-carbon chemical products. Hence, they are likely to generate domestic demand for low-carbon hydrogen in the future. However, production potentials for green or blue hydrogen largely exceed the possible domestic demand, which makes exports feasible.
4. Energy carriers are the main export goods for most GCC countries. Therefore, exporting hydrogen and its derivatives is of strong economic interest.
5. The GCC countries do not only look into the European market for hydrogen and derivatives, as shipping distance to Asian markets or other off-takers are similar. Therefore, it is questionable in which way business-cases for hydrogen production will adapt to European regulations (such as RED- II). This contrasts with regions like North Africa where the bonding to the EU off-take market can be expected to be much stronger.
6. There is no integrated hydrogen strategy of the GCC states. However, there are collaborations and MoUs between single members of the GCC in place aiming at joint efforts.
7. Compared to other potential regions of hydrogen production, the cost of capital is relatively low in the GCC countries. This lowers the production costs of hydrogen. However, this does not necessarily reduce the hydrogen market prices.

Even though there are no hydrogen strategies in place, there are several **main strategies** that can be drawn from the publications, press releases and presentations available:

1. Hydrogen from natural gas will be the short to midterm focus for the GCC countries. Even hydrogen from converted crude oil and petroleum products is seen as an option in the short term.
2. Green hydrogen will be the mid to long term focus for countries with large, low-cost RES-E potentials. However, Bahrain and Qatar likely do not have sufficient RES-E potentials to produce green hydrogen for exports.

3. Ammonia is seen as the most promising export product as it can be shipped with existing vessels.

Hydrogen based on natural gas or even crude oil is a feasible option for Saudi Arabia, UAE, Qatar and Kuwait. However, the term "blue hydrogen" is defined in multiple ways and differs from current regulation on blue hydrogen in Europe. Especially, how to deal with the captured CO_2 is defined quite broadly while all the following options are referred to as blue hydrogen:

- Storing CO_2 underground or in solid rock (Oman)
- Storing CO_2 in operating oil or gas fields for enhanced oil or gas recovery (all GCC)
- Using CO_2 in the chemical industry to produce for example methanol or plastics. If those products are burnt later (as plastics or as fuels) the CO_2 emissions are not reduced overall.

All of today's CCS facilities in the GCC countries use CO_2 for enhanced oil or gas recovery. Accordingly, the White Paper for the Kuwait hydrogen strategy describes the following gains from enhanced oil recovery technologies: Maximize recovery of its oil reserves, extend the life of its oilfields and attain (potentially) carbon-neutrality for its petroleum exports (provided a disproportionate amount of CO_2 is injected for every barrel of oil recovered).

This definition for blue hydrogen found in the GCC clearly deviates from the European regulation. The current "*Commission Implementing Regulation (EU) 2018/2066 on the monitoring and reporting of greenhouse gas emissions*"[1] states in Article 49 that CO_2 emissions can only be subtracted if

- stored in a long-term geological storage or
- used to produce precipitated calcium carbonate, in which the used CO_2 is chemically bound

In addition, the Proposal for a "DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union, Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and Regulation (EU) 2015/757"[2] states that

- For carbon capture and utilisation that "[…] surrender obligations do not arise for emissions of CO_2 that end up permanently chemically bound in a product so that they do not enter the atmosphere under normal use."
- Also Recital 13 states that: "Greenhouse gases that are not directly released into the atmosphere should be considered emissions under the EU ETS and allowances should be surrendered for those emissions unless they are stored in a storage site in accordance with Directive 2009/31/EC of the European Parliament and of the Council13, or they are permanently chemically bound in a product so that they do not enter the atmosphere under normal use."

1 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02018R2066-20210101&from=EN
2 https://eur-lex.europa.eu/resource.html?uri=cellar:618e6837-eec6-11eb-a71c-01aa75ed71a1.0001.02/DOC_1&format=PDF

➔ **There is a need to define and discuss with the GCC countries which CCS options are suitable for GHG-reductions and which are in line with the European Hydrogen Strategy.**

➔ **Blue hydrogen comes with a need to monitor methane emissions in the whole value chain.**

Green hydrogen needs renewable electricity and water. Electricity systems of the GCC countries are dominated by electricity generation from natural gas and oil. This results in high specific GHG emissions of electricity generation in the GCC countries which are about twice as high compared to those of the EU. The uptake of RES-E has hardly started in the GCC countries (867MW in 2018). The United Arab Emirates account for the largest part (589MW) of the RES-E capacity of all GCC countries, however, the respective RES-E share in electricity generation (2018) is still as low as about 1%. The planned and projected RES-E plants add up to a substantial uptake (6.732MW mainly solar PV) of RES-E within the next 5 to 10 years. But again, the share of RES-E generation in the electricity mix will remain low. Saudi Arabia's goals aim the highest with 50% RES-E share in 2030.

➔ The current and future low share RES-E indicates that an additional uptake of RES-E generation for producing green hydrogen will be essential.

➔ 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.

All the GCC countries studied show high **water** stress in almost all parts of the countries. Already today, sea water desalination plants produce large amounts of fresh water in the GCC countries. In fact, GCC countries are leading the world with about 40% of the total world desalinated water[3]. Especially the Arabian coast of the Persian Gulf hosts over 800 sea water desalination plants already. Additional sea water desalination plants will be needed to cover the water demand to produce green hydrogen. Scientific literature indicates that brine disposal already is a significant risk to local marine ecosystems[4]. Sustainability standards for sea water desalination plants are needed to make sure, that additional plants will not worsen impacts on local marine ecosystems. In addition, the Arabian coast of the Persian Gulf as well as the Red Sea hosts several protected marine ecosystems. These need to be protected from substantial disposal of brine.

Shipping is expected to be the only **transport option** towards Europe in the short to midterm. This will increase landing costs in Europe[5] compared to expected costs from countries that could export pure hydrogen via retrofitted pipelines (such as Morocco). Furthermore, transport via ship will reduce the options of which products can be exported in the short and midterm. It is expected that ammonia could be the most feasible product to be exported until large scale vessels for transportation of liquified hydrogen or LOHCs and related port infrastructures are available. Even though transport distance from Saudi Arabia to Europe is much shorter due to access to the Red Sea, overall transport

3 https://www.greenjournal.co.uk/2020/02/gcc-countries-are-leading-the-world-in-desalination-with-around-40-of-the-total-world-desalinated-water/

4 Roberts, David A.; Johnston, Emma L.; Knott, Nathan A. (2010): Impacts of desalination plant discharges on the marine environment: A critical review of published studies. In: *Water research* 44 (18), S. 5117–5128. DOI: 10.1016/j.watres.2010.04.036.

5 Hydrogen Council (H2C) (Hg.) (2021): Hydrogen Insights. A perspective on hydrogen investment, market development and cost competitiveness. McKinsey & Company, zuletzt geprüft am 18.02.2021.

costs will not vary substantially between the GCC countries. This is because the shipping costs are dominated by infrastructure and conversion losses (e.g. liquification) which are relevant irrespective of the shipping distance. The option of a new pipeline has been put on the table by the NEOM project and could be a long-term option[6].

[6] EWI (2020) assume cost of pipeline transport (0,64 $/1000km/kg H2) for a high cost new pipeline (for hydrogen). If we assume that a high costs new pipeline needs to build to transport hydrogen from Saudi Arabia towards Italy (about 4,000km) the costs for transport would be about 2,56$/kg H_2. This translates to ~65€/MWh H_2. This would even exceed costs for shipping liquified hydrogen assumed in EWI (2020) to be about 46€/MWh H_2.

1 Convergence & Divergence with the EU & comparing the countries

1.1 Aspects for all GCC countries

Overall Convergence & Divergence with EU hydrogen strategy	
Convergence • Potentials for low cost green hydrogen are enormous while domestic demand is expected to be much lower than economic production potential • Existing experience in blue hydrogen and ammonia • Existing experience in LNG terminals and export infrastructure • Green hydrogen economy could speed up the RES-E uptake in GCC countries.	**Divergence** • The uptake of hydrogen in short- and midterm will largely be based on blue hydrogen and not on green hydrogen • The definition of blue hydrogen is not clear and broadly used by GCC countries. • Negative environmental impacts due to necessary sea water desalination and brine disposal can be a concern if not addressed appropriately • The lack of pipeline transport-options will lead to shipping of ammonia, liquified hydrogen or other derivatives. This leads to relatively high landing costs at ports in Europe.

Strengths	Weaknesses
Electricity	
• Large low-cost potentials for electricity from Wind and PV and therefore green hydrogen (except for Bahrain and Qatar which cannot be assumed to be bulk producers of green hydrogen) • Potentials for combination of PV and wind to achieve high full load hours of technologies and hence low production costs.	• Almost no uptake of RES-E to date in all GCC countries and hence limited experience in RES-E technologies and infrastructure • High specific THG-emission factors of grid electricity in all GCC countries
Transport	
• Existing LNG and natural Gas infrastructure in place in most GCC countries • Experience in handling ammonia	• No pipeline network for transporting natural gas towards Europe that could be retrofitted • Exports of pure hydrogen will be costly due to high shipping costs. Other derivatives such as ammonia or methane or even e-fuels might therefore be the more realistic focus.
Water	
• Experience with large scale sea water desalination plants in all GCC countries • Research and development of sea water desalination with zero liquid discharge (NEOM) which would lower environmental impact of brine disposal	• High water stress throughout the GCC countries and even large areas with arid conditions • High density of sea water desalination plants especially in gulf region with resulting large discharge of brine • There are large areas that are classified as protected marine areas in Gulf as well as Red Sea

Strengths	Weaknesses
	where impacts from brine disposal should be avoided.
Socio-economics	
• Production of green hydrogen could foster the uptake of RES-E within the GCC countries which overall show very low shares of RES-E up to now. • The GCC countries expressed that exports of green or blue hydrogen and derivatives can be a steppingstone for moving away from exporting fossil fuels while securing jobs, know-how and income.	• Bahrain is not likely to export hydrogen. • Qatar can only export blue hydrogen and derivatives. • Socio-economic indicators that could indicate economic participation etc. are not available
Hydrogen Strategy & Economy	
• First hydrogen and ammonia projects already started • Experience in refining and chemical industries can be used in hydrogen economy	• No specific hydrogen strategies in place yet • The hydrogen economy will not focus on Europe as shipping distance to other regions (e.g. Japan) are similar. Therefore, the GCC countries are not bound to the European hydrogen market and specific (sustainability) criteria.

1.2 Saudi Arabia

Convergence & Divergence with EU hydrogen strategy	
• Saudi Arabia will be ready to export green ammonia (NEOM) from 2025 onwards. • Potentials for low cost green hydrogen are enormous while domestic demand is expected to be way lower than production potential. • Compared to other GCC countries shorter shipping distance to Europe via Red Sea. • Research and development of sea water desalination with zero liquid discharge which would lower environmental impact of brine disposal. • First hydrogen and ammonia projects already started (eg. NEOM).	• Potential to deliver blue hydrogen in the short term as well as green hydrogen in the long term. • The uptake of hydrogen will largely be based on blue hydrogen. • Definition of blue hydrogen is very broad (CCU & enhanced oil and gas recovery). • Negative environmental impacts due to sea water desalination can be a concern if not addressed appropriately. • The lack of pipeline transport-options will lead to shipping of ammonia, liquified hydrogen or other derivatives. This leads to high landing costs at ports in Europe. • Less experience with and extend of natural gas infrastructure (pipelines and LNG harbours) compared to other GCC countries.

1.3 Oman

Convergence & Divergence with EU hydrogen strategy	
• No hydrogen strategy published yet. • But several planned projects for the next years. • Export will play a major role (as an alternative for existing fossil gas exports). • Existing LNG port.	• Potential to deliver blue hydrogen in the short term as well as green hydrogen in the long term. • Exporting plans only with non-EU countries for the time being. • No hydrogen strategy but planned. • Definition of blue hydrogen is very broad (CCU & enhanced oil and gas recovery)

1.4 United Arab Emirates (UAE)

Convergence & Divergence with EU hydrogen strategy	
• Highest ambitions in RES-E uptake • Targets 25% of global hydrogen fuel market by 2030 • UAE and Germany have signed a joint declaration of intent (JDI) for clean hydrogen and its derivates in Nov. 2021 • Dubai Electricity and Water Authority (DEWA) will release its strategy on hydrogen in 2022 • Hydrogen Leadership Roadmap announced in Nov. 2021 by Ministry of Energy and Infrastructure (MOEI) at COP26 in Glasgow	• Potential to deliver blue hydrogen in the short term as well as green hydrogen in the long term. • Definition of blue hydrogen is very broad (CCU & enhanced oil and gas recovery)

1.5 Qatar

Convergence & Divergence with EU hydrogen strategy	
• Short term potential for exporting blue hydrogen due to existing experience and first projects	• Potential mainly on blue hydrogen • Limited midterm option to export green hydrogen due to missing RES-E potentials • Definition of blue hydrogen is very broad (CCU & enhanced oil and gas recovery)

1.6 Kuwait

Convergence & Divergence with EU hydrogen strategy	
• Short term potential for exporting blue hydrogen due to existing experience and first projects	• Potential to deliver blue hydrogen in the short term as well as green hydrogen in the long term. • Definition of blue hydrogen is very broad (CCU & enhanced oil and gas recovery)

1.7 Bahrain

Convergence & Divergence with EU hydrogen strategy	
	• Export not mentioned in documents • Blue hydrogen only based on crude oil if at all • No midterm option to export green hydrogen due to missing RES-E potentials

1.8 Indicators and comparing the countries

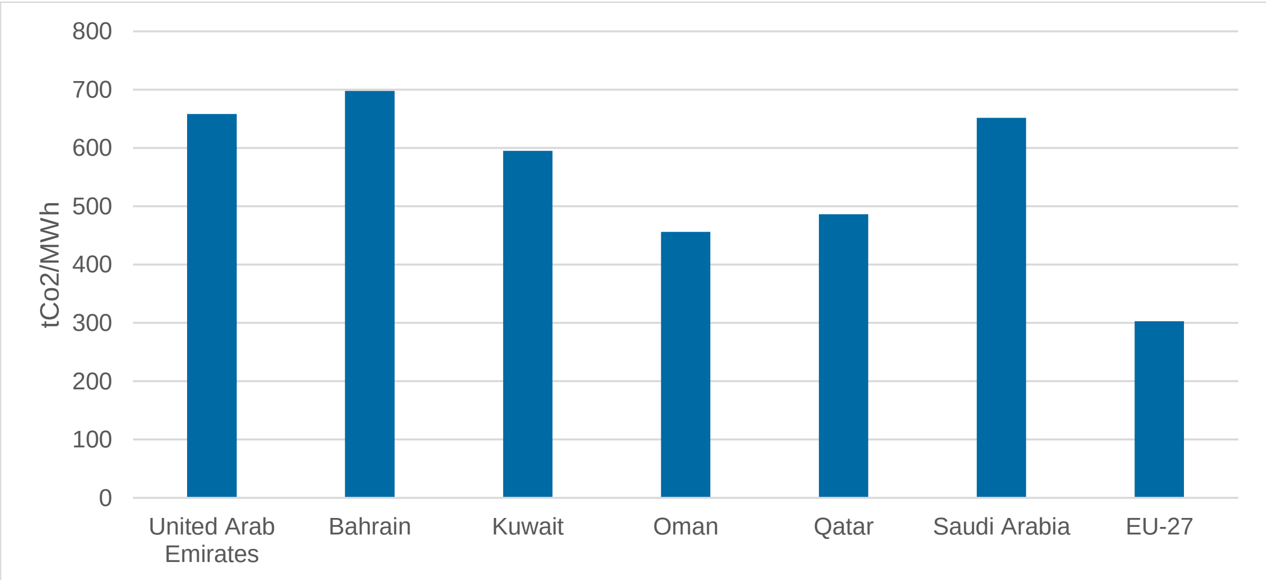
In the following sections we compare the countries studied based on various data sets.

1.8.1 Current CO_2-emissions of electricity generation

The current specific CO_2-intensity of electricity generation for the GCC countries is shown in Figure 1-1. All GCC countries show higher CO_2-intensity of electricity generation compared to the EU-27 average. Electricity generation is based mainly on natural gas (as well as associated gas) and oil.

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 to cover additional demand caused by hydrogen production.

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

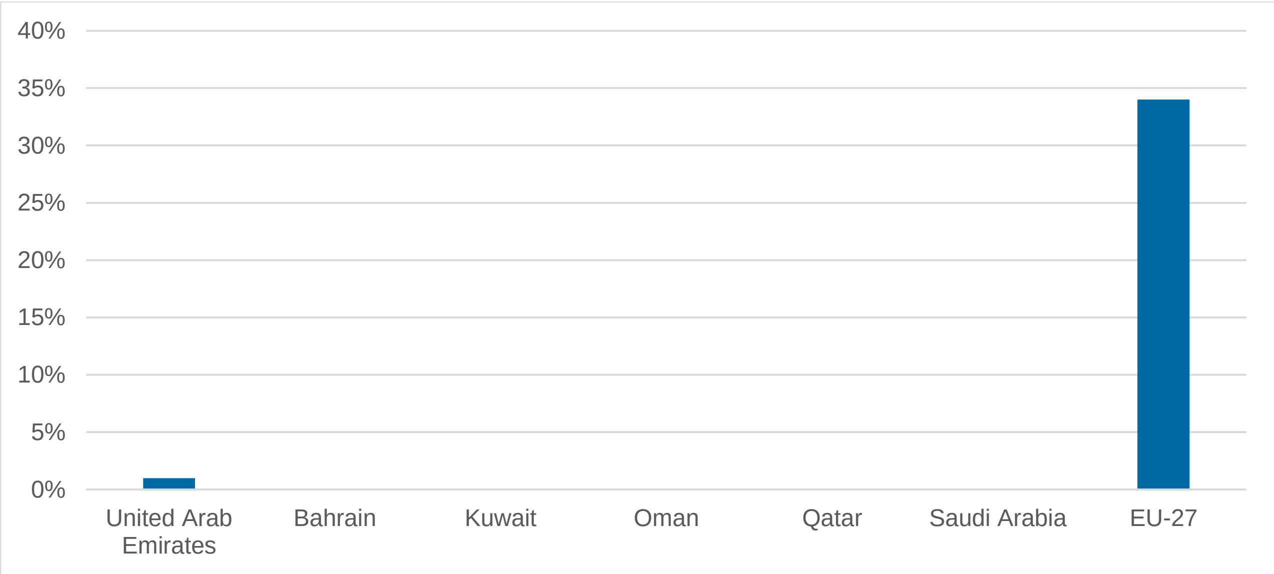


Source: IEA CO_2 from combustion https://www.iea.org/data-and-statistics/data-product/greenhouse-gas-emissions-from-energy#ghg-emissions-from-fuel-combustion

1.8.2 Current RES-E shares

The current RES-E share in electricity generation is shown in Figure 1-2. The data shows that RES-E uptake has hardly started yet in the GCC countries. The installed capacity of RES-E plants in 2018 accounted for 867 MW (UAE with the largest share of 589 MW).

Figure 1-2: RES-E share of electricity generation [2018]

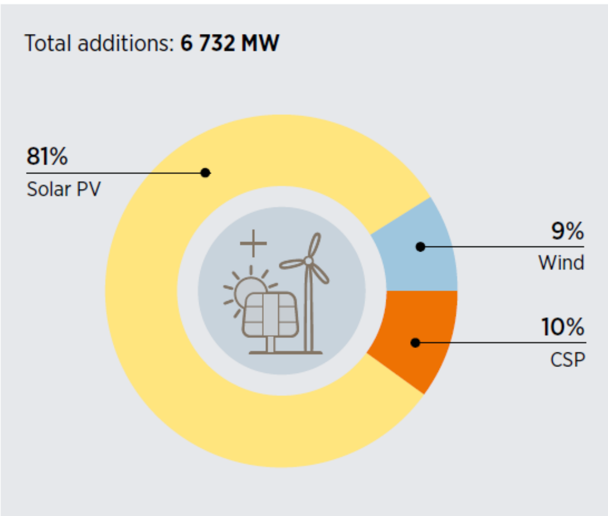


Source: own compilation based on data from IRENA Database

However, there is a substantial number of projects in the pipeline for 2025 (6,732MW) mainly in the United Arab Emirates, Oman and Kuwait (see Figure 1-3). Most planned projects are solar PV plants.

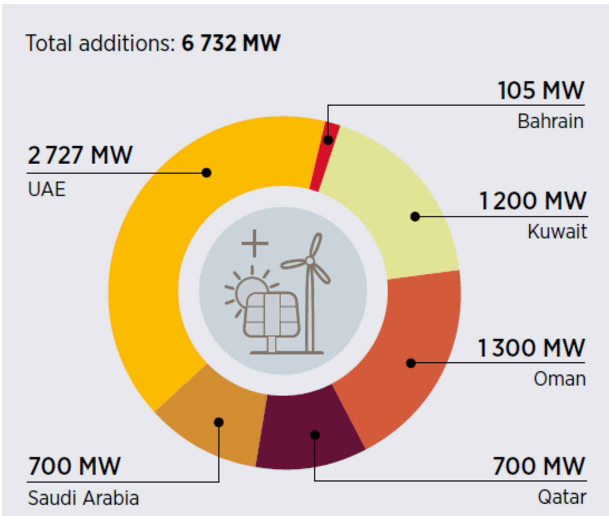
Figure 1-3: RES-E project pipeline in GCC countries

Figure 2.4 Renewable power planned additions by technology



Source: IRENA, 2018a.

Figure 2.5 Renewable power planned additions by country



Source: IRENA, 2018a.

Source: (IRENA 2019)

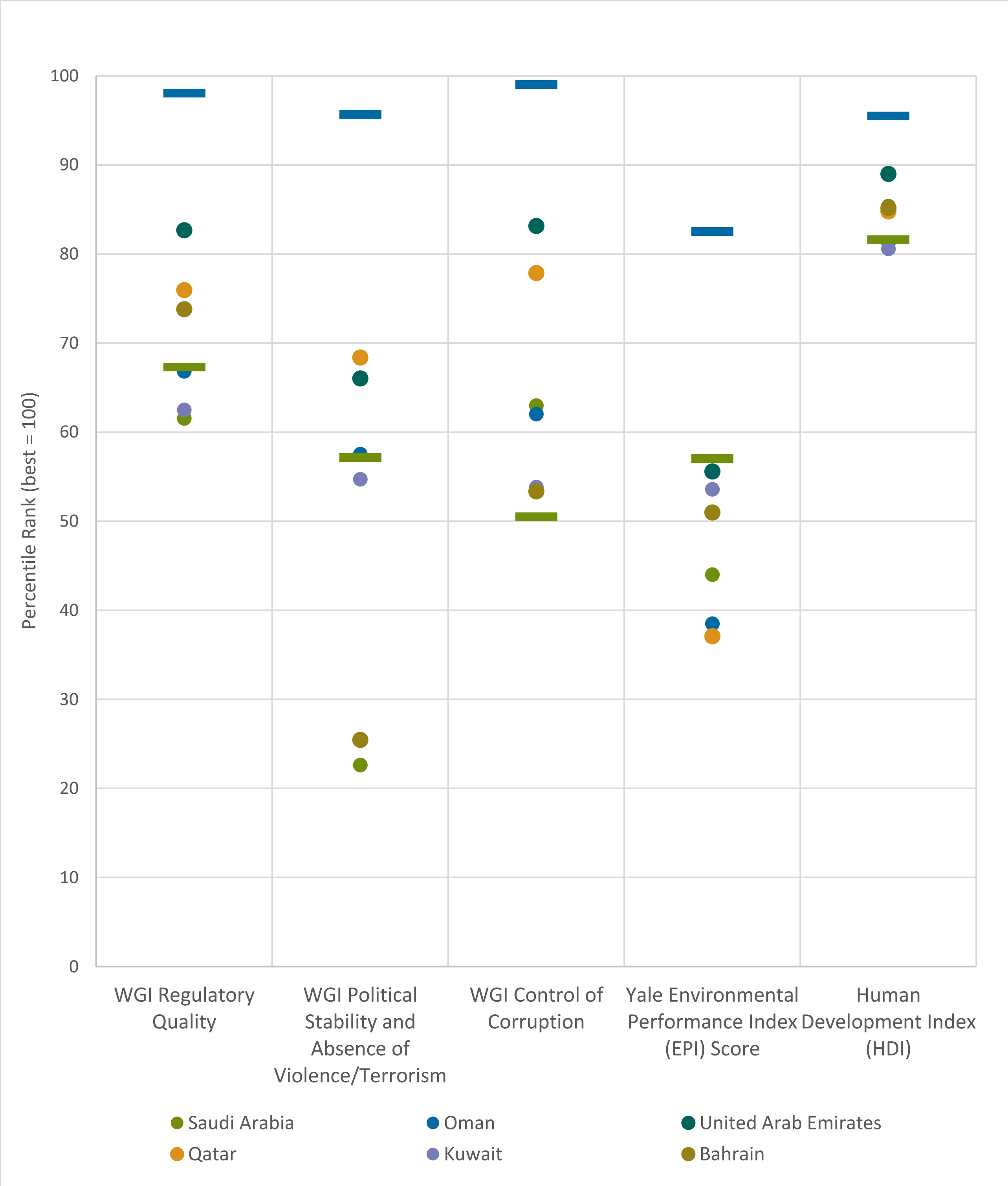
1.8.3 Comparing socio-economic and political indicators

In the following, we focus on country-specific aspects related to socio-economic development and governance.

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 1-4 also taken from the same source. In both figures, the range of the EU-27 Member-states is indicated. All indicators are described in detail in section 3 in the appendix. Most indicators for the GCC countries are within the range of the EU-27.

- ➔ Saudi Arabia and Bahrain rank very low in "Political stability and absence of terrorism and violence".
- ➔ The Environmental Performance in the GCC countries is reported to be lower than the performance in the EU-27. This indicates that issues such as monitoring of methane emissions, brine disposal of sea water desalination plants and respect of protected areas are highly relevant if hydrogen is produced in the GCC countries.

Figure 1-4: Economic, regulatory, environmental and human development Indicators and HDI



Source: own compilation based on data from world bank

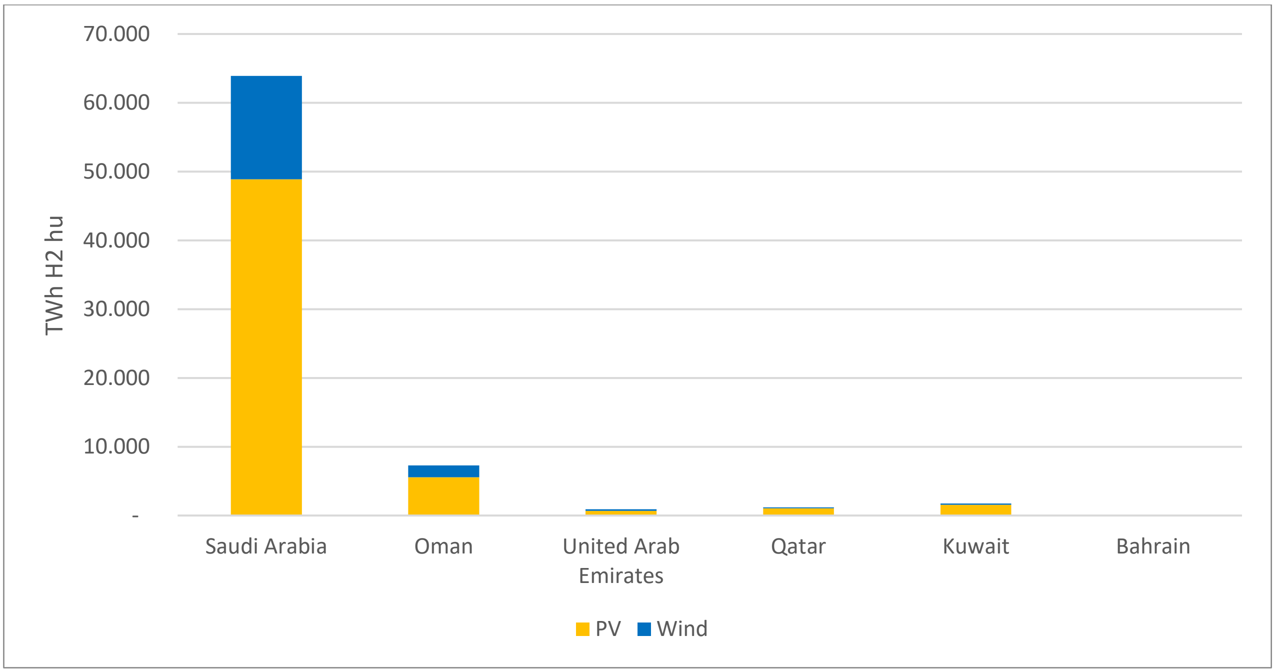
1.8.4 H_2 production potentials

The technical production potentials to produce green hydrogen for the GCC countries shown in Figure 1-5 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 1-6.

➔ The main share of the potential is based on PV technology.

➔ Saudi Arabia stands out with high overall RES-E potentials and a substantial share of potential for wind power.

Figure 1-5: Theoretical yearly production potential for gaseous hydrogen by country



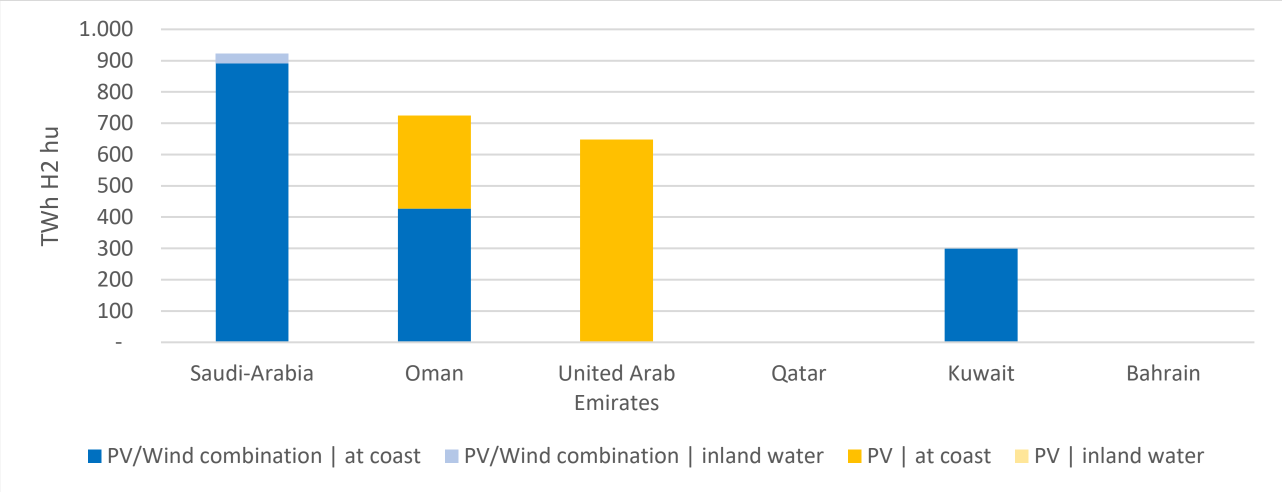
Source: own compilation based on data from (EWI 2020)

Figure 1-6 shows the annual production potential reported for gaseous hydrogen production by the PtX Atlas from Fraunhofer Institute. While this source also estimates production potentials on 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 1-5. The main driver that reduces the potential areas for hydrogen production is 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. The PtX Atlas also takes into account distance to infrastructure, cities and the coast (please see https://devkopsys.de/ptx-atlas/#methodik for detailed information). Further, 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 1-5) and an export potential (Figure 1-6).

➔ High production potentials (650 to 900 TWh H_2) are seen in Saudi Arabia, Oman and the United Arab Emirates while Kuwait shows lower production potential (300 TWh H_2).

- ➔ Qatar and Bahrain do not show any potential for green hydrogen production. This is due to the various limitations the PTX Atlas sets, described in the section above.
- ➔ Saudi Arabia show high potentials sources by RES-E from PV and Wind combinations at the coast of the Red Sea.
- ➔ Oman shows a mix of potentials using PV at coastal location and PV and Wind combinations at the coast.
- ➔ The United Arab Emirates, however, only show potentials by making use of PV at the coast.
- ➔ Kuwait is expected to have potentials based on PV and Wind combinations at the sea.

Figure 1-6: Annual potential for producing gaseous hydrogen



Source: Data based on (Fraunhofer IEE 2021)

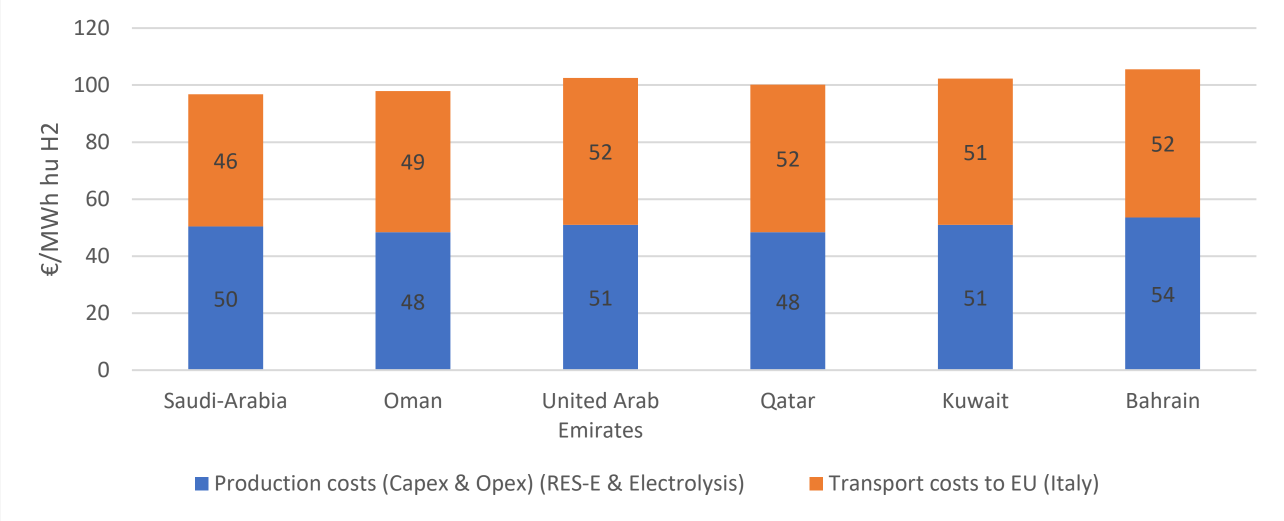
1.8.5 Supply costs for hydrogen

Figure 1-7 shows the total supply costs for gaseous hydrogen from the GCC countries to Italy (chosen, because ports are in place and could be connected to the European Hydrogen Backbone) in 2030 based on data from EWI 2020.

Hydrogen production costs are reported to be in the same range for the selected countries (about 100 €/MWh H_2).

Transport costs vary slightly due to the larger shipping distance from the Gulf to Europe. However, as the main share of transport costs are due to conversion and reconversion of hydrogen into a transport-medium (Liquid, ammonia, LOHC) which accounts for about 75% of the transport costs, the shipping distance does not alter the overall transport costs significantly.

Figure 1-7: Total supply costs of gaseous hydrogen incl. transport to Italy in 2030



Source: 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

2 Detailed Information – Country Factsheets

2.1 Information that is relevant for all GCC

Trade agreements with GCC and Europe

As trade agreements between the EU and the GCC states are common for all GCC states, they are not documented in the specific country fact sheets.

- The GCC countries have formed their own customs union and are working towards the goal of completing an internal market.
- A structured informal EU-GCC Dialogue on Trade and Investment was launched in May 2017.
- The World Bank classifies the six GCC countries as high-income economies. Therefore, they do not benefit from preferential access to the EU market under the EU's (GSP[7]).
- The EU-GCC Dialogue on Economic Diversification has been working since 2019 to develop connections and to build partnerships based on the exchange of EU experience and expertise to assist GCC countries in their economic diversification strategies.

Transportation

The transport of the generated hydrogen involves similar issues for the GCC countries. Most countries have LNG and infrastructure for natural gas.[8] However, there is no transport network for gas to Europe, which could be transformed for the transport of hydrogen. Accordingly, the only transport option is by ship. The fastest way would be a route from the Red Sea to the Mediterranean Sea, and finally Italy. Italy provides an entry port into the European hydrogen distribution network (EWI 2020). Although the transport distance from Saudi Arabia is the shortest, the calculated costs for the remaining GCC states differ only marginally[9]. However, transportation by ship increases the cost of imported hydrogen in general. In addition, ship transport limits the transported derivatives to ammonia, methane or e-fuels.

2.2 Saudi Arabia

Trade	
Main export partners [% of trade volume $][10]	• China (20,1%) • EU (12,0%) • India (11%)
Main export goods [% of trade volume $][11]	• Crude Petroleum (63,3%) • Refined Petroleum (9,6%) • Ethylene Petroleum (4,9%)

7 Generalised Scheme of Preferences
8 see Figure 9
9 see **Figure 1-7**
10 https://oec.world/en/profile/country/sau ; EU as a trading partner is calculated proportionally from the member states of the EU in Europe.
11 https://oec.world/en/profile/country/sau

Hydrogen strategy and economy	
Existing hydrogen strategy	• None to date
Existing bilateral hydrogen agreements	• Memorandum of Understanding (MoU) establishing cooperation on hydrogen between Germany and Saudi Arabia.[12] • The German Government funded the electrolysis technology of the Project "Element One" which is part of the NEOM Project.[13] • A MoU has been signed by Saudi Arabia's ACWA power and OQ (Oman's state-owned energy company) to conduct a feasibility study to produce green ammonia in Dhofar (Oman).[14] • Saudi Aramco signed a MoU with Japanese ENEOS to consider a CO_2-free hydrogen and ammonia supply-chain.[15]
Existing projects[16] (incl. Blue hydrogen)	**Green hydrogen** • ? MW | announced start 1993, not operating | HYSOLAR Pilot • ? MW | started 2020 | Yanbu **Blue ammonia** • ? MW | 2020 | First shipment of blue ammonia to Japan as part of pilot study | Saudi Aramco[17]
Planned projects [up to 2030] [18] (incl. Blue hydrogen)	**Green ammonia and hydrogen** • 2,000 MW | starting date 2025 | Data for overall NEOM project • 1,5 GW | starting date not documented | Helios Green Fuels as part of NEOM[19] **Blue hydrogen** • ? MW | starting date not documented | Saudi Aramco • Other undefined project: Saudi Aramco wants to develop gas field for blue hydrogen[20]
support schemes or funding facilities for clean hydrogen	• None to date

12 https://www.bmwi.de/Redaktion/EN/Pressemitteilungen/2021/03/20210311-altmaier-signs-memorandum-of-understanding-on-german-saudi-hydrogen-cooperation.html

13 https://www.bmwi.de/Redaktion/DE/Pressemitteilungen/2020/12/20201216-altmaier-uebergibt-foerderbescheid-fuer-internationales-projekt-fuer-gruenen-wasserstoff.html

14 https://www.spglobal.com/platts/en/market-insights/latest-news/energy-transition/120821-Saudi Arabias-acwa-power-omans-oq-to-study-hydrogen-project-in-dhofar

15 https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/032521-japans-eneos-signs-mou-with-aramco-to-develop-hydrogen-ammonia-supply-chain

16 IEA Hydrogen Project Database 2020 and 2021

17 https://marketingstorageragrs.blob.core.windows.net/webfiles/Hydrogen-Handbook_MiddleEast.pdf

18 IEA Hydrogen Project Database 2020 and 2021

19 https://iea.blob.core.windows.net/assets/e57fd1ee-aac7-494d-a351-f2a4024909b4/GlobalHydrogenReview2021.pdf (page 136)

20 https://www.bloomberg.com/news/articles/2021-06-27/aramco-says-timing-of-next-blue-ammonia-cargo-depends-on-buyers

Potential branches for domestic hydrogen demand	• (strategy& 2020)) suggest for Saudi Arabia to have low domestic demand for green hydrogen due to cheap electricity and natural gas resources. • Refineries (~10% of export volume) as well as some processes of the chemical industry (~20% of export volume) can use low-carbon hydrogen to reduce the THG-footprint of end-products. However, the question is if the trade partners will ask for products with low THG footprint. • In the project NEOM it is planned to use hydrogen and derivatives in the transport sector and as energy storage.
Exporting potential in strategy [TWh per year]	• No strategy yet • However, official statements do not see a significant uptake even of blue hydrogen before 2030[21]
Main Hydrogen production technology in focus	• Saudi Arabia officials stated that blue hydrogen will be the relevant export business-case in the short to mid-term. However, bulk exports of blue hydrogen are not expected before 2030. • Green hydrogen in the long-term.
Primary focus of export substance	• Ammonia (blue ammonia has been shipped to Japan in 2020) • Other derivatives
Production potential for blue hydrogen	• Saudi Arabia has the sixth largest proven natural gas reserves in the world (behind Russia, Iran, Qatar, US and Turkmenistan). The natural gas production has increased steadily over the last decades while the share of associated gas (in connection with crude oil production) has dropped especially since 2015.[22] • This shows that potential for blue hydrogen is high. Especially because first projects with CCS technologies have been carried out and blue ammonia has been shipped to Japan already. • However, transport infrastructure for natural gas such as pipelines and shipping are not as developed as in other GCC countries such as Qatar. • There is experience in CCS technology: The Uthmaniyah CO_2-EOR Demonstration compresses and dehydrates CO_2 from the Hayiyah NGL natural gas liquids recovery plant. Operations started in 2015, it captures about 0.8 Mtpa. CO_2 is transported via pipeline to be injected into an oil field for enhanced oil recovery.[23]

21 https://www.bloomberg.com/news/articles/2021-06-27/aramco-says-timing-of-next-blue-ammonia-cargo-depends-on-buyers
22 https://www.eia.gov/international/content/analysis/countries_long/Saudi_Arabia/saudi_arabia.pdf
23 https://co2re.co/FacilityData

Transportation to Europe in hydrogen strategy	There is no strategy yet. Pipeline • There are no existing natural gas pipelines from Saudi Arabia towards Europe. • However, there are first comments that piping hydrogen towards Europe through Egypt and North Africa could be an option.[24] Shipping • Shipping from Saudi Arabia to Europe is the option most referred to in literature. • (McKinsey & Company 2021)) assumes a transport distance of 8,700km from the Red Sea to Rotterdam. In case of using liquid hydrogen or LOHC as the transport medium, costs for transport (1.6 – 2.7 USD/kg H_2) more than double the cost for hydrogen production (~1.5 USD/kg H_2). Shipping Ammonia is a low-cost option but only if ammonia is not reconverted into hydrogen in the destination country. • Compared to the other GCC states, Saudi Arabia's shipping distance towards Europe is much shorter (~ 2,000km less) as is has access to the Red Sea. This will result in lower shipping costs. • Shipping distances from GCC countries would decrease if a European Hydrogen grid is connected to harbours in the Mediterranean Sea. However, the main costs for shipping arise from converting hydrogen into transportable states (liquid) or other mediums (LOHC). • The Ministry of Energy (Saudi Arabia) stated that the shipping of ammonia is likely to be the most relevant transport option.[25]
Key actors	• Saudi Aramco (state owned energy company) • ACWA Power (a Saudi Arabian power plant developer) • NEOM project (Air Products, an American chemical company, is a major player) • KAPSARC (a Saudi-Arabian Research center) • Ministry of Energy of Saudi Arabia
Sustainability issues and potential conflicts [26]	
Water conflicts	• The maps show a high density of population along the coast with high density of sea water desalination plants already. Sustainable and additional sea water desalination for hydrogen production will be a major challenge.
Water stress level	• Most areas are arid or show high water stress. Saudi Arabia is one of the most water scarce nations.[27] • In the project NEOM desalinated sea water is to be used, however zero-liquid discharge is envisaged.
Land conflicts	• None documented in Environmental Justice Atlas • Densely populated coastal area pressured due to water stress[28] • Marine protection zones both in the Red Sea and Persian Gulf[29] compete for water use

[24] https://www.rechargenews.com/markets/Saudi Arabia-could-pipe-green-hydrogen-to-europe-to-keep-leading-energy-role/2-1-972920
[25] Stated in a bilateral work-shop
[26] Main source is the Environmental Justice Atlas: https://ejatlas.org/
[27] https://www.sciencedirect.com/science/article/pii/S2214999615012217
[28] See **Fehler! Verweisquelle konnte nicht gefunden werden.** and **Fehler! Verweisquelle konnte nicht gefunden werden.**
[29] See https://www.protectedplanet.net/region/AF

Socio-economic	• None documented in Environmental Justice Atlas	
Existing and future energy system & decarbonisation strategy	2018	2030
Total gross electricity production (net imports)[30] [TWh]	387 (0)	No projections available
RES share in gross electricity generation[31] [%]	0	50%[32]
CO_2 intensity of gross electricity generation [gCO_2/kWh, 2017][33]	652	Not available
Largest fossil fuel-based electricity generation (share in total generation)]	Natural gas (58%) Mainly based on associated gas Oil is the other dominant source	50% natural gas[34] (switch from oil)
CO_2 emissions from electricity and heat production (from other energy industry own use, manufacturing industries and construction) [$MtCO_2$, 2017][35]	247 (130)	Not available
Goals decarbonisation for 2030[36] (NDC discussion) and net zero targets	• Reduction of 278 MtCO2e probably below a baseline scenario • Climate Action Tracker estimates this target as an increase of 146–275% compared to 1990 levels • Net zero target for 2060 announced	

2.3 Oman

Trade	
Main export partners [% of trade volume $][37]	• China (46,2%) • India (7,9%) • Japan (6,5%)
Main export goods [% of trade volume $][38]	• Crude Petroleum (47,8%) • Petroleum Gas (14,4%) • Refined Petroleum (6,9%)
Hydrogen strategy and economy	

30 IEA (2021): Electricity Information Statistics. https://doi.org/10.1787/elect-data-en
31 IRENA (2020): Renewable Energy Statistics
32 https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Saudi%20Arabia%20First/KSA%20NDC%202021%20FINAL%20v24%20Submitted%20to%20UNFCCC.pdf
33 Calculated as CO_2 emissions from electricity and heat production divided by gross electricity generation.
34 https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Saudi%20Arabia%20First/KSA%20NDC%202021%20FINAL%20v24%20Submitted%20to%20UNFCCC.pdf
35 IEA (2020): IEA CO_2 Emissions from Fuel Combustion Statistics. https://doi.org/10.1787/co2-data-en
36 https://climateactiontracker.org/countries/Saudi Arabia/targets/
37 https://oec.world/en/profile/country/omn
38 https://oec.world/en/profile/country/omn

Existing hydrogen strategy	• No strategy yet, but planned • National hydrogen feasibility study to be finished by end of 2021[39] • National hydrogen alliance (Hy-Fly) established[40]
Existing bilateral hydrogen agreements	MoU with Saudi Arabia's ACWA Power to conduct a feasibility study on hydrogen projects to produce 1 million tons of green ammonia annually[41]. A further MoU between ACWA and Omanoil and Air Products was signed in Dez. 2021 to produce green hydrogen in Oman's Salalah Free Zone.[42] MoU with Japanese firm Sumitomo for blue hydrogen plants[43]
Existing projects[44] (incl. Blue hydrogen)	None documented
Planned projects [up to 2030] [45] (incl. Blue hydrogen)	**Green Methanol** • 250 MW | Starting 2026 | Hyport@Dupm **Green hydrogen** • ? MW | starting date not documented | Oman Green Energy Hub • ? MW | starting date not documented | PDO's solar-panelled car park • ? MW | starting date not documented | Amin Solar Renewable Energy Project • 4,7-14 GW | starting 2028 | Oman green H2 project **Green ammonia** • ? MW | starting 2023 | Port of Duqm NH3 plant **Green ammonia and hydrogen** • 25 GW | starting 2028 | InterContinental Energy, OQ, EnerTech[46] • ? MW | starting date not documented | ACME[47] **Blue hydrogen** • ? MW | starting 2023 | Sumitomo Oman; using flare gas and producing for the local market
support schemes or funding facilities for clean hydrogen	None to date
Potential branches for domestic hydrogen demand	The main branch is the national oil and gas industry (whether for local demand or export)
Exporting potential in strategy [TWh per year]	No strategy yet
Main Hydrogen production technology in focus	• Green hydrogen • Blue hydrogen

39 https://www.zawya.com/mena/en/projects/story/PROJECTS_Omans_national_hydrogen_feasibility_study_to_be_completed_by_end_2021-ZAWYA20210610110721/
40 https://www.pdo.co.om/en/news/press-releases/Pages/Oman%E2%80%99s%20Hydrogen%20Alliance%20to%20Drive%20National%20Hydrogen%20Economy.aspx
41 https://www.spglobal.com/platts/en/market-insights/latest-news/energy-transition/120821-Saudi Arabias-acwa-power-omans-oq-to-study-hydrogen-project-in-dhofar
42 https://www.arabnews.com/node/1981956/business-economy
43 https://www.sumitomocorp.com/en/africa/news/release/2021/group/14290
44 IEA Hydrogen Project Database 2020 and 2021
45 IEA Hydrogen Project Database 2020 and 2021
46 IEA 2021. Global hydrogen Review 2021. https://iea.blob.core.windows.net/assets/e57fd1ee-aac7-494d-a351-f2a4024909b4/GlobalHydrogenReview2021.pdf
47 IEA 2021. Global hydrogen Review 2021. https://iea.blob.core.windows.net/assets/e57fd1ee-aac7-494d-a351-f2a4024909b4/GlobalHydrogenReview2021.pdf

Primary focus of export substance	• Ammonia • Hydrogen	
Production potential for blue hydrogen	• Approx. 0.4% of world gas reserves[48] • Large CO_2 storage potential in Hajar Mountain[49]	
Transportation to Europe in hydrogen strategy	• No strategy yet • But existing LNG infrastructure with Qalhat LNG Terminal • In the short-term shipping could be a sufficient export option to Europe.	
Key actors	• Ministry of Energy and Minerals • Petroleum Development Oman • Energy and petroleum companies: OQ, Oman LNG, BP Oman, Oman Shell and Total Energies Oman • Research: Sultan Qaboos University and GUTech	
Sustainability issues and potential conflicts [50]		
Water conflicts	• None documented in EJ Atlas	
Water stress level	• Water stress levels in Oman are diverse, ranging from small low-medium water stress areas in Dhofar and A Sharqiya to high water stress levels and arid regions. Risk for water shortages is high. • Water stress level is high in densely populated areas of the coastal region (except A Sharqiya region). • Potentials for renewables are highest in the arid regions of Dhofar.	
Land conflicts	• None documented in EJ Atlas • Densely populated coastal area in the Gulf of Oman overlaps with marine protection zones.[51] • Protected Areas for terrestrial species overlap with potential renewable energy production zones in Dhofar.[52]	
Socio-economic	• None documented in EJ Atlas	
Existing and future energy system & decarbonisation strategy	2018	2030[53]
Total gross electricity production (net imports)[54] [TWh]	38 (-0.0)	44 TWh
RES share in gross electricity generation[55] [%]	0	20%
CO_2 intensity of gross electricity generation [gCO_2/kWh, 2017][56]	456	Not available

48 https://www.worldometers.info/gas/#gas-reserves
49 https://mega.online/en/articles/carbon-capture
50 Main source is the Environmental Justice Atlas: https://ejatlas.org/
51 See https://www.protectedplanet.net/region/AF and **Fehler! Verweisquelle konnte nicht gefunden werden.**
52 See https://www.protectedplanet.net/region/AF and **Fehler! Verweisquelle konnte nicht gefunden werden.**
53 https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Oman%20Second/Second%20NDC%20Report%20Oman.pdf
54 IEA (2021): Electricity Information Statistics. https://doi.org/10.1787/elect-data-en
55 IRENA (2020): Renewable Energy Statistics
56 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 (97%)	80% fossil gas
CO_2 emissions from electricity and heat production (from other energy industry own use, manufacturing industries and construction) [$MtCO_2$, 2017][57]	16 (25)	Not available
Goals decarbonisation for 2030 (NDC discussion) and net zero targets.[58]	Reduction of 7% in 2030 relative to BAU, with total GHG emissions capped to 116.486 MTCO2e in 2030 Upstream oil and gas sector in Oman aspire a net zero target for 2050.	

2.4 United Arab Emirates (UAE)

Trade	
Main export partners [% of trade volume $][59]	• India (10,8%) • Japan (9,6%) • Saudi Arabia (7,22%)
Main export goods [% of trade volume $][60]	• Crude Petroleum (23,1%) • Refined Petroleum (13%) • Gold (8,63%)
Hydrogen strategy and economy	
Existing hydrogen strategy	• Dubai Electricity and Water Authority (DEWA) will release its strategy on hydrogen in 2022[61] • Hydrogen Leadership Roadmap announced in Nov. 2021 by Ministry of Energy and Infrastructure (MOEI) at COP26 in Glasgow[62] • Targets 25% of global hydrogen fuel market by 2030
Existing bilateral hydrogen agreements	• UAE and Japan signed a cooperation agreement in Apr. 2021 to explore opportunities in hydrogen development[63] • UAE and Germany have signed a joint declaration of intent (JDI) for clean hydrogen and its derivates in Nov. 2021[64] • UAE and Russia signed a JDI in Nov. 2021 to collaborate on hydrogen development[65]

57 IEA (2020): IEA CO_2 Emissions from Fuel Combustion Statistics. https://doi.org/10.1787/co2-data-en
58 https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Oman%20Second/Second%20NDC%20Report%20Oman.pdf
59 https://oec.world/en/profile/country/are
60 https://oec.world/en/profile/country/are
61 https://www.thenationalnews.com/business/energy/2021/09/13/dewa-to-release-its-green-hydrogen-strategy-in-2022/
62 http://wam.ae/en/details/1395302988986
63 https://www.moei.gov.ae/en/media-centre/news/11/4/2021/a-cooperation-agreement-between-uae-and-japan-to-explore-the-opportunities-available-in-the-field-of-hydrogen-development.aspx#page=1
64 https://www.bmwi.de/Redaktion/EN/Pressemitteilungen/2021/11/20211102-new-hydrogen-task-force-germany-and-united-arab-emirates-to-expand-bilateral-energy-partnership.html
65 https://www.spglobal.com/platts/en/market-insights/latest-news/energy-transition/111821-uae-russia-ink-agreement-to-partner-on-hydrogen-development-amid-net-zero-pledges

Existing projects[66] (incl. Blue hydrogen)	**Green hydrogen** • 1,25 MW | started 2020 | Mohamad Bin Rashid Solar Park • ? MW | started 2020 | StudyPilot • ? MW | started 2019 | Air Liquide, Khalifa University, Al Futtaim Motors **Blue hydrogen** • ? MW | started 2009 | BP **Other hydrogen** • ? MW | started 2016 | Al Reyadah CCUS
Planned projects [up to 2030] [67] (incl. Blue hydrogen)	**Green hydrogen** • 20 MW | starting 2022 | Masdar City green H_2 • ? MW | starting date not documented | TAQA-Emirates Steel Green H_2 **Blue hydrogen** • ? MW | starting 2025 | Ruwais, Fertilglobe, ADNOC • 800 MW | starting date not documented | Kizad Helios, Thyssenkrupp **Green ammonia** • ? MW | starting 2024 | Khalifa Industrial Zone Abu Dhabi (KIZAD) **Other hydrogen** • ? MW | starting 2025 | Bee'ah waste-to-hydrogen
Support schemes or funding facilities for clean hydrogen	None to date
Potential branches for domestic hydrogen demand	• Synthetic fuels • Steel industry
Exporting potential in strategy [TWh per year]	No strategy to date
Main Hydrogen production technology in focus	Since green hydrogen "remains in its infancy requiring an international collaboration to accelerate its development"[68] "blue is the colour for now"[69]. But green hydrogen is envisaged to play a significant role for UAE's 2050 Net-Zero goals. Blue and green hydrogen and ammonia production are included in UAE's roadmap.
Primary focus of export substance	• None to date • Roadmap highlights export of blue hydrogen and derivates to meet UAE's 2050 Net-Zero goals[70]

66 IEA Hydrogen Project Database 2020 and 2021
67 IEA Hydrogen Project Database 2020 and 2021
68 http://wam.ae/en/details/1395302988986
69 https://www.wfw.com/articles/hydrogen-in-the-uae/
70 http://wam.ae/en/details/1395302988986

Production potential for blue hydrogen	• Experience with CCS since 2016 • Seventh-largest proved reserves of natural gas in the world[71] • Coming into operation in 2016 the first commercial CCS facility in the iron and steel industry. It involves the capture of CO_2 using high purity CO_2 produced as a by-product of the direct reduced iron-making process. The compression facility has a capture capacity of 0.8 Mtpa. The CO_2 is transported via pipeline to be used for enhanced oil recovery. Abu Dhabi National Oil Company is developing its second CCUS facility in the UAE. It will capture 1.9 to 2.3 Mtpa of CO_2 from its gas processing plant for EOR (Enhanced Oil Recovery) and will be operational due in 2025.[72]	
Transportation to Europe in hydrogen strategy	• No strategy to date • But existing LNG harbour in Abu Dhabi (which is currently substantially extended) • However, JDI of UAE and Germany implies a strategy for transport of hydrogen. • In the short-term shipping could be a sufficient export option to Europe.	
Key actors	• MOEI • DEWA Dubai Electricity and Water Authority • Khalifa University • TAQA, BP, Thyssenkrupp • Leadership roadmap states to continue public-private-partnerships (ADNOC, Mubadala, ADQ and DEWA).	
Sustainability issues and potential conflicts [73]		
Water conflicts	• None documented in EJ Atlas	
Water stress level	• Most of UAE is under high to extreme water stress with arid areas. • High potentials for solar energy overlaps with water critical areas. • Water scarcity is extreme, and competition cannot be excluded since water stress is high in densely populated areas.	
Land conflicts	• None documented in EJ Atlas • Densely populated coastal region pressured by water stress • Protected Area for terrestrial species in the border triangle of UAE, Oman and Saudi Arabia overlaps with greatest renewable potential for solar energy.[74] Densely populated coastal region of Abu Dhabi includes five marine protected areas.	
Socio-economic	• None documented in EJ Atlas	
Existing and future energy system & decarbonisation strategy	2018	2030
Total gross electricity production (net imports) [TWh][75]	136 (0.0)	Not available

[71] https://www.eia.gov/international/analysis/country/ARE
[72] https://co2re.co/FacilityData
[73] Main source is the Environmental Justice Atlas: https://ejatlas.org/
[74] See https://www.protectedplanet.net/region/AF and **Fehler! Verweisquelle konnte nicht gefunden werden.**
[75] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA_RRA_Mauritania_EN_2015.pdf

RES share in gross electricity generation [%][76]	1	n.a. for 2030 2050: 44%
CO_2 intensity of gross electricity generation [gCO_2/kWh, 2017][77]	658	Not available
Largest fossil fuel-based electricity generation (share in total generation)[78]	Natural gas (98%)	n.a. for 2030 2050: 38% fossil gas 12% "clean coal"
CO_2 emissions from electricity and heat production (from other energy industry own use, manufacturing industries and construction) [MtCO_2, 2017][79]	89 (66)	Not available
Goals decarbonisation for 2030 (NDC discussion) and net zero targets[80]	23.5% reduction below the BAU scenario in 2030 (505% above 1990 level excl. LULUCF) Net zero target for 2050 announced	

2.5 Qatar

Trade	
Main export partners[81] [% of trade volume $]	• Japan (17,1%) • South Korea (15,6%) • India (13,6%)
Main export goods [% of trade volume $][82]	• Petroleum Gas (57,5%) • Crude Petroleum (20%) • Refined Petroleum (10,7%)
Hydrogen strategy and economy	
Existing hydrogen strategy	(Although Qatar does not have a specific hydrogen strategy), they are studying several aspects: • Blue hydrogen [83] • Hydrogen production from biomass and electrolysis • SMR process powered by solar thermal energy with carbon capture[84] • LNG-Hydrogen synergies[85]
Existing bilateral hydrogen agreements	• H2Korea and QatarEnergy signed a MoU to expand and enhance the hydrogen supply chain. • QatarEnergy and Shell are to explore hydrogen projects in the UK

76 https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA_RRA_Mauritania_EN_2015.pdf
77 Calculated as CO_2 emissions from electricity and heat production divided by gross electricity generation.
78 https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA_RRA_Mauritania_EN_2015.pdf
79 IEA (2020): IEA CO_2 Emissions from Fuel Combustion Statistics. https://doi.org/10.1787/co2-data-en
80 https://climateactiontracker.org/countries/uae/targets/
81 https://oec.world/en/profile/country/qat
82 https://oec.world/en/profile/country/qat
83 https://www.rvo.nl/sites/default/files/2020/12/Hydrogen%20in%20the%20GCC.pdf
84 https://www.sciencedirect.com/science/article/pii/S0360319921033061
85 https://www.qnrf.org/en-us/Newsroom/Research-Matters-Newsletter/qnrf-community-2

Existing projects[86] (incl. Blue hydrogen)	Qatar National Research Fund: *Solar Hybrid Hydrogen Production Cycle with In-situ Thermal Energy Storage*[87] • Research focused on technologies that can produce hydrogen directly from solar energy in an economically and environmentally friendly way. • Contribute to Qatar's visionary efforts in diversifying energy use by including renewable energy sources for the clean production of fuels and commodities
Planned projects [up to 2030] [88] (incl. Blue hydrogen)	• None in Database
support schemes or funding facilities for clean hydrogen	• Qatar National Research Foundation (QNRF) plans to launch a fund dedicated to exploring the prospects and opportunities for hydrogen energy in Qatar[89]

Potential branches for domestic hydrogen demand	• **QatarEnergy:** responsible for the development of the oil and gas industry in the State of Qatar and beyond. It produces liquefied natural gas (LNG), natural gas liquids (NGL), gas to liquids (GTL) products, refined products, petrochemicals, fertilizers, steel and aluminium.
	  • Steel production[90]: 2.3 million tonnes per year
	  • Aluminium production[91]: 660.000 tonnes per year
	• **Qatar Fuel Additives Company (QAFAC):** its plant produces Methanol and Methyl Tertiary Butyl Ether. QAFAC plant implements Carbon dioxide recovery and reuses the recovered CO_2 in its methanol production.
	  • Methanol production[92]: 1.01 million tonnes per year
	• **Qatar Fertiliser Company (QAFCO):** QAFCO together with its subsidiaries is engaged in the production of ammonia, urea, melamine and formaldehyde condensates.
	  • Ammonia production[93]: 2.7 million tonnes per year

Hydrogen Exports in strategy [TWh per year]	No strategy to date
Main hydrogen production technology in focus[94]	Blue hydrogen
Secondary hydrogen production technology in focus	SMR process powered by solar thermal energy with carbon capture
Primary focus of export substance	• Gaseous hydrogen • Ammonia

86 IEA Hydrogen Project Database
87 https://www.qnrf.org/en-us/spotlight-7
88 IEA Hydrogen Project Database
89 https://www.zawya.com/mena/en/projects/story/PROJECTS_QNRF_plans_to_launch_a_fund_for_exploring_hydrogen_prospects_next_year-ZAWYA20210603041018/
90 https://iq.com.qa/en/about-iq/iq-group-companies/steel/qatar-steel-company/
91 https://www.qatalum.com/Products/Pages/default.aspx
92 https://www.qafac.com.qa/annual-sustainability-reports
93 https://iq.com.qa/en/about-iq/iq-group-companies/fertiliser/qatar-fertiliser-company-qafco/
94 The locations with high potentials can be drawn from the maps in the following chapter showing the PV and Wind energy potential.

Production potential for blue hydrogen	• Great potential due to large natural gas resources • CCS experience: Starting in 2019, Qatargas separates CO_2 in the Ras Laffan LNG production from its North Field. The CO_2 capture and storage capacity is about 2.1 Mtpa.[95] • Qatar defines hydrogen that is produced based on natural gas with CCS for enhanced oil recovery and CCU (CO_2 used to produce for example Methanol) as blue hydrogen. • Fugitive methane emissions in the blue hydrogen chain will be relevant and independent data is necessary
Transportation to Europe in hydrogen strategy	LNG/LPG terminals[96]**:** • Ras Laffan Industrial City • Mesaieed Industrial City In the short-term shipping could be a sufficient export option to Europe.
Key actors	• QatarEnergy: is a state-owned petroleum company of Qatar. The company operates all oil and gas activities in Qatar, including exploration, production, refining, transport, and storage. • Qatar Fuel Additives Company • Qatar Fertilizer Company • Ministry of Environment and Climate Change • Ministry of Energy and Industry
Sustainability issues and potential conflicts[97]	
Water conflicts	Regarding the production of green hydrogen by electrolysis, one of the most challenging aspects in Qatar is the water availability: • Qatar has the largest GTL plant in the world, with the capacity to produce 280,000 barrels of water as by-product of its activities. This could be a potential water source that can be integrated with H_2 production through electrolysis[98].
	• Total capacity of Desalinisation plants of Qatar: 2.27 million Imperial Gallons per Day (MIGD)[99]
Water stress	• Level of water stress in Qatar is critical[100]
Land conflicts	• None documented in EJ Atlas • Densely populated coastal area of Doha under pressure for water scarcity[101] • Protected area for terrestrial species may interfere with renewable potentials for solar energy[102]
Socio-economic	• None documented in EJ Atlas
Other	• Local protests and concerns about environmental impacts of large-scale sand mining at the north-western coast

95 https://co2re.co/FacilityData
96 https://www.qatarenergy.qa/en/MarketingAndTrading/QPSPP/Pages/LPG.aspx
97 Main source is the Environmental Justice Atlas: https://ejatlas.org/
98 Green hydrogen for industrial sector decarbonization: Costs and impacts on hydrogen economy in Qatar
99 Desalination in Qatar: Present Status and Future Prospects
100 http://www.fao.org/sustainable-development-goals/indicators/642/en/
101 See **Fehler! Verweisquelle konnte nicht gefunden werden.** and **Fehler! Verweisquelle konnte nicht gefunden werden.**
102 See https://www.protectedplanet.net/region/AF and **Fehler! Verweisquelle konnte nicht gefunden werden.**

Existing and future energy system & decarbonisation strategy	2018	2030[103]
Total gross electricity production (net imports)[104] [TWh]	48 (0.0)	Not available
RES share in gross electricity generation[105] [%]	0	Not available
CO_2 intensity of gross electricity generation [gCO_2/kWh, 2017][106]	486	Not available
Largest fossil fuel-based electricity generation (share in total generation)]	Natural gas (100%)	Not available
CO_2 emissions from electricity production and heat (from other energy industry own use, manufacturing industries and construction) [$MtCO_2$, 2017][107]	22 (44)	Not available
Goals decarbonisation for 2030 (NDC discussion)	25% reduction for 2030 compared to BAU scenario No net zero target announced	

2.6 Kuwait

Trade	
Main export partners [% of trade volume $][108]	• China (20,2%) • South Korea (16%) • India (14,7%)
Main export goods [% of trade volume $][109]	• Crude Petroleum (69,7%) • Refined Petroleum (10,6%) • Planes, Helicopters, and/or Spacecraft (4,03%)
Hydrogen strategy and economy	
Existing hydrogen strategy	• White paper on Hydrogen Strategy published in Jan. 2021 by Kuwait Foundation for the Advancement of Sciences (KFAS) (short version[110]) • Preparations for an adaptable Kuwait National hydrogen Strategy (KNHS)
Existing bilateral hydrogen agreements	• Planned feasibility studies for flagship export projects to Asia (Japan/South Korea) and Europe (Germany/Netherlands) • Planned engagement with industry players operating in blue hydrogen and ports that promote hydrogen trade routes

103 https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Qatar%20First/Qatar%20NDC.pdf
104 IEA (2021): Electricity Information Statistics. https://doi.org/10.1787/elect-data-en
105 IRENA (2020): Renewable Energy Statistics
106 Calculated as CO_2 emissions from electricity and heat production divided by gross electricity generation.
107 IEA (2020): IEA CO_2 Emissions from Fuel Combustion Statistics. https://doi.org/10.1787/co2-data-en
108 https://oec.world/en/profile/country/kwt
109 https://oec.world/en/profile/country/kwt
110 https://www.tresor.economie.gouv.fr/Articles/04a6e749-3ebf-4024-b663-e8f0e6c5be60/files/1eefadd0-39bc-41e0-946b-500c4b04cf4a

Existing projects[111] (incl. Blue hydrogen)	None mentioned in IAE database
Planned projects [up to 2030] [112] (incl. Blue hydrogen)	None mentioned in IAE database
support schemes or funding facilities for clean hydrogen	• None yet
Potential branches for domestic hydrogen demand	The White Paper states the following demands: • Co-firing with CH_4 • H_2 gas turbines • Seasonal energy storage • District cooling • Fuel Cell Electric Vehicles
Hydrogen Exports in strategy [TWh per year]	None to date
Main hydrogen production technology in focus	According to the white paper, • low-cost blue hydrogen is seen as a large opportunity • green hydrogen based on solar and wind is possible and large-scale demonstration projects are envisaged • blue hydrogen from converted crude oil and petroleum products is mentioned needs further investment
Primary focus of export substance	• Both green and blue hydrogen are expected to be produced. Kuwait has a great natural potential for blue hydrogen, since it exploits oil and gas. Renewable potentials (Wind and PV) are also given.[113]
Production potential for blue hydrogen	• There are no CCS projects in database[114] • However, the White Paper on hydrogen emphasis the need for research on CCUS. It is to be defined how CCU can provide for blue hydrogen. • Kuwait defines hydrogen that is produced based on natural gas with CCS for enhanced oil recovery and CCU (CO_2 used to produce for example Methanol) as blue hydrogen. • Fugitive methane emissions in the blue hydrogen chain will be relevant and independent data is necessary
Transportation to Europe in hydrogen strategy	None to date yet • Since a partnership with Germany and the Netherlands is planned a transportation strategy can be expected in the future. • In the short-term shipping could be a sufficient export option to Europe.
Key actors	• Kuwait Foundation for the Advancement of Sciences (KFAS) • Kuwait Institute for Scientific Research (KISR) • Kuwait National Petroleum Company (KNPC) • Kuwait Integrated Petroleum Industries Company (KIPIC) White paper states to further explore public-private-partnerships and engage with local private companies.

111 IEA Hydrogen Project Database
112 IEA Hydrogen Project Database
113 see **Fehler! Verweisquelle konnte nicht gefunden werden.**
114 https://co2re.co/FacilityData

Sustainability issues and potential conflicts [115]		
Water conflicts	• None documented in EJ Atlas	
Water stress	• Most of Kuwait is considered arid with low water use. In those arid areas lay high potential for renewables (especially wind). • High water stress can be identified in densely populated areas.	
Land conflicts	• None documented in EJ Atlas • Protected area on the boarder to Iraq hold great potential for renewable energy production from wind.[116]	
Socio-economic	• None documented in EJ Atlas	
Existing and future energy system & decarbonisation strategy	2018	2030
Total gross electricity production (net imports)[117] [TWh]	74 (0.0)	Energy demand will triple[118]
RES share in gross electricity generation[119] [%]	0	15%[120]
CO_2 intensity of gross electricity generation [gCO_2/kWh, 2017][121]	595	Not available
Largest fossil fuel-based electricity generation (share in total generation)]	Natural gas (59%)	Not available
CO_2 emissions from electricity and heat production (from other energy industry own use, manufacturing industries and construction) [$MtCO_2$, 2017][122]	43 (32)	Not available
Goals decarbonisation for 2030 (NDC discussion) and net zero targets	7.4% reduction below the BAU scenario in 2035 No net zero target announced	

2.7 Bahrain

Trade	
Main export partners [% of trade volume $][123]	• United Arab Emirates (30,5%) • Saudi Arabia (12,3%) • Japan (7,6%)
Main export goods [% of trade volume $][124]	• Refined Petroleum (41,6%) • Raw Aluminium (14%) • Crude Petroleum (5,1%)

[115] Main source is the Environmental Justice Atlas: https://ejatlas.org/
[116] See https://www.protectedplanet.net/region/AF and **Fehler! Verweisquelle konnte nicht gefunden werden.**
[117] IEA (2021): Electricity Information Statistics. https://doi.org/10.1787/elect-data-en
[118] https://www.iea.org/policies/6106-kuwait-renewable-energy-target
[119] IRENA (2020): Renewable Energy Statistics
[120] https://www.iea.org/policies/6106-kuwait-renewable-energy-target
[121] Calculated as CO_2 emissions from electricity and heat production divided by gross electricity generation.
[122] IEA (2020): IEA CO_2 Emissions from Fuel Combustion Statistics. https://doi.org/10.1787/co2-data-en
[123] https://oec.world/en/profile/country/bhr
[124] https://oec.world/en/profile/country/bhr

Hydrogen strategy and economy	
Existing hydrogen strategy	No specific hydrogen strategy in place • MoU signed between Air Products and NOGA holding (investment and business development arm of National Oil and Gas Authority (NOGA)) in Nov. 2020 with the aim to use hydrogen to decarbonise the transport sector[125]
Existing bilateral hydrogen agreements	• Bahrain and India signed a MoU in Jul. 2018 for cooperation in renewable energy[126] including hydrogen[127]
Existing projects[128] (incl. Blue hydrogen)	**Green hydrogen** • 0,005 MW | started 2009 | BAPCO: R&D
Planned projects [up to 2030] [129] (incl. Blue hydrogen)	**Green hydrogen** • ? MW | starting date not documented | US Air Products
support schemes or funding facilities for clean hydrogen	None to date
Potential branches for domestic hydrogen demand	• Transportation[130] • Refineries and chemical industry
Exporting potential in strategy [TWh per year]	Bahrain is likely to be an off-taker of hydrogen rather than exporting hydrogen
Main Hydrogen production technology in focus	• Bahrain is a very small country with hardly any potential to produce bulk green hydrogen based on wind or solar PV power. • The publications available reference to "sustainable" or "clean" hydrogen.[131]
Primary focus of export substance	No export ambitions defined
Production potential for blue hydrogen	• Bahrain has proven reserves equivalent to 5.8 times its annual consumption. This means it has about 6 years of gas left (at current consumption levels and excluding unproven reserves).[132] • However, blue hydrogen from crude oil could be an option
Transportation to Europe in hydrogen strategy	No export ambitions defined
Key actors	• BAPCO (Bahrain Petroleum Company) • Ministry of Energy (NOGA)
Sustainability issues and potential conflicts [133]	
Water conflicts	• Land reclamation projects pollute surface water and decrease water quality
Water stress level	• Bahrain shows extremely high water-stress on the whole country level.

[125] https://www.gasworld.com/air-products-and-nogaholding-focus-on-hydrogen-in-bahrain/2020168.article
[126] https://www.albawaba.com/business/india-signs-strategic-bahrain-saudi-renewable-energy-co-operation-agreement-1409646
[127] https://www.idsa.in/issuebrief/india-national-hydrogen-mission-n-gcc-lpriya-270821
[128] IEA Hydrogen Project Database
[129] IEA Hydrogen Project Database
[130] https://www.gasworld.com/air-products-and-nogaholding-focus-on-hydrogen-in-bahrain/2020168.article
[131] https://www.albawaba.com/business/india-signs-strategic-bahrain-saudi-renewable-energy-co-operation-agreement-1409646
[132] https://www.worldometers.info/gas/bahrain-natural-gas/
[133] Main source is the Environmental Justice Atlas: https://ejatlas.org/

Land conflicts	• Land reclamation projects pressures local fishery and livelihoods of fishing communities and coastal area • Potentials for renewable energy of solar energy are the highest in densely populated areas of Riffa and the Central region[134]	
Socio-economic	None documented in the EJ Atlas	
Existing and future energy system & decarbonisation strategy	2018	2030[135][136]
Total gross electricity production (net imports) [TWh]	30 (0.2)	Not available
RES share in electricity generation[137] [%]	0	10% of peak capacity 2035
CO_2 intensity of electricity generation [gCO_2/kWh, 2017]	698	Not available
Largest fossil fuel-based electricity generation (share in total generation)]	Natural gas (100%)	Not available
CO_2 emissions from electricity and heat production (from other energy industry own use, manufacturing industries and construction) [$MtCO_2$, 2017]	20 (5)	Not available
Goals decarbonisation for 2030 or 2050 (NDC discussion) and net zero targets	"the Kingdom of Bahrain strives to avoid and reduce emissions in its economic development" Net zero target for 2060	

[134] See **Fehler! Verweisquelle konnte nicht gefunden werden.** and **Fehler! Verweisquelle konnte nicht gefunden werden.**

[135] https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Bahrain%20First/NDC%20of%20the%20Kingdom%20of%20Bahrain%20under%20UNFCCC.pdf

[136] https://www.ief.org/news/international-energy-forum-commends-bahrain-for-net-zero-2060-pledge

[137] IRENA (2020): Renewable Energy Statistics

3 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)

4 Literature

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