Imagination Is everything.
It is the preview of life's coming attractions
Albert Einstein

Dii Desert Energy

An overview of recent developments in Mena
H4D Partnership
25th September 2023

Desertec idea: Solar and wind from the deserts (and oceans)

Just a few % of the vast MENA Deserts alone would in theory (!) be more than sufficient to power the world's 160.000 TWH Energy Consumption!

A failed idea? (common opinion in Germany)

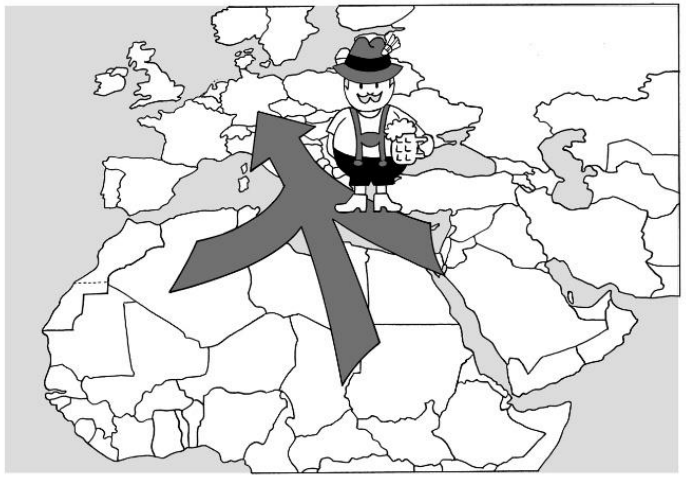
The deserts of Northern Africa and the Middle East (MENA) are still almost fully 'fossil' based, but they a emerging supplier of lowest cost green energy for their 500 mln inhabitants and for the world markets

Dii Desert Energy (Desertec3.0) is an international industry initiative, founded in 2009 in Germany as an international industry **Market Enabler** for 'Green Electrons and Molecules' (e.g. Hydrogen, PtX), connecting people and countries for accelerating the energy transition in MENA.

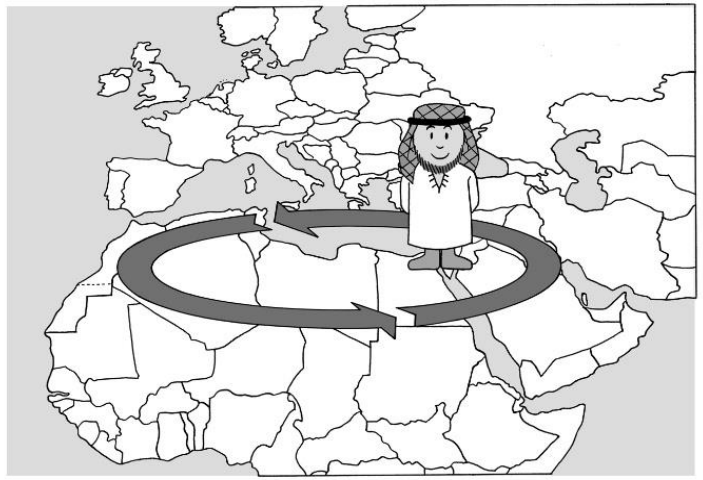
Desertec 1.0, 2.0 and 3.0: the Arab world to become a Powerhouse for itself and a global green exporter

2004	2009	2015	2019
Great Idea! Pre-phase	**It works!** Concept phase	**First Harvest!** Implementation phases	**Acceleration!** Green Electrons and green molecules

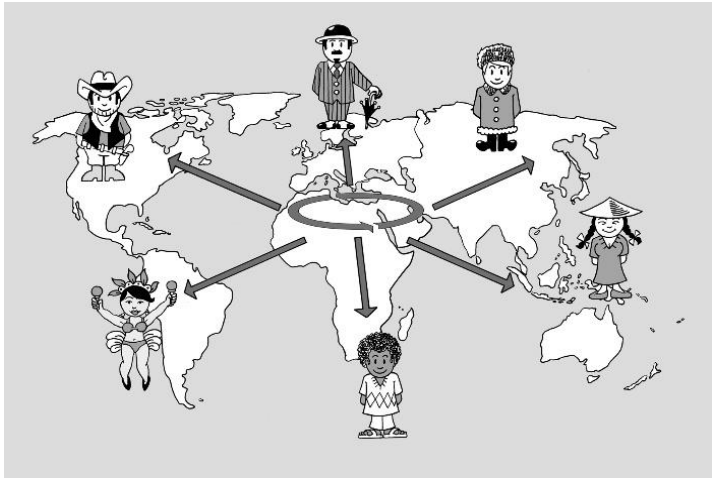
Development phases of Desertec



Desertec 1.0
Export Oriented



Desertec 2.0
Region Oriented



Desertec 3.0
Region and World Oriented

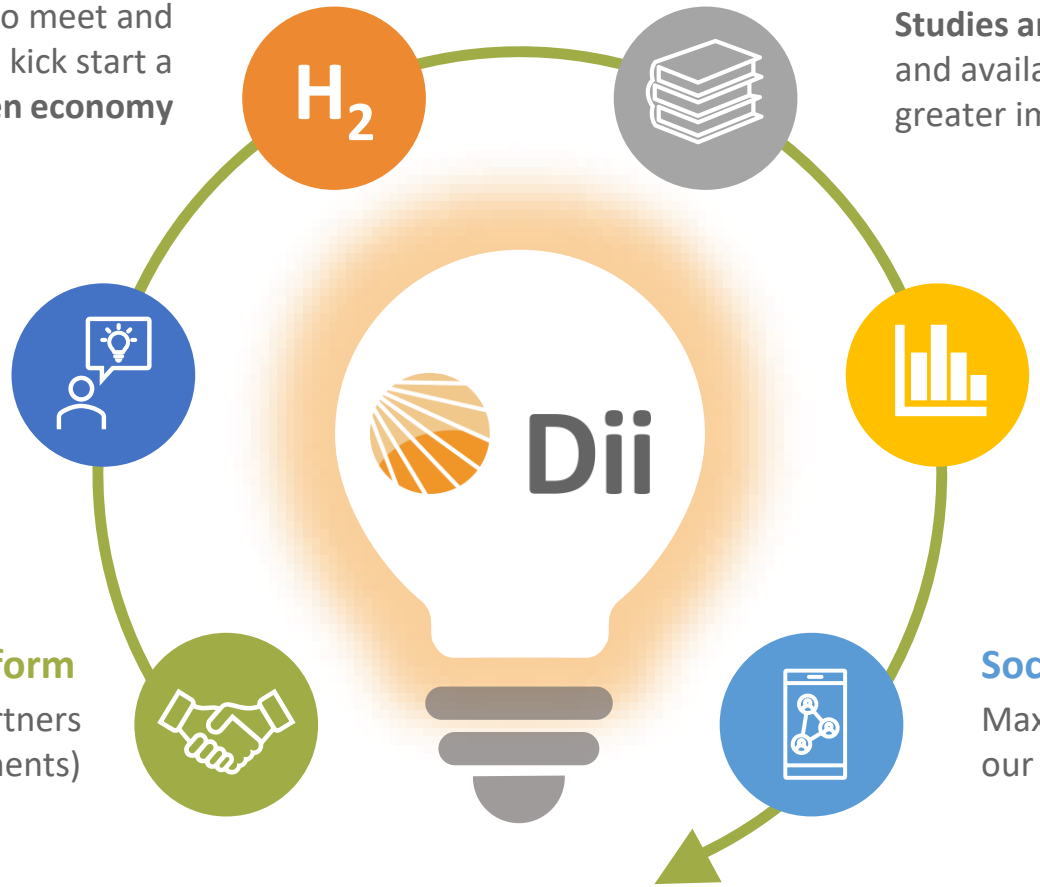
Dii Desert Energy and Desertec 3.0: creating good momentum and positive vibes in the market

MENA Hydrogen Alliance

A platform for members to meet and discuss pathways forward to kick start a **low-carbon hydrogen economy**

Think Tank

Studies and papers well received by the market and available freely to increase knowledge for a greater impact



Knowledge partner

Strong presence in leading industry event to help shape programs by providing **exclusive insights and market updates**

RE Initiative Toolkit

Levelized Cost of Energy (LCoE), Storage (LCoS), Hydrogen (LCoH) and Ammonia (LCoA) financial models integrate the toolkit.

A reinforced and unique platform

Since 2019, **more than tripled** its industrial partners (now almost 100 from 30 countries, 5 continents)

Social Media

Maximize social media platform to amplify our **activities and partners achievements**

To date: Over 100 industry partners from 35 countries

OUR STRATEGIC PARTNERS

ACWA POWER
ENOWA. NEOM
国家电网公司 STATE GRID CORPORATION OF CHINA
thyssenkrupp

OUR LEAD PARTNERS

AIR PRODUCTS QUDRA
AL GIHAZ HOLDING الجهاز القابضة
AMEA POWER
Envision Net Zero Tech Partner
NAREVA
e·on
Reliance New Energy
Worley energy | chemicals | resources

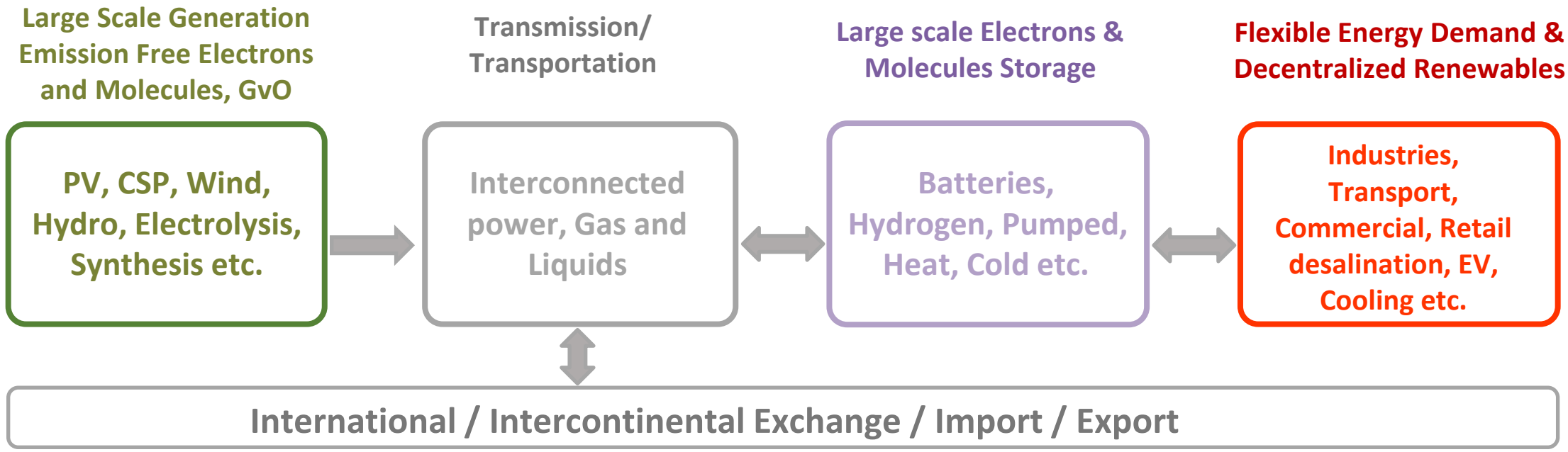
All Partners of Dii Desert Energy are members of the MENA Hydrogen Alliance

OUR ASSOCIATED PARTNERS

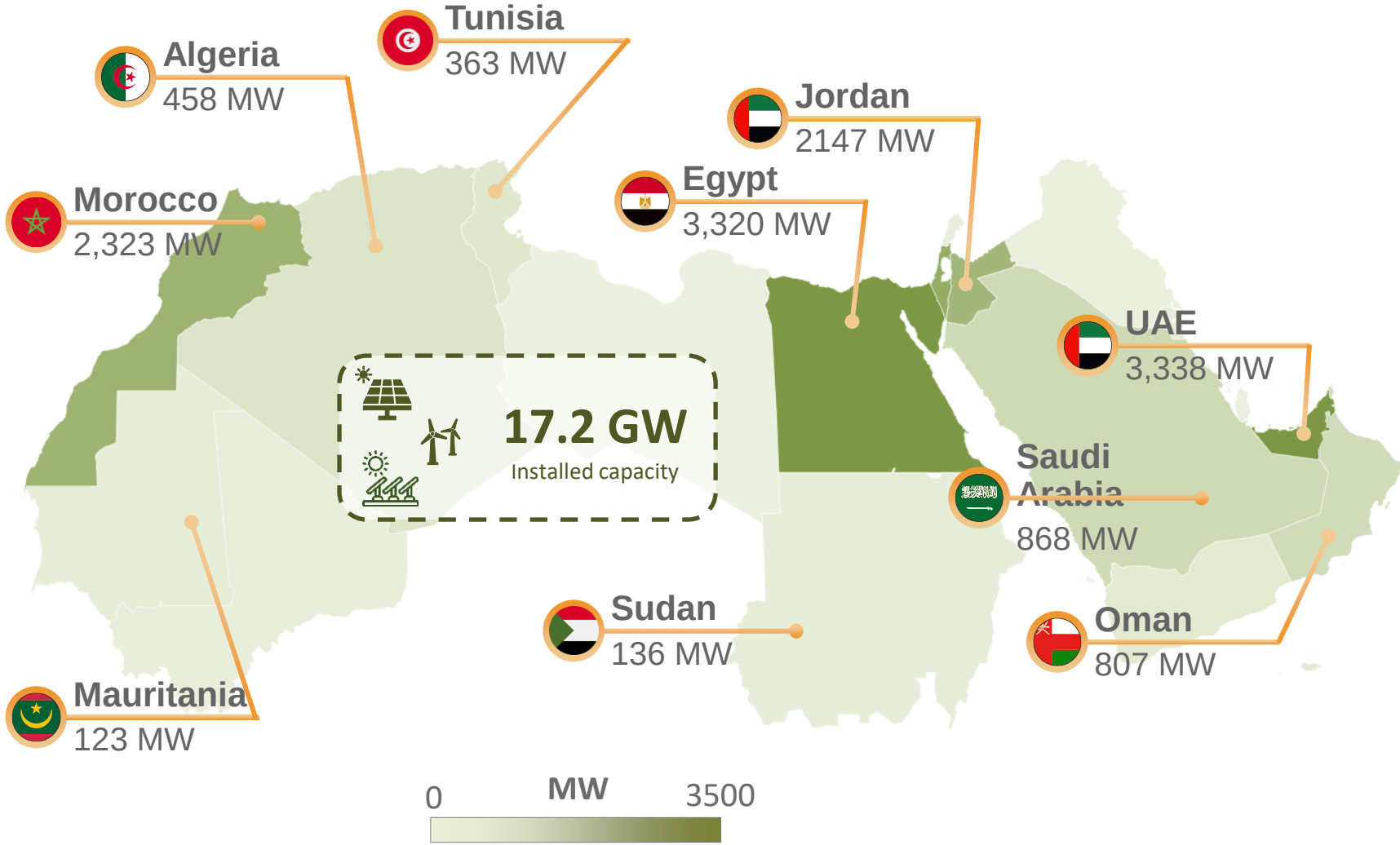
Integration of Green ‘Electrons’ and ‘Molecules’ along the Emission-Free Energy Value Chain

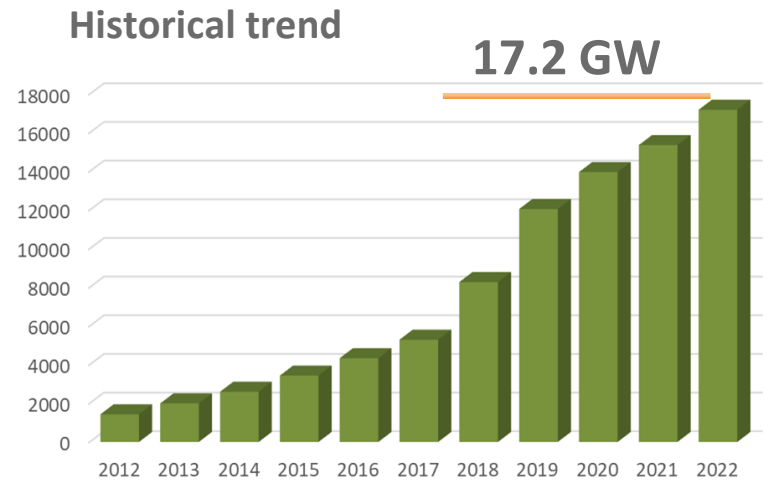
Objectives: Lowest cost, secure, emission free and local benefits

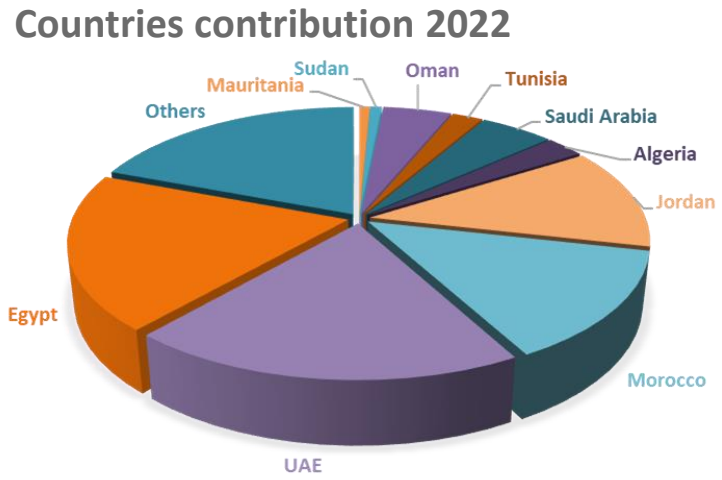
Chain Optimization: Virtual (Guarantees of Origin) and Physical Trading



Egypt is currently leading installed RE capacity in MENA, but other countries move faster!







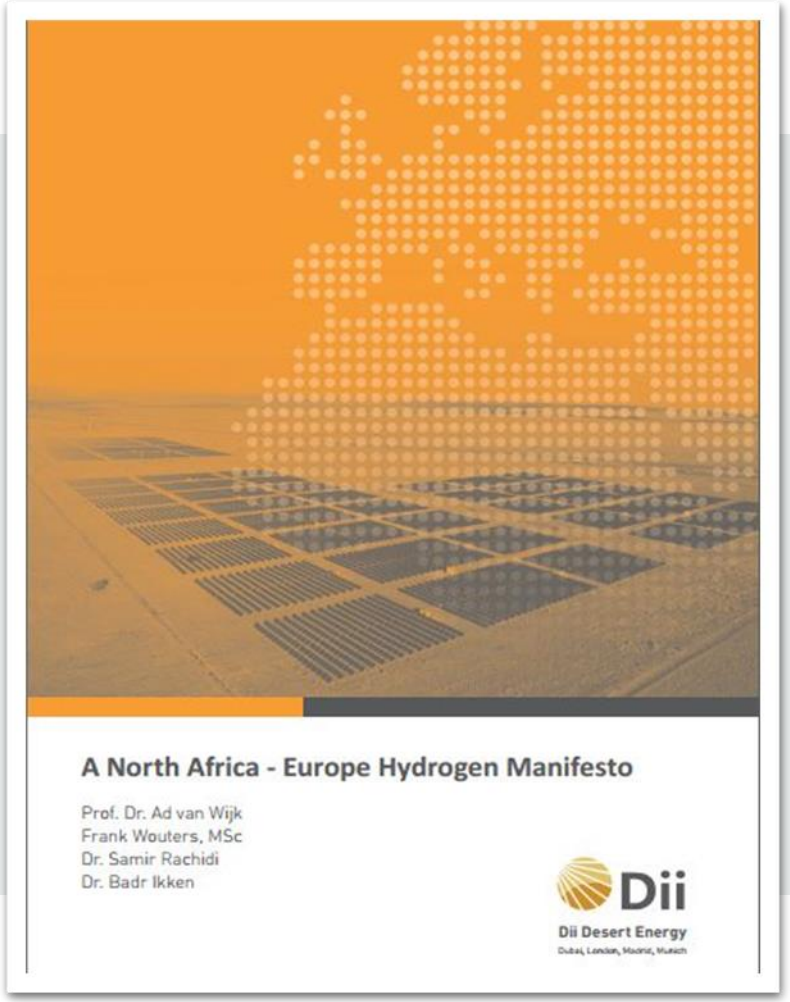
Other countries:
Bahrain, Iraq, Israel, Kuwait, Lybia, Mali, Palestine, Qatar, Syrian AR, Yemen

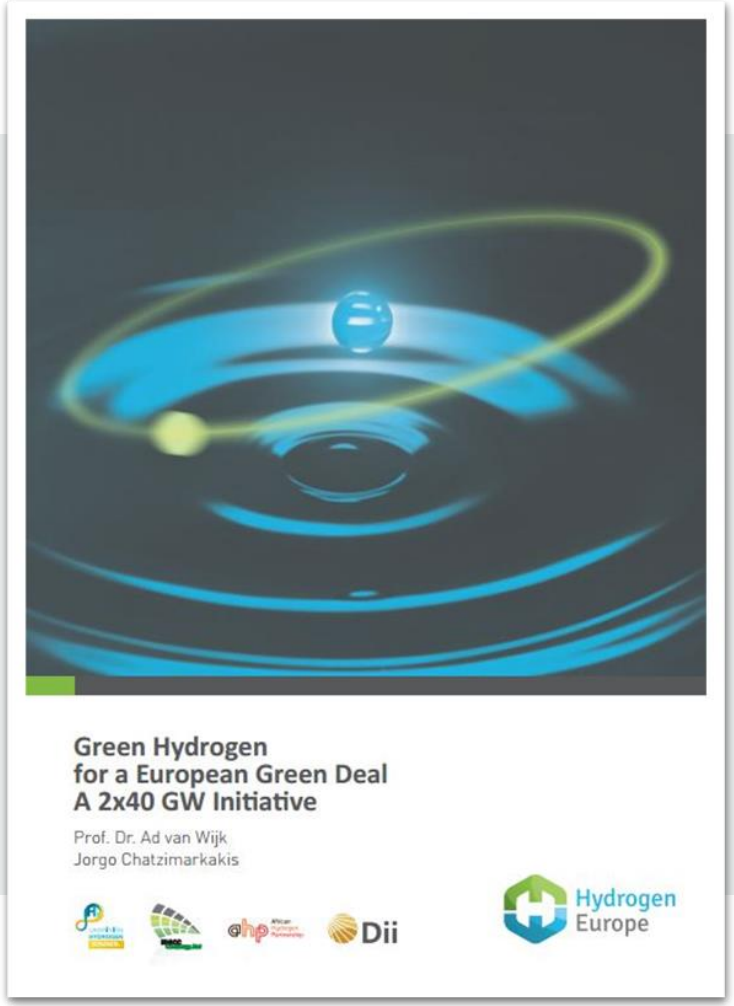
Source: IRENA database 2022, Dii Database

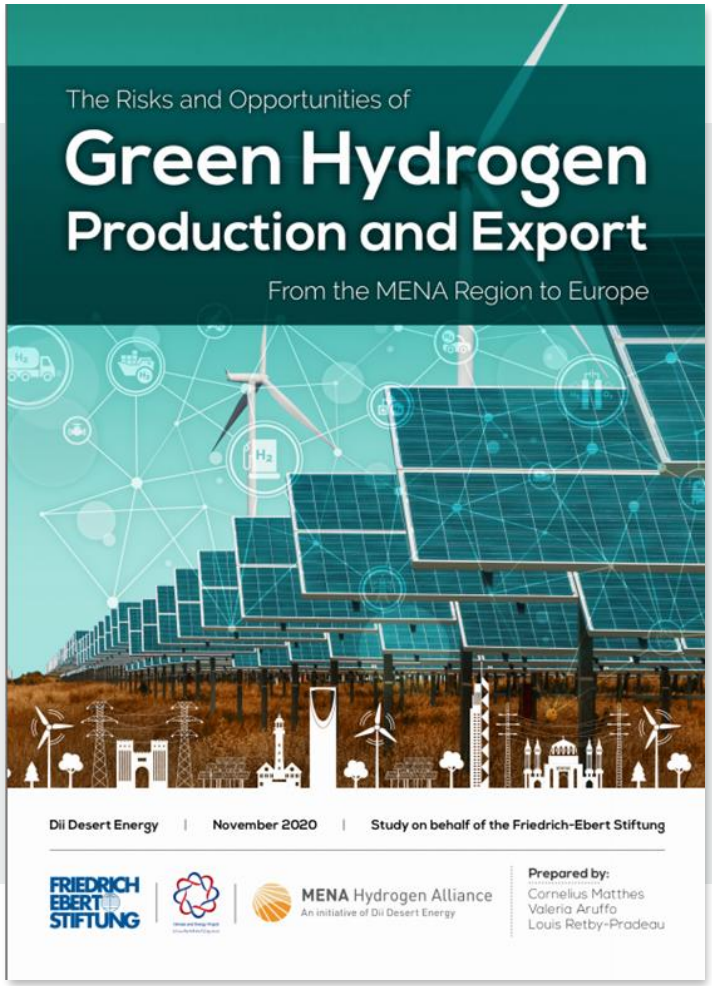
MENA Hydrogen Alliance
Industry Forces bundled by Dii Desert Energy

- The MENA Hydrogen Alliance focuses on connecting MENA to Europe by fostering a regional partnership between Europe, North Africa and the Middle East to kick-start green hydrogen economies, to accelerate the deployment of green hydrogen projects and local value chains.
- First two physical meetings at WFES, January 2020 hosted by Masdar and March 2020 at InterSolar
- Presentation of 2x40 GW initiative to EVP Timmermanns
- Numerous bilateral talks with Minister of Energy in Morocco, Masen, Nareva, IRESEN, AMEE, CEO of Sonelgaz, STEG Tunisia, League of Arab States

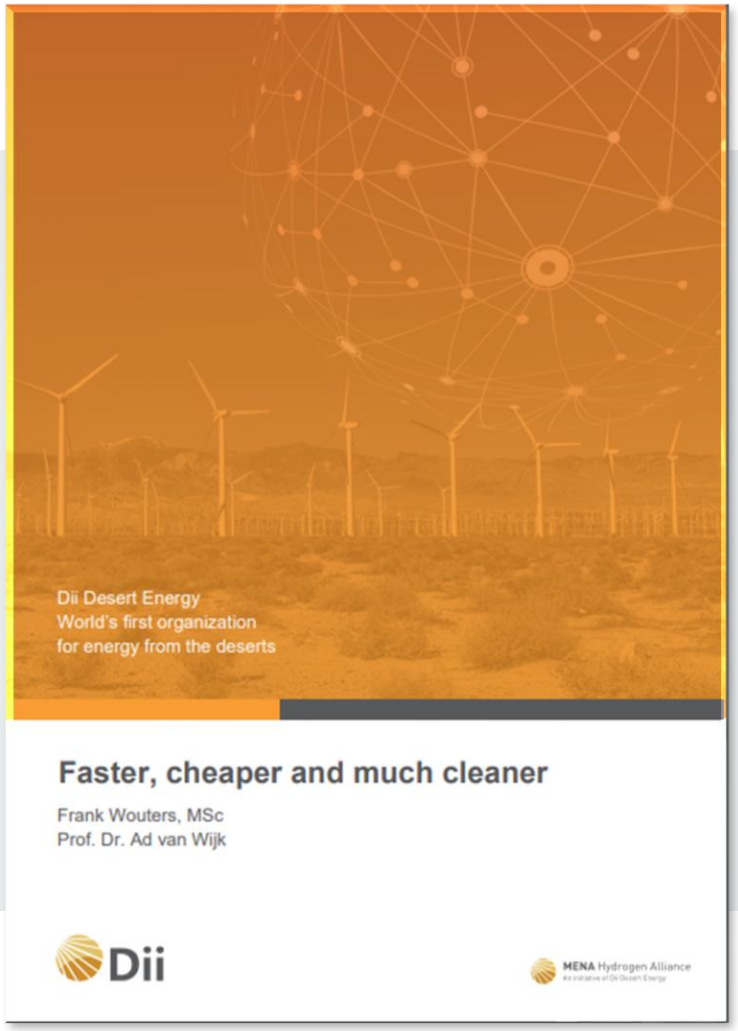
Dii's MENA Hydrogen Alliance: first ideas for connecting MENA with Europe

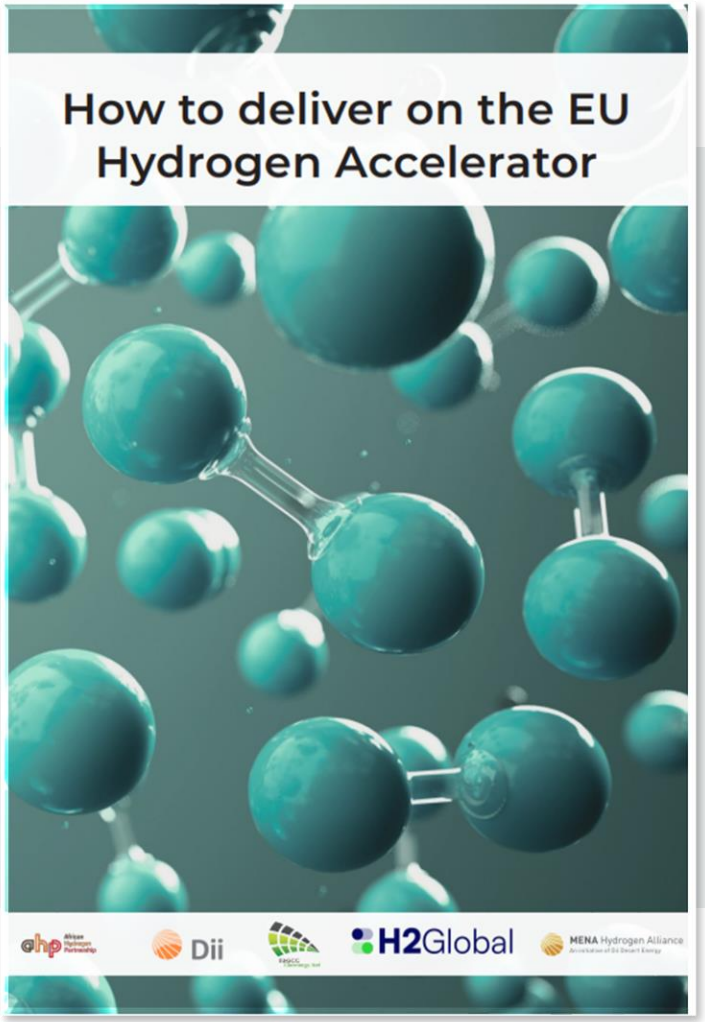






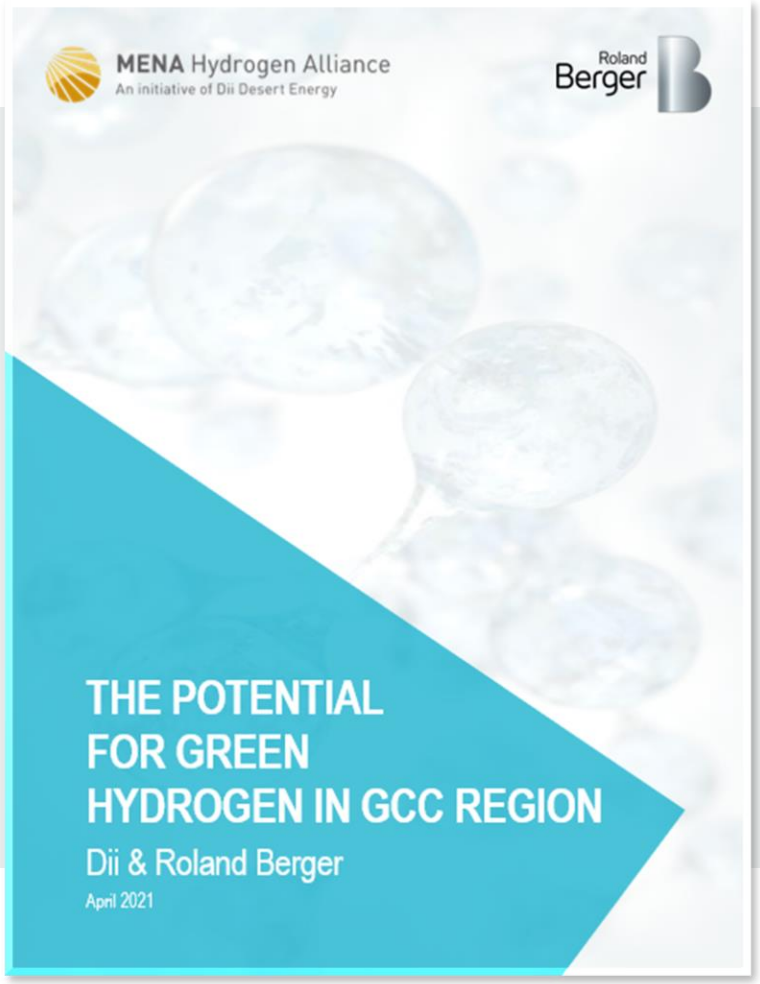
Dii's MENA Hydrogen Alliance: connecting MENA with Europe





Green Hydrogen Study on Jobs!
Dii Desert Energy & Roland Berger!

- Joint study with Roland Berger on **'The Potential of Green Hydrogen in GCC Region'**
- Focus on **localization** of hydrogen value chain **and job creation**
- Launched in April at the **World MENA Hydrogen** (virtual) Congress



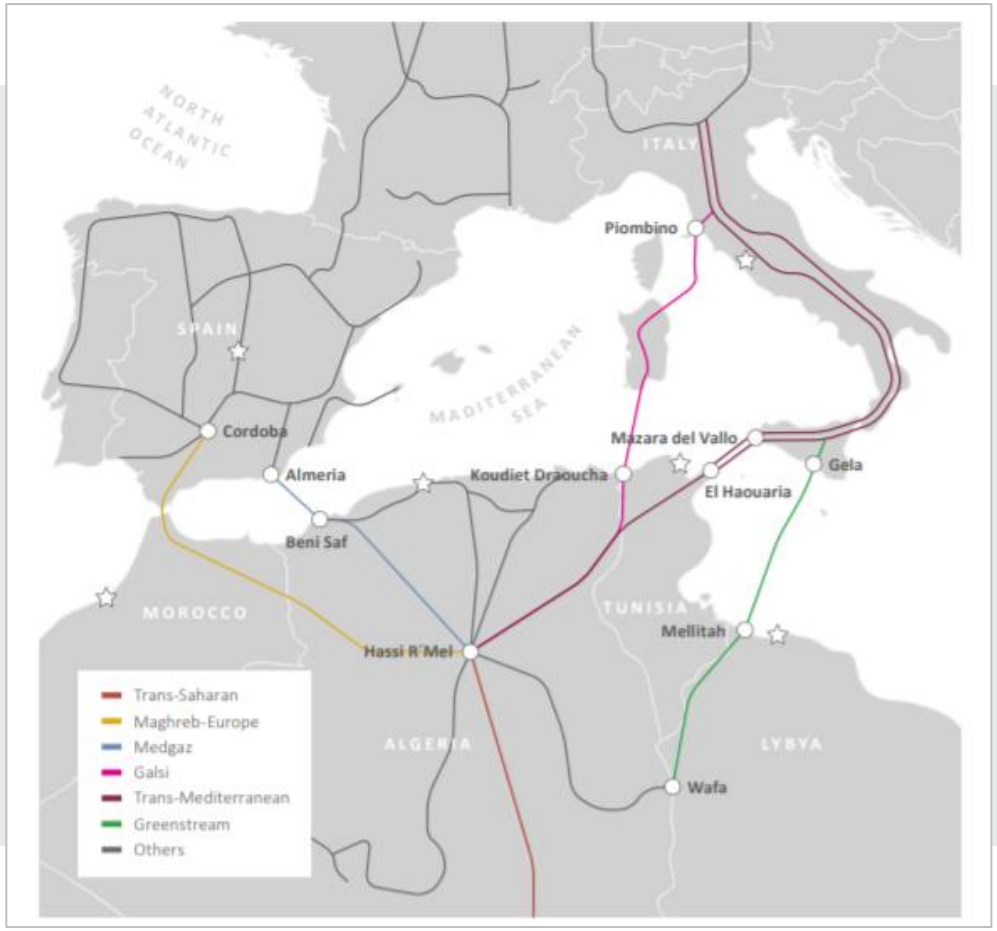
Launch of *Net Zero Emission Traders Alliance* (ZETA)

ZETA
An initiative of Dii Desert Energy

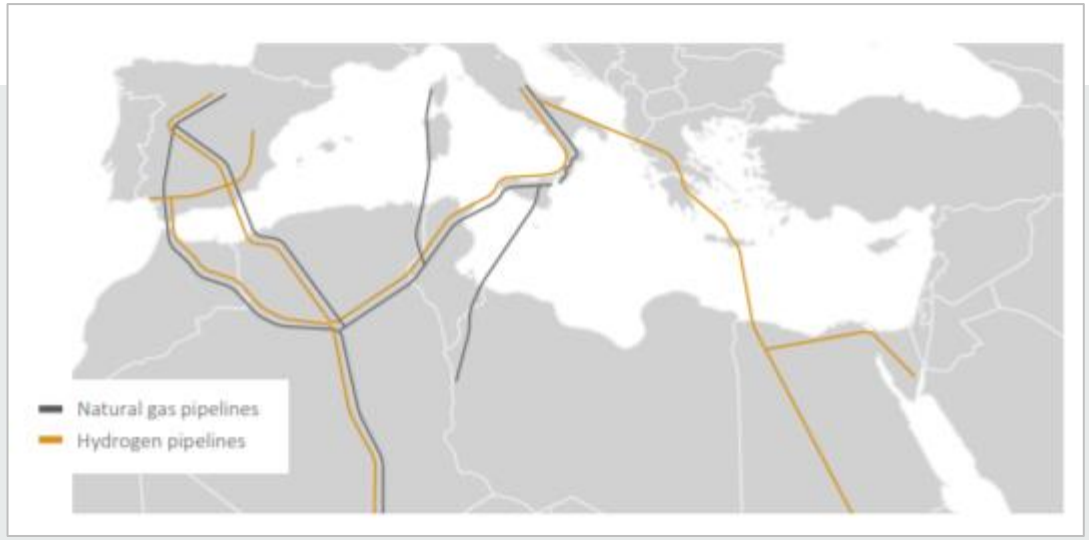
- Anticipating the emerging importance of international trade of net emission free energy carriers bilateral trade concepts (e.g. connecting production in MENA with Off-takers in Europe) have been initiated in early 2022.
- On March 29th Paul van Son (Dii) and Jan Haizmann (formerly EFET) have founded the foundation ZETA (Zero Emission Traders Alliance) in Amsterdam with support by Dii.
- ZETA will closely cooperate with Dii and draw Dii partners and other qualified companies with an energy trading interest together to discuss, propose and advocate concepts, certification, standards and mechanisms for bilateral and multilateral zero / low emission energy trade
- First focus will be on green H2 and Ammonia in MENA.

The MENA Gas infrastructure is ideally positioned for a fast exchange and export of green hydrogen!

Natural gas infrastructure Europe - North Africa



First outline for a hydrogen backbone infrastructure Europe-North Africa



- An existing gas infrastructure from Algeria and Morocco could be **converted** to a hydrogen infrastructure (grey-orange lines). A ''new'' hydrogen transport pipeline must be realized **from Italy to Greece**, crossing the Mediterranean Sea to Egypt, which could eventually be **extended to the Middle East** (orange line).

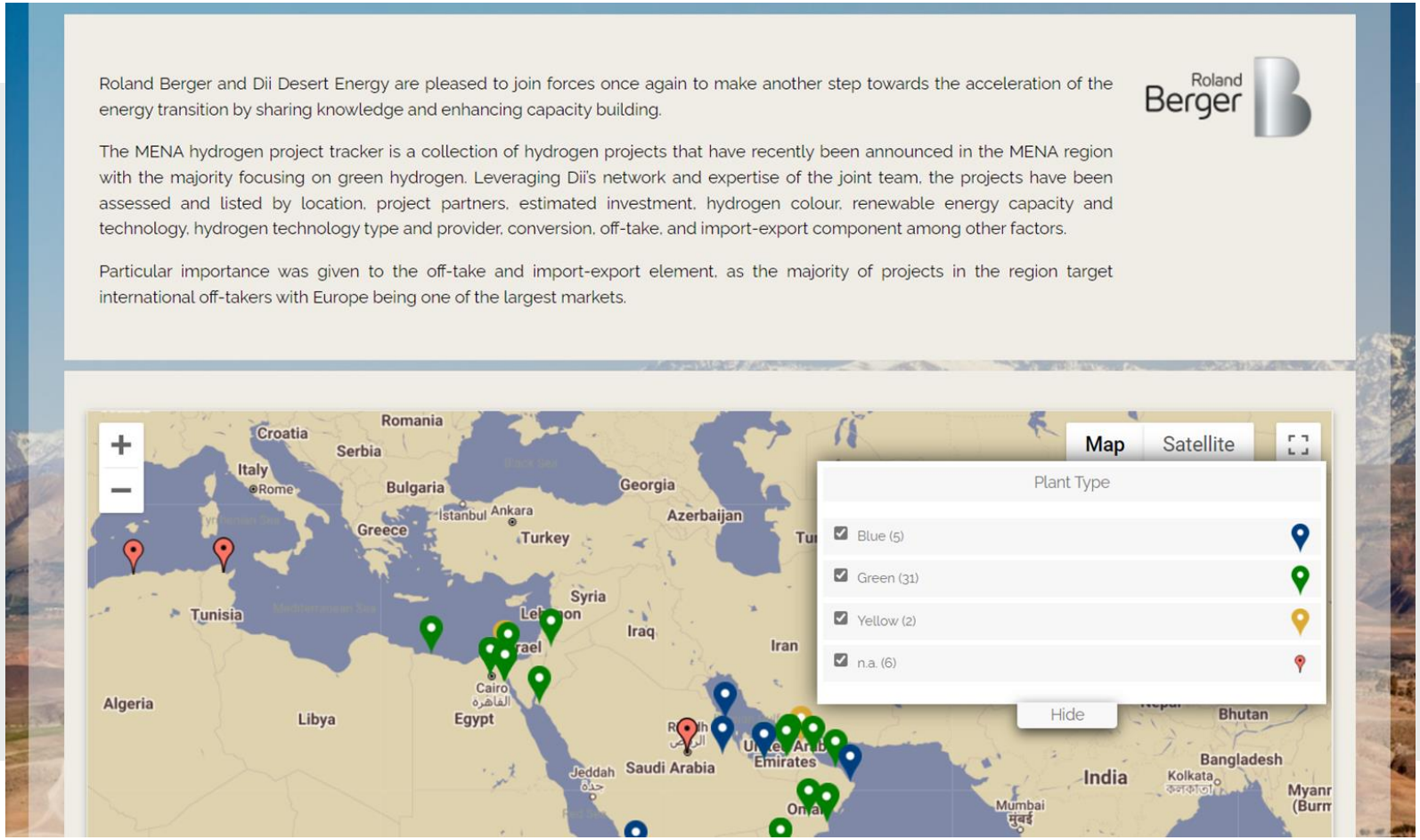
Source: The North Africa-Europe Hydrogen Manifesto, Prof. Dr. Wijk A. v. , Frank Wouters F., Ikken, B., Samir, R.

An Eastern Mediterranean hydrogen pipeline could be easily filled by up to 100 GW zero emission energy from three or more countries

- NEOM will be powered by **100% low-cost renewable energy** (40 – 60 GW)
- One of three strategic projects of **Saudi Agenda 2030**
- Given the availability of competitive and low-cost renewable energy, NEOM will produce **green hydrogen at scale** for local and world markets
- **Largest green hydrogen project globally** currently under construction (1.5 GW wind, 2.5 GW solar PV), 2,200 MW electrolyzer capacity
- 24 hydrogen projects already announced in Egypt
- Jordan has become a leader in solar and wind
- Excellent available infrastructure in the region, including local offtakers

Hydrogen Tracker in cooperation with Roland Berger

- Produced in cooperation with **Roland Berger**
- A collection of hydrogen projects recently announced in the MENA region with the majority focusing on **green hydrogen**
- Includes – among others - project **partners**, estimated **investment**, renewable energy **capacity** and **technology**, off-take, and import-export component



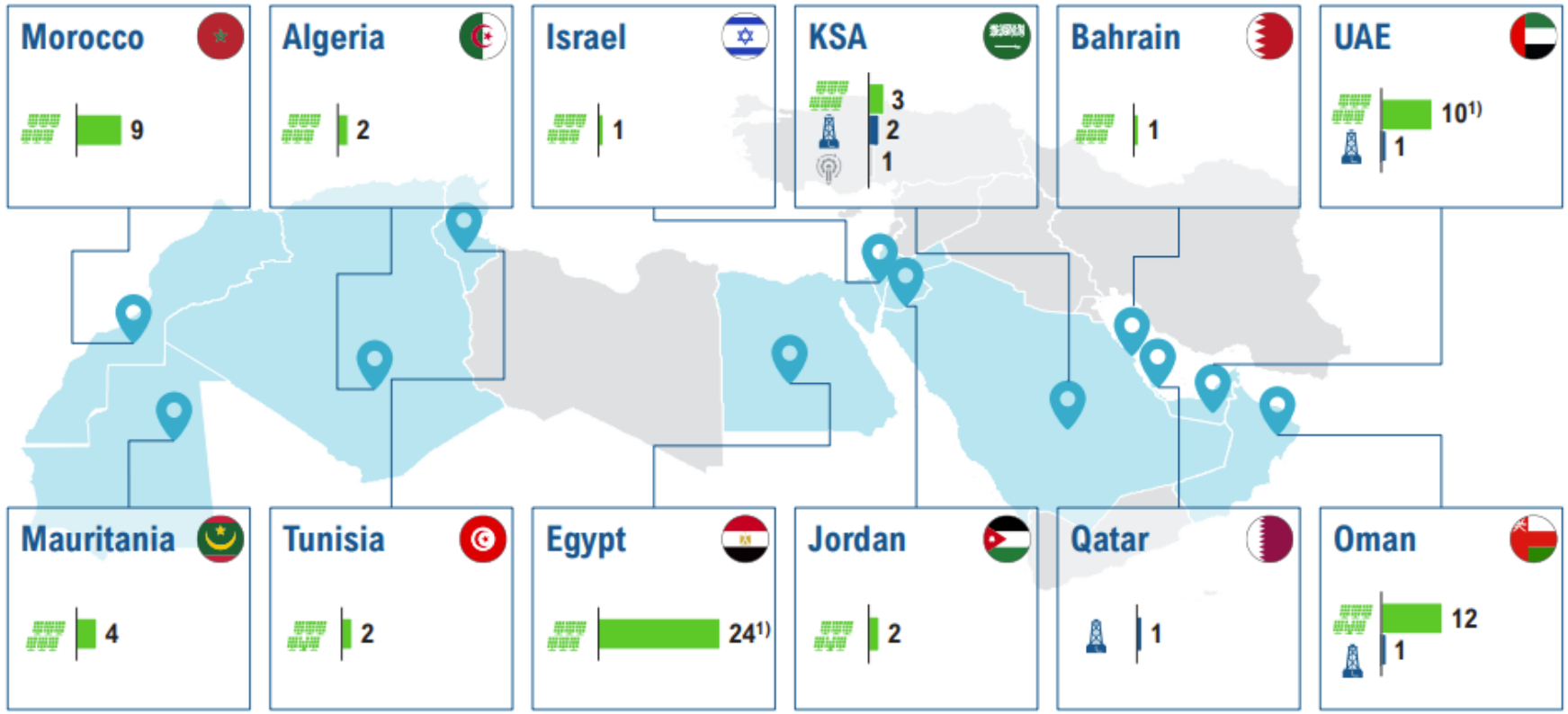
Various hydrogen projects have recently been announced in the MENA region – with the majority focusing on green hydrogen

Non-exhaustive

v13: 02-Sep-2023

Hydrogen project announcements in MENA

Total of 76 projects across the **MENA** region – with **>85%** projects geared towards production of **green hydrogen**



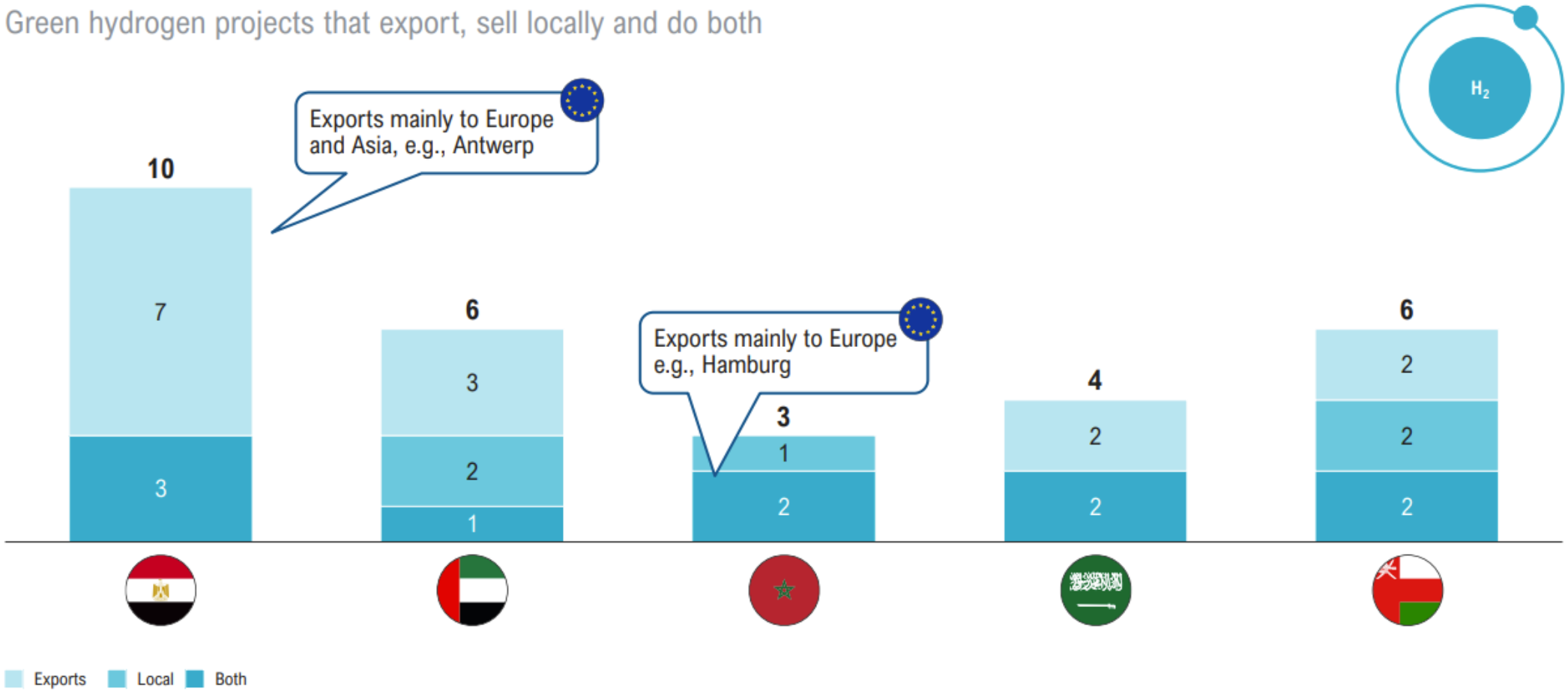
1) Includes some yellow H_2 projects

Source: Desk research, Dii, Roland Berger

Majority of projects in the region target international off-takers with Europe being one of the largest markets

Non-exhaustive

v13: 02-Sep-2023



Source: Desk research, Dii, Roland Berger

Largest green hydrogen projects to be built in Oman, Mauritania and Egypt

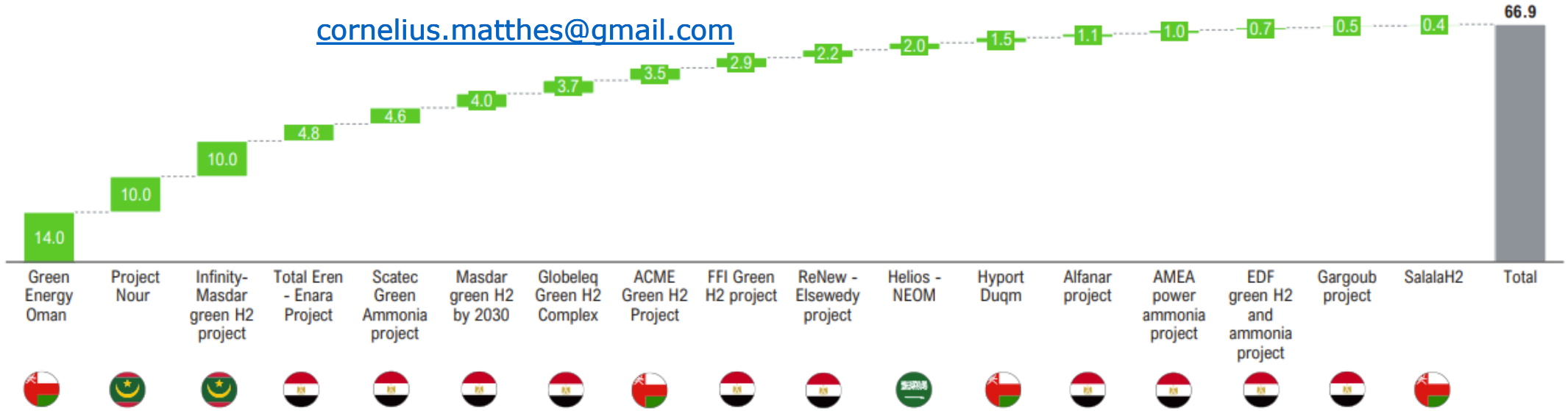
Non-exhaustive

v13: 02-Sep-2023

Largest known green H_2 projects by electrolyzer capacity [GW]

17 projects are powered by a combined **~67 GW of electrolyzer capacity**

cornelius.matthes@gmail.com



Source: Desk research, Dii, Roland Berger

NEOM GREEN HYDROGEN COMPANY

شركة نيوم للهيدروجين الأخضر

Building the world's largest green hydrogen plant

3 equal joint venture partners with more than 80 years experience across ACWA Power, Air Products and NEOM

A total investment value of $8.4 billion with $6.1 billion non-recourse financing from 23 local, regional and international banks

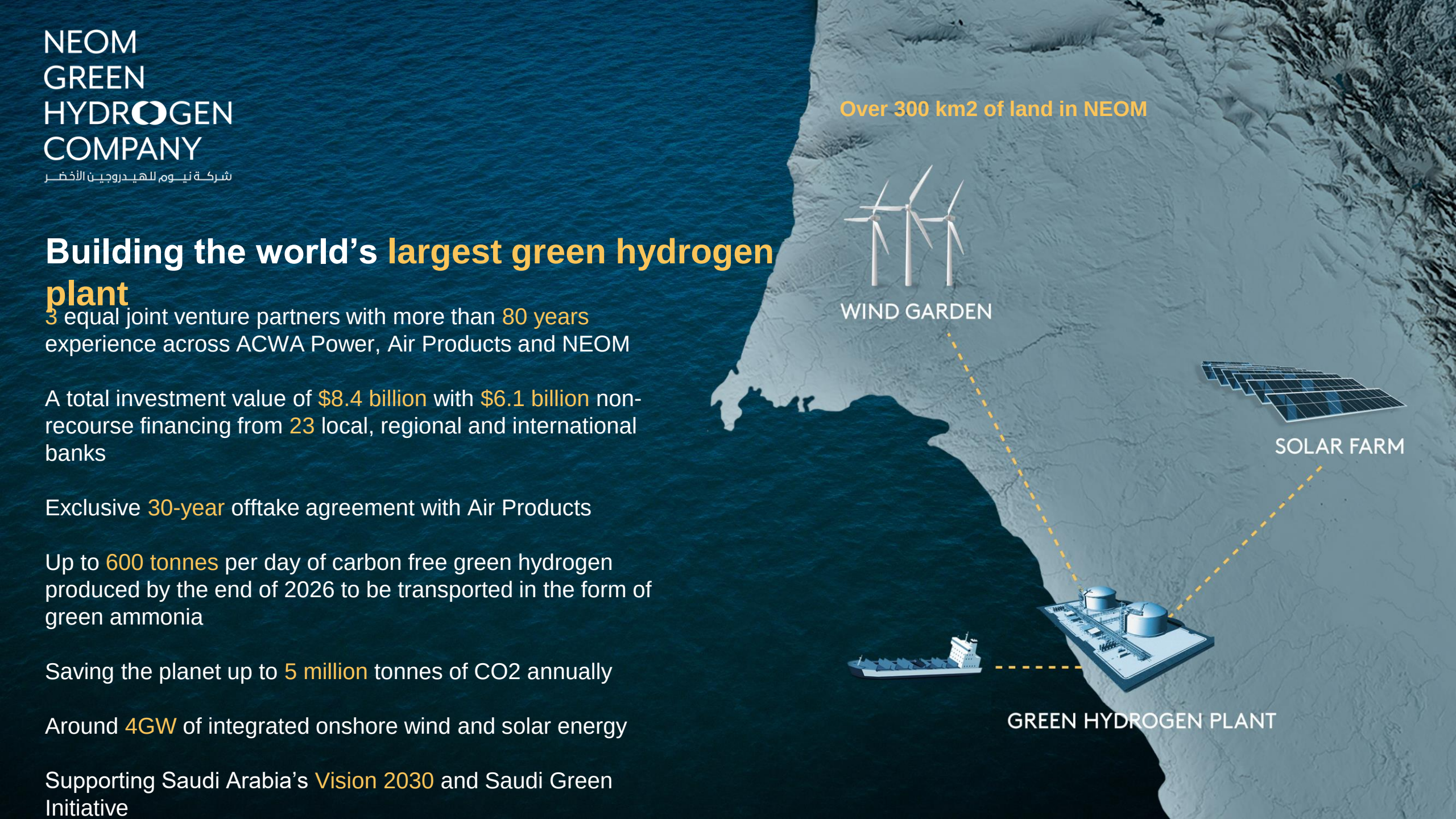
Exclusive 30-year offtake agreement with Air Products

Up to 600 tonnes per day of carbon free green hydrogen produced by the end of 2026 to be transported in the form of green ammonia

Saving the planet up to 5 million tonnes of CO_2 annually

Around 4GW of integrated onshore wind and solar energy

Supporting Saudi Arabia's Vision 2030 and Saudi Green Initiative



NGHC

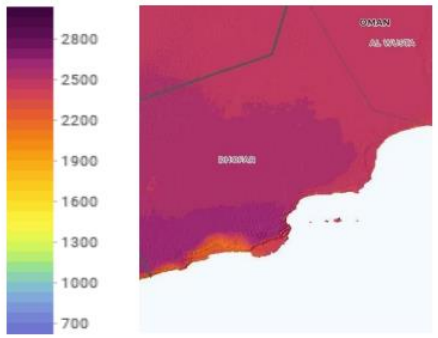
NEOM GREEN HYDROGEN PLANT

Hydrogen potential for Omani Ports

Oman is one of the top countries for renewable resources

Solar PV potential[1]

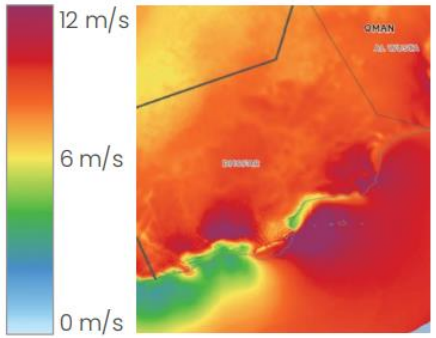
kWh/m²



>2400 kWh/m²

Wind speed

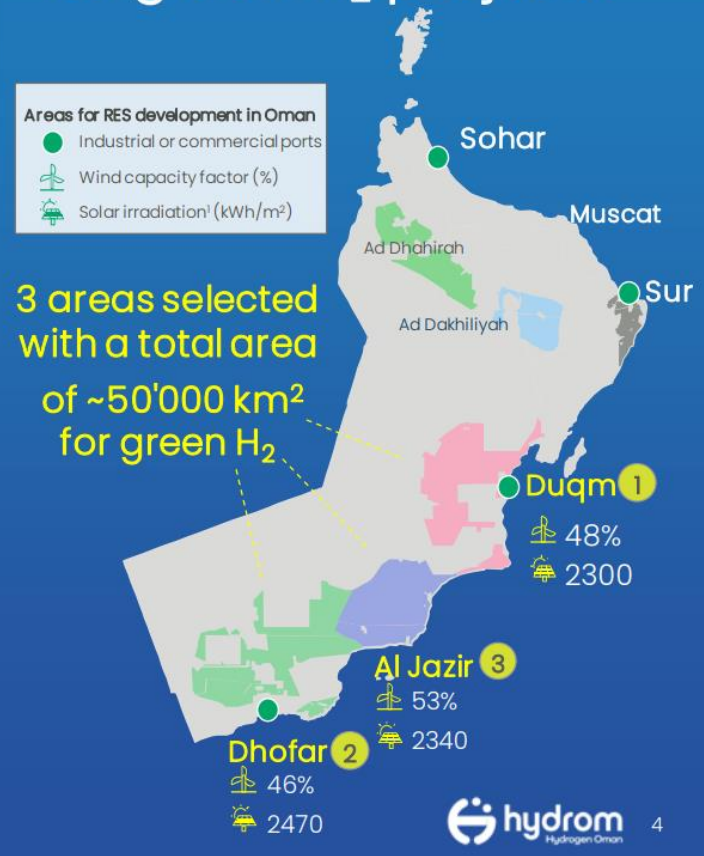
m/s



Up to 11 m/s

1. Global Horizontal Irradiation (GHI)
Source: Global solar atlas, Global wind atlas (July '22)

50,000 km² allocated for green H_2 projects



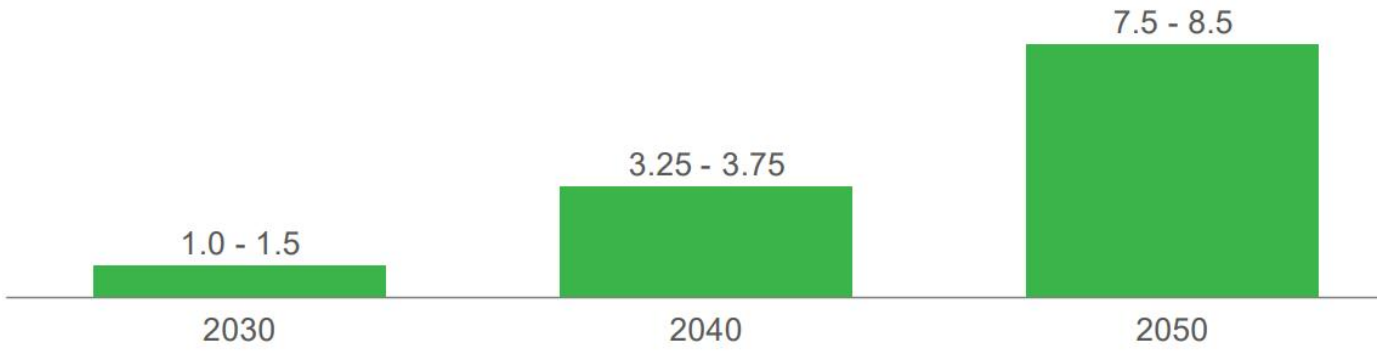
Hydrogen potential for Omani Ports

Oman has ambitious production targets until 2050, with already >1 Mtpa by 2030

Green H_2 production ambition for Oman in 2030-2050 (Mtpa)

Includes exports mainly to Europe and Asia, and local Omani demand

Oman expected to become among top 10 H_2 exporters by 2030 according to IEA



	2030	2040	2050
Electrolyzer capacity[1] (GW)	8-15	35-40	95-100
Renewables capacity[1,2] (GW)	16-30	65-75	175-185

1. Approximate values for Duqm, Oman 2. Includes 25% buffer over Renewables needed for electrolyzers to account for Balance of plant load (which includes NH3 synthesis loop, Storage tanks for H2/NH3, another auxiliary facilities load). Assumption: Sustainable Development Scenario (2°C). Source: Team analysis; IEA

Hydrogen potential for Omani Ports

5 projects in the Duqm region awarded in June 2023, positioning Oman as one of the world's leading gH_2 hubs

1st Public Auction round: 2 projects awarded
(out of 2 auctioned)

1 Amnah — CIP, AL KHADRA PARTNERS, BLUE POWER PARTNERS — 1st Jun

2 POSCO HOLDINGS, PTTEP, EWP, SAMSUNG ENGINEERING, ENGIE, KOSPO — (21st Jun)

Legacy Initiative process: 3 projects awarded so far
(out of 6 term sheets signed)

1 GEO Green Energy Oman, EnerTech Holding Company, InterContinental Energy, OQ, Shell — 1st Jun

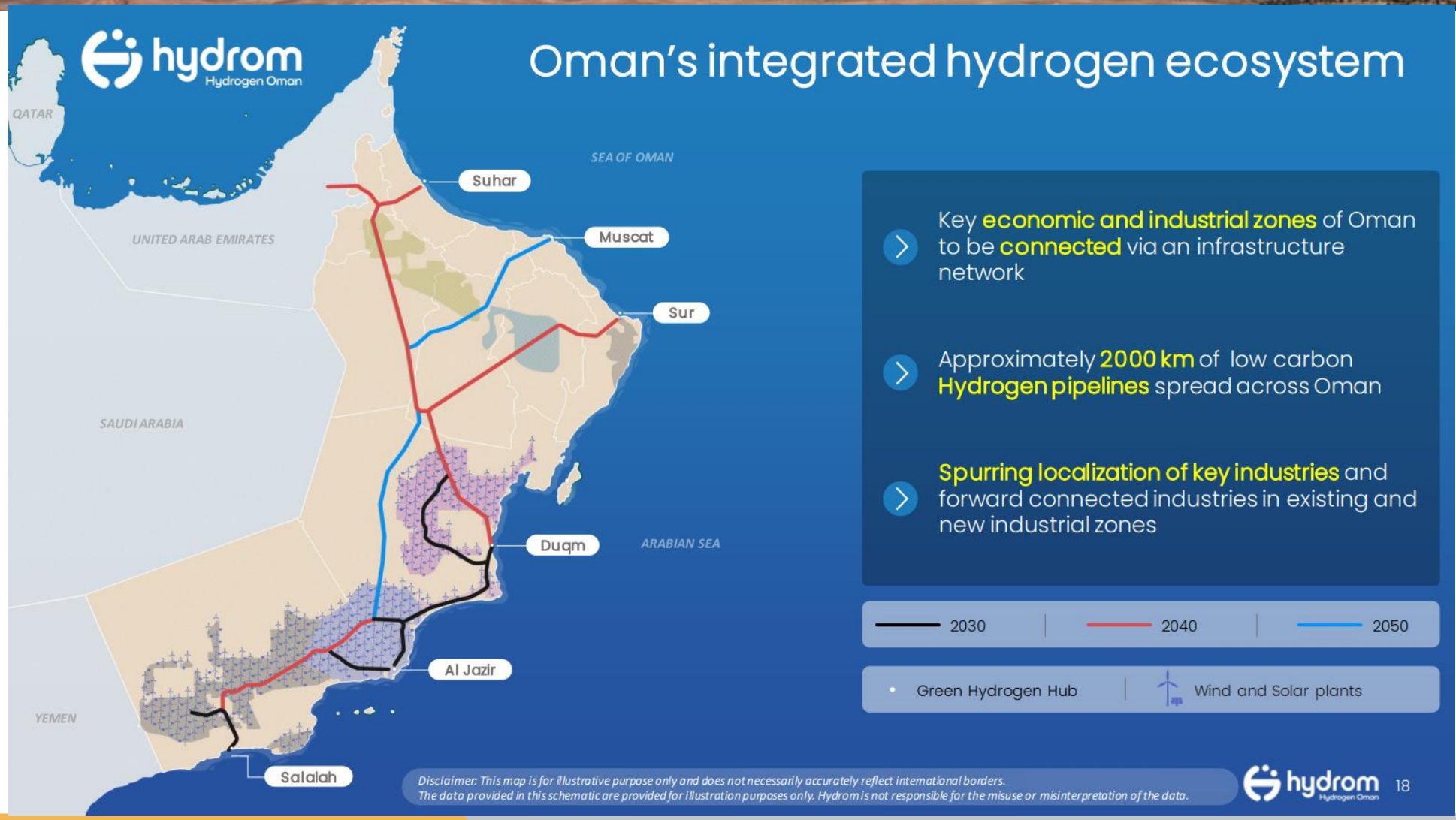
2 bp — 1st Jun

3 HYPORT DUQM, DEME, OQ — (21st Jun)

RES = Renewable Energy Sources; LIs = Legacy Initiatives

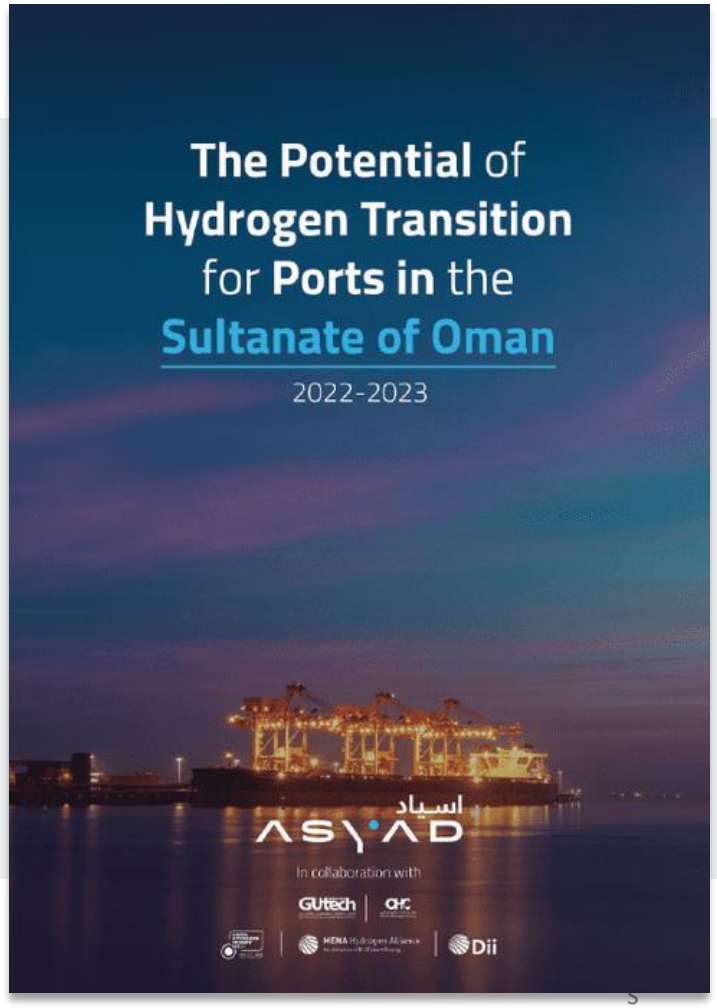
hydrom Hydrogen Oman 11

Hydrogen potential for Omani Ports



Hydrogen potential for Omani Ports

- A report in cooperation with the **Oman Hydrogen Center for ASYAD**, Oman's new **integrated logistics provider** that aims to be one of the world's top ten logistics hubs by 2040
- Established in 2016, ASYAD Group is comprised of **three deep ports** and **three free zones** supported by Oman's five airports, a new rail network and a world class road network
- Exploring the **hydrogen potential** for the three main ports of Oman and their role in the energy transition: **Port of Sohar**, **Port of Duqm** and **Port of Salalah**



Highlights and recommendations

- **ASYAD** has a huge opportunity to develop an **integrated strategy** to make Oman one of the key global hubs for hydrogen;
- A **hydrogen economy** should be developed aiming at both **export and meeting local demand**;
- Ports should develop as **fully integrated clean industrial hubs** to decarbonize or reaching net zero emissions in their own operations in the first instance;
- As repurposing the existing gas network is not likely to be achievable due to the substantial costs involved, there is the opportunity to **develop a new separate hydrogen infrastructure system**;
- Oman could play a **strategic role in the evolving ammonia and methanol market**, attracting new business and should aspire at becoming a global production and bunkering hub;
- Oman has the chance to **contribute setting global standards** and create a competitive advantage as **early mover** in an emerging market for low emission molecules;
- Emerging **hydrogen valleys** around the three ports will be the key enabler for a hydrogen economy in Oman, creating significant **job opportunities** for the country; and
- **Collaboration** among the three ports, and with international ports and associations, will be a key factor to provide a common strategy to position Oman as the export leader in hydrogen.

26

ASYAD Ports

2 Weeks

Sailing range to all major ports globally

200 weekly services

To 86 commercial ports across more than 40 countries

2 Billion Consumers

Market covered by direct trade & feeder's operations to Middle-East, Africa, East-Asia.

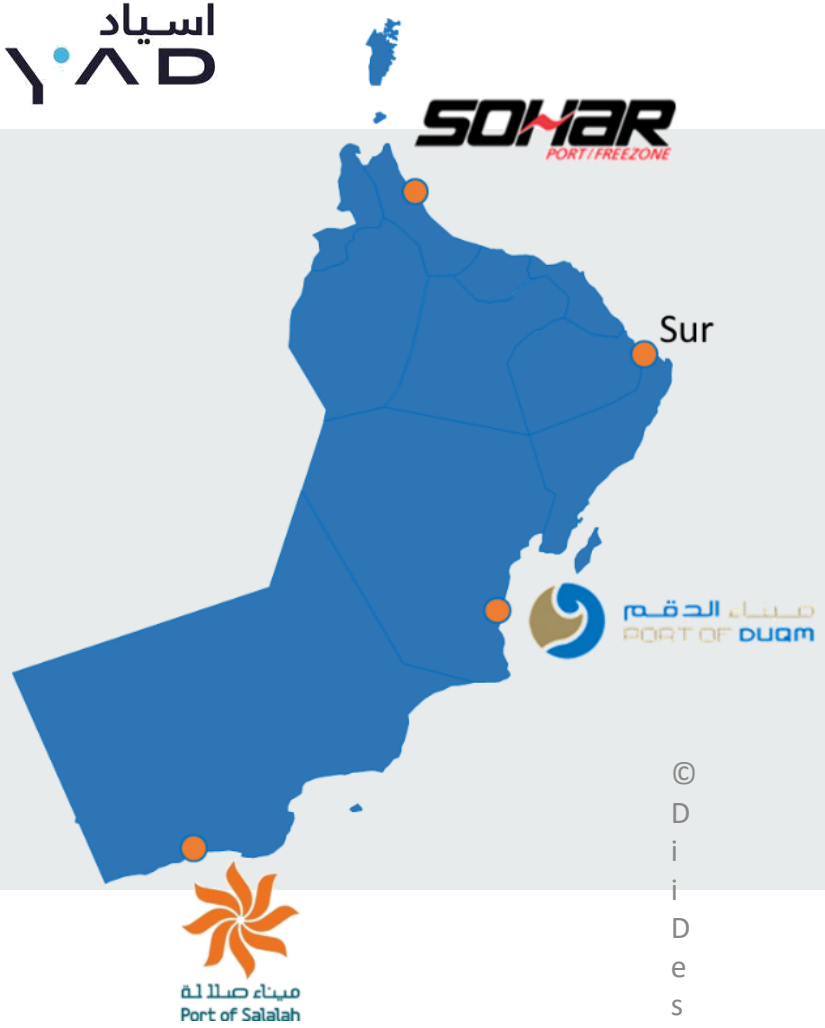
- **Port of Sohar** - 20.6 sq km
- **Port of Salalah** - 6.3 sq km
- **Port of Duqm** - 44.3 sq km

Capacity

- General Cargo: 100+ Million MT
- Container: 8+ Million TEUs
- Liquid Cargo: 10 Million + MT

Volumes handled (in 2021)

- Containers: 5.2m TEUs
- Dry & Break Bulk: 57.7m Tons
- Liquid Cargo: 19.7m MT



Ports as hydrogen valleys

It will be important for Oman moving forward to develop projects that can **cover the value chain**, **leverage local assets** and **address local needs**

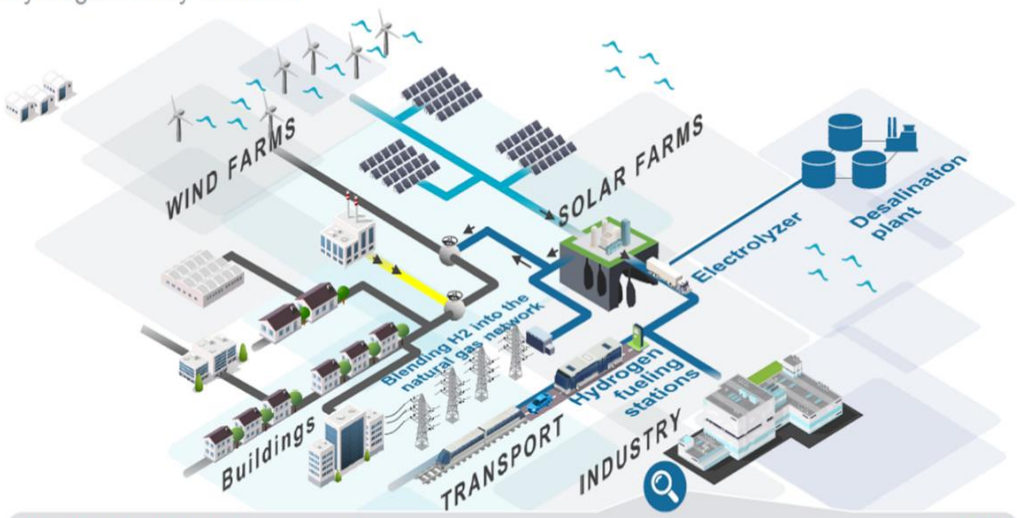
All three Omani ports have the **potential to emerge as hydrogen valleys**, with an integrated approach, including the free and Industrial zones around each port

Building production facilities close to the coastal areas i.e. at the ports or in their vicinity would minimize transport costs that remain a key challenge in developing hydrogen economies

Using and processing hydrogen directly at the ports, and thus making them gateway hubs and fully integrated clean industrial hubs, would represent a great opportunity for establishing a hydrogen-driven industry.

Hydrogen valleys combine elements of the **value chain** forming an integrated hydrogen ecosystem

Modified from Roland Berger



Full **integrated clusters** that include free and industrial zones around each port.

In a recent study, the MENA Hydrogen Alliance and Roland Berger looked at the potential to localize the hydrogen value chain and learning from hydrogen valleys in Europe

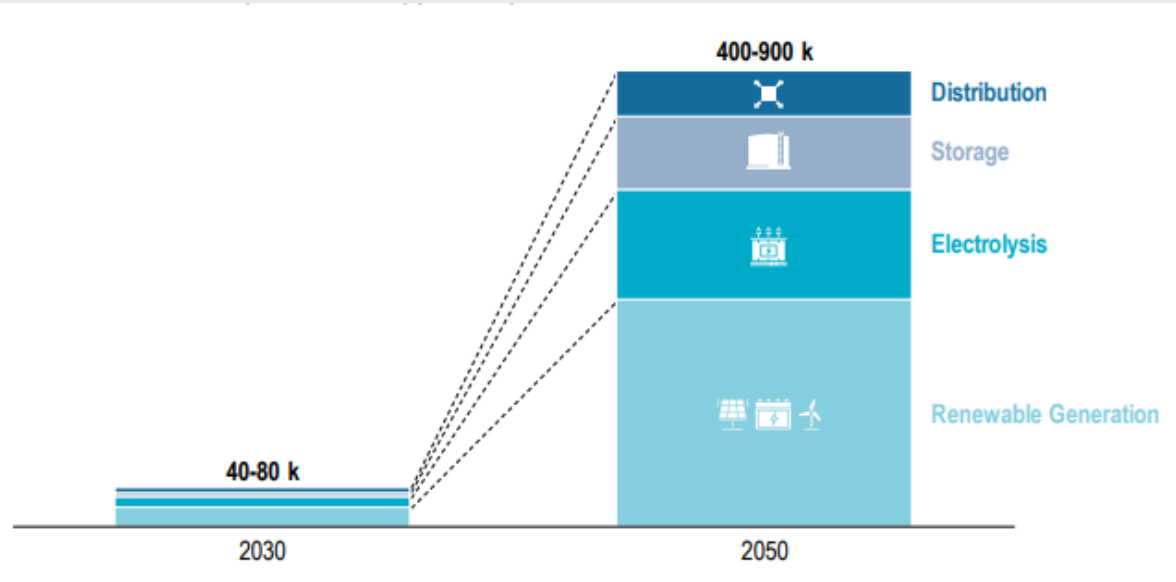
Hydrogen valleys and the potential for new jobs

The **Ministry of Energy and Minerals** during the presentation of Oman's green hydrogen strategy envisaged the creation of- cumulative till 2050 - **70,000 jobs** that would be directly related to hydrogen developments

A recent study from the MENA Hydrogen Alliance and Roland Berger indicates that the **localization of the hydrogen value chain activities in the Gulf region could result in 400,000-900,000 new indirect jobs**

Oman expected to account for 20% of the job demand i.e. 80,000-180,000 jobs. Almost half of the new jobs created would be in the renewable generation space, followed by electrolysis, storage and distribution

Across the value chain, **multiple skills will be required**, creating diversified opportunities for high-skilled workers, technicians and unskilled workers



Forecast job creation in the GCC region by value chain activity.
Source: MENA Hydrogen Alliance, Roland Berger

Potential applications of hydrogen in ports

Ship refueling (Sohar, Duqm, Salalah)

Ports could offer the possibility of **refueling ships with low-emission ammonia or e-methanol** during unloading or loading.

An important development is anticipated in the fuel market for ocean-going vessels. Ammonia will be **traded as a possible fuel**, together with e-methanol, and used **for co-firing gas turbines** to reduce emissions in electricity generation.

Heavy industry (Sohar)

Various types of heavy industry, such as the production of ammonia or methanol, already **require large quantities of hydrogen**.

This hydrogen produced by fossil fuel sources could be **gradually replaced by low-emission hydrogen** in the short to medium term.

Steel and **Cement** are the earlier adapter of such production technologies.

Refineries (Sohar, Duqm)

Hydrogen-based fuels (**e-fuels**) can be blended with conventional fuels.

E-fuels will have a **premium price and help towards reaching quotas** e.g. in aviation, a minimum quota of sustainable fuels is expected to spread globally.

In the long term, many refineries are already thinking about applying a **circular carbon approach**.

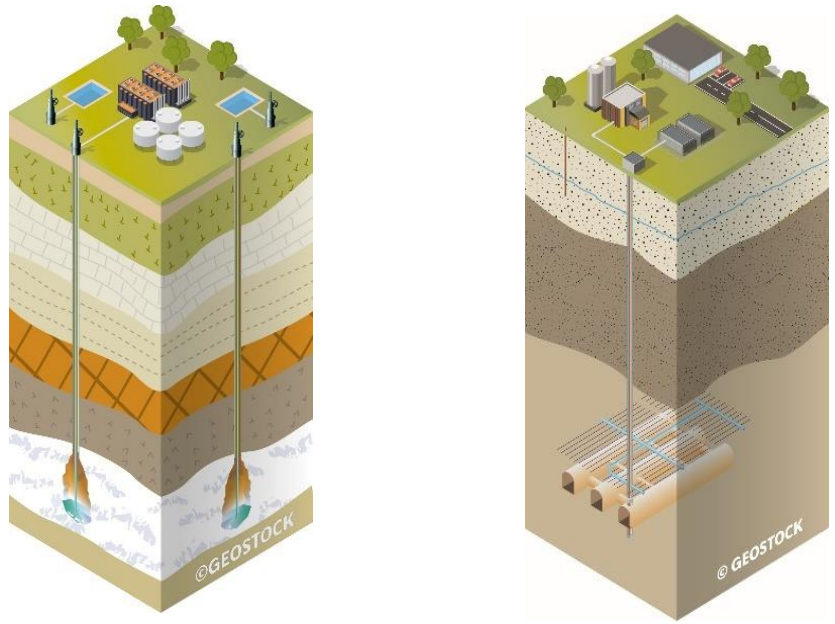
Mining (Sohar, Duqm, Salalah)

Traditional mining activities require the **consumption of substantial water and diesel**.

The first projects for **alternative propulsion of mining vehicles**, which are usually in mobile operation 24/7, are being tested on a hydrogen basis e.g. by Anglo-American in South Africa.

Developing a dedicated infrastructure for hydrogen

- As repurposing the existing gas network is not likely to be achievable due to the substantial costs involved, there is the opportunity to **develop a new separate hydrogen infrastructure system.**
- In addition to transport, **storage will also be an important component of the hydrogen value chain** and must be considered early on in the planning.
- Underground storage will be one of the best ways, with numerous advantages in terms of **environment protection**, **safety**, and above all, **CAPEX** and **OPEX**.
- Distance of the three deep-sea ports from salt cavern locations range from **35 to 80 km,** therefore **s**torage in **lined rock caverns** could also be considered as viable option.

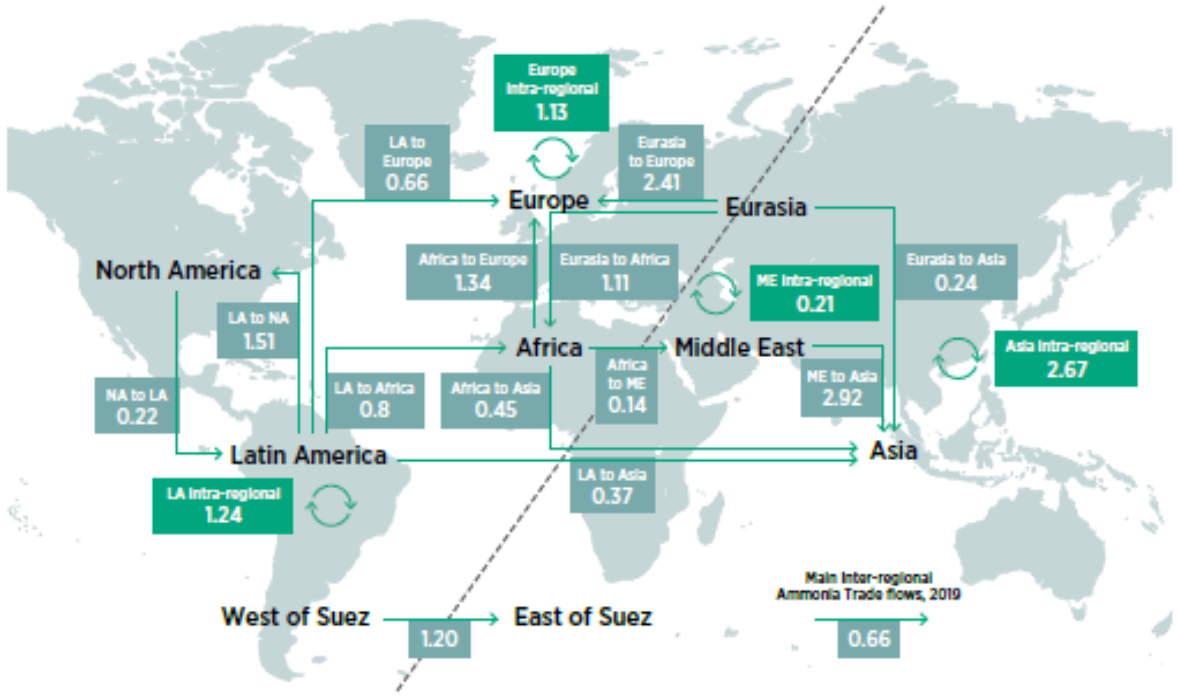


Schematics of underground hydrogen storage in salt formations (left) and rock caverns (right). (Courtesy of Geostock)

Boosting the ammonia market

- Oman might be to take a **leading role in boosting the global market for ammonia**. Ammonia production could globally increase three-to-six-fold (from 185 Mt in 2020 to 540-1,140 Mt by 2050)
- While a race between green ammonia and methanol is expected for the decarbonization of global shipping, **ammonia has a clear edge as the transport vector of choice** for most projects announced through 2030
- **E-methanol could play an important role in the industrial development of the country**, leveraging on a current total production capacity of 2 million tonnes.

FIGURE 2.1. Global trade flows of ammonia in 2019 (Mt)



Disclaimer: This map is provided for illustration purposes only. Boundaries and names shown on this map do not imply the expression of any opinion on the part of IRENA concerning the status of any region, country, territory, city, or area or of its authorities, or concerning the delimitation of frontiers or boundaries.

Source: (Topsoe, 2020).

Note: LA: Latin America; NA: North America; ME: Middle East.

A bunkering spot between Singapore and Rotterdam

- Oman is ideally located **midway on the Rotterdam-Singapore** route
- Oman should aim at becoming a **low carbon bunkering spot** for hydrogen and derivatives, adopting a flexible approach for the three ports
  - **Sohar** recently launched bunkering services by leveraging on being the **main export center** for petroleum products in Oman
  - **Salalah**, which has the highest container traffic in the country, has also ambitions to become a **bunkering hub by focusing on methanol**
  - **Duqm** could focus on becoming a **bunkering hub for ammonia**

Source: Getting to Zero Coalition

Opportunities and challenges for Omani ports

	PORT OF SOHAR	PORT OF DUQM	PORT OF SALALAH
OPPORTUNITIES	▪ Well-developed **infrastructure** and **industrial zone** ▪ Diversified group of **off-takers** ▪ Proximity to **industrial and residential centers** ▪ Higher **job demand** in the area	▪ Abundance of **solar and wind resources** ▪ **Availability of land** for renewable energy and hydrogen production ▪ **Mining sector** active in the region ▪ Largest **distance from potential conflict zones**	▪ Abundance of **solar and wind resources** ▪ Availability of space within the FZ for **further expansion** ▪ **Largest trans-shipment port** and biggest container hub
CHALLENGES	▪ Lack of **renewable energy sources** and **land** for further expansion ▪ **Proximity to Fujairah** as leading bunkering hub in the region ▪ Proximity to **potential conflict zones**	▪ Distance from **residential and industrial centers** ▪ Workers will be required **to work on rotations**, at least initially ▪ Lack of **existing infrastructure**	▪ Difficulty of **transport logistics** outside the ports area ▪ Furthest from big **residential and industrial centers** ▪ Limited **job demand**, with Port of Salalah already being the first employer in the area

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