OAPEC

VIRTUAL CONFERENCE ON

GREEN HYDROGEN MIDDLE EAST

Production, Storage, Transport and Export

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" Challenges of Hydrogen Storage & Transport and Key Export Projects in the Arab Region"

Eng.Wael Hamed Abdel Moati

Gas Industries Expert

Organization of Arab Petroleum Exporting Countries

(OAPEC)

Agenda

01

Hydrogen Value Chain

02

Challenges/Options of Hydrogen Storages and Transport

03

Hydrogen Production and Export Plans in the Arab Region

Hydrogen value chain

Production

- Fossil Fuel-based hydrogen
- Renewable Hydrogen

Storage and transportation

Storage
Compressed H_2, Liquid H_2
Transportation
Pipelines, trailers , tankers

End-use applications

- Power Generation sector
- Heat generation
- Transportation sector
- Industrial sector

Storage and transport of hydrogen: why and where is needed?

« For hydrogen to be a key component of a global resilient energy system, a large scale hydrogen value chain is needed with **adequate storage capacity and functionality** »

Production/ Export Sites

Large Hydrogen storage is needed at export terminal for shipping purposes

Hydrogen infrastructure is still limited (4,500 km X a total of 3,000,000 km for NG)

Hydrogen pipelines are geographically concentrated!

Import / Demand sites

Large hydrogen storage is needed to meet changes in seasonal demand. Also, hydrogen is needed in refueling stations

Storage of hydrogen: key challenges and options

Lowest Energy density (Mj/l)

Hydrogen has the lowest energy density compared with other fossil fuels (0.01 MJ/L* for gaseous H_2)

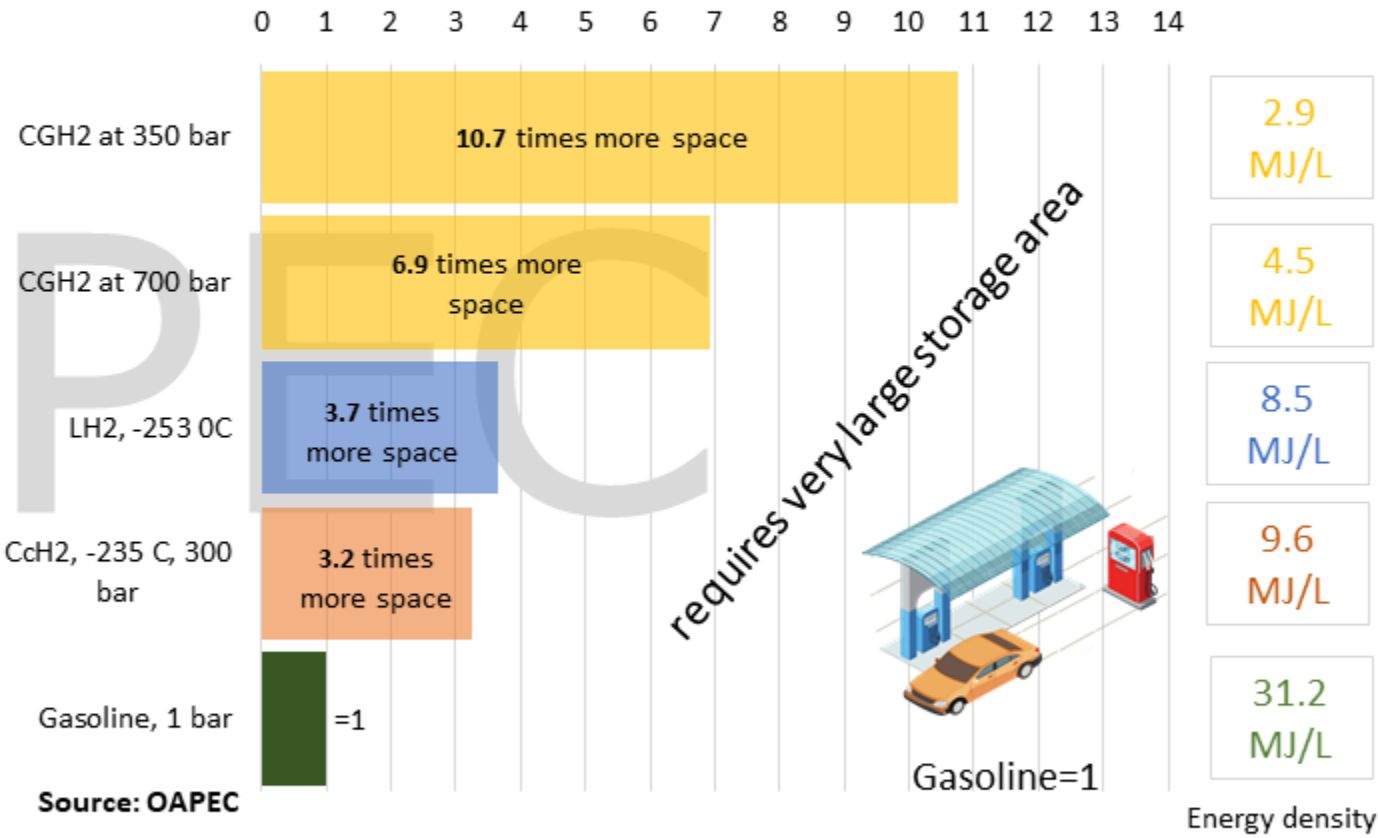
Hydrogen requires very large storage area

*MJ/L: Mega joule per liter

Solutions: increasing pressure to compress hydrogen or lowering temperature to liquify hydrogen or a mix of both processes

- Compressed Gaseous Hydrogen **CGH_2**
- Liquified Hydrogen **LH_2**
- Cryo-compressed Hydrogen **CcH_2**
- Slush (Jelly) Hydrogen SH_2

Hydrogen storage area ratio in comparison with gasoline storage



Source: OAPEC

- Specific material is needed to contain compressed or liquified hydrogen
- Extra energy is needed to liquify or compress hydrogen

Transport and distribution of hydrogen: key challenges and options

Lowest Energy density (Mj/l)

Expensive to transport hydrogen over long distances

- **Pipelines**
  - Building New Hydrogen Infrastructure
  - Converting Existing Natural Gas Networks
- **Trucks**
  - Compressed Gaseous Hydrogen Trucks
  - Cryo-compressed Hydrogen Trucks
- **Tankers**
  - Liquid Ammonia or Liquified Hydrogen Tankers

Key factors affecting the optimal hydrogen transport method

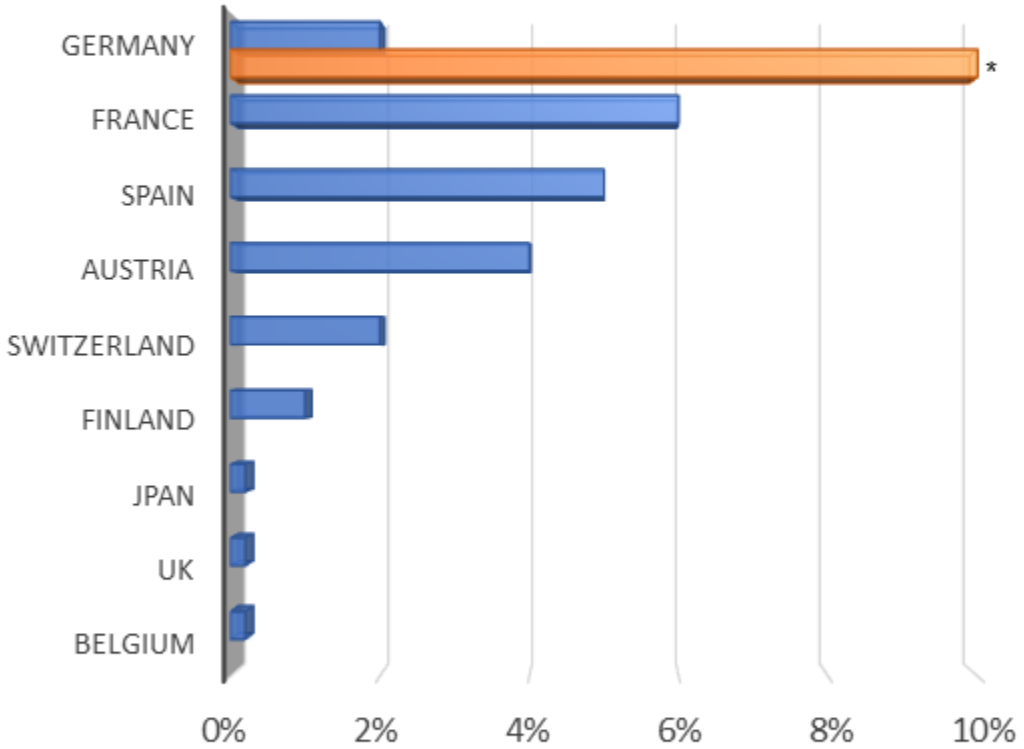
1. THE DISTANCE TO THE DEMAND CENTRES
2. VOLUME OF HYDROGEN TO BE TRANSPORTED AS PER DEMAND
3. GEOGRAPHY AND MATURITY OF EXISTING GAS INFRASTRUCTURE

Transport and distribution of hydrogen: comparison

Method	New Hydrogen Networks	Blending in Existing Gas Networks	Compressed Hydrogen Trucks	Liquified Hydrogen Trucks	Ammonia Tankers
					
CAPEX	High	**Low** (in case of blending up to 20%) **High** (in case of to modification to transport 100% hydrogen	**low**	**Medium** due to liquification process (~ 50% of the total cost)	**High**
Capacity	**High** (over 1000 kg/day)	**High** (over 1000 kg/day)	**Low** up to 1000 kg	**High** up to 4000 kg	30,000-80,000 cubic meter of ammonia **(1 m^3 ammonia=120 kg H2)**
Distance	1000-4000 km	1000-4000 km	1000 km	up to 4000 km	> 4000 km
Key Challenge	High CAPEX and time	**High costs** in case of modification for 100% hydrogen transport	Specialized material for high pressure container	Specialized material for isolation -vapor loss 0.3% daily	Ammonia is toxic and harmful to the marine environment

Transport and distribution of hydrogen: blending in natural gas networks

Current allowable hydrogen blending % in natural gas pipelines in selected countries



*in case of no CNG stations are connected to gas networks

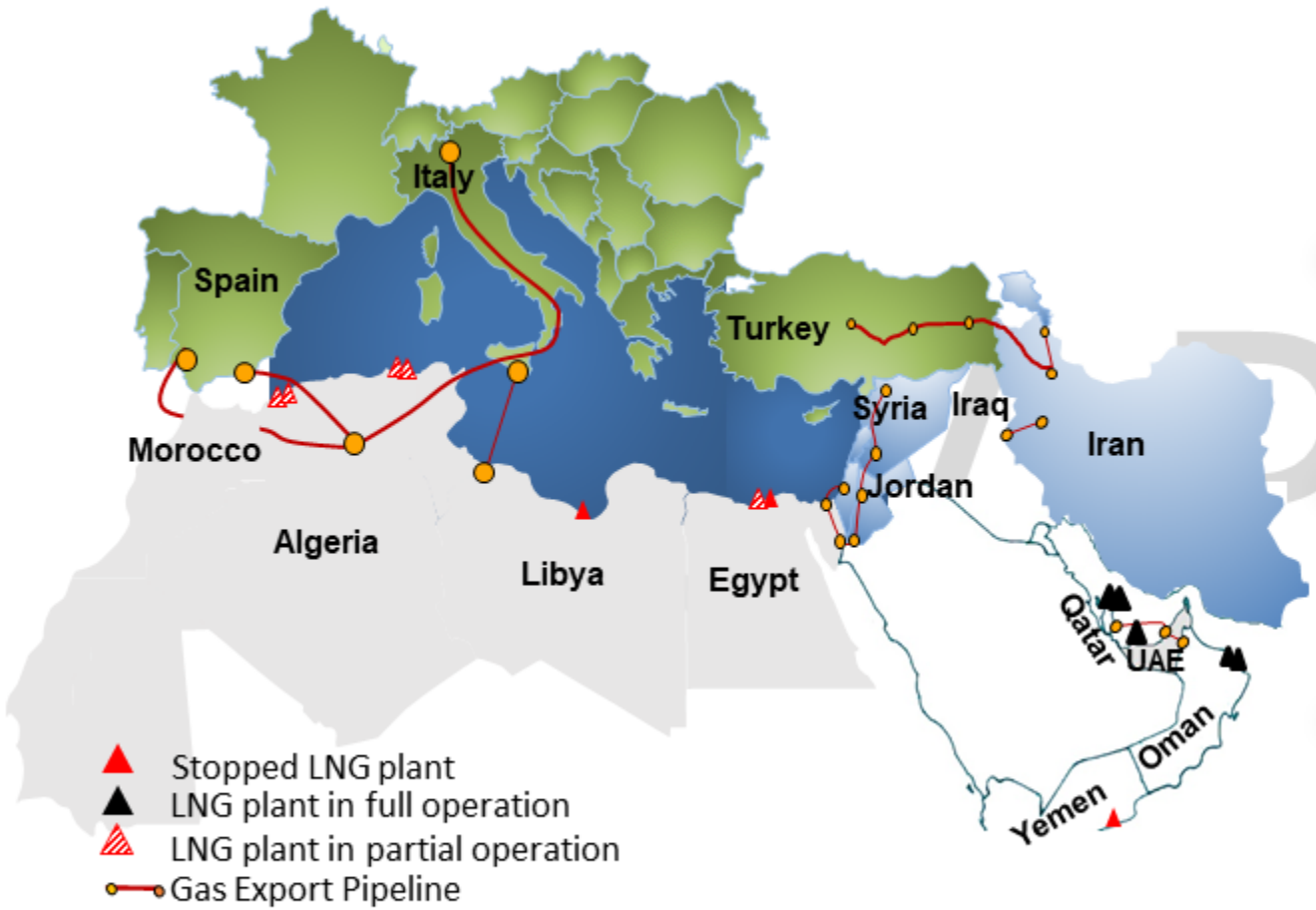
Source: IEA,2019

Key considerations in hydrogen blending in natural gas networks

- Converting natural gas pipelines to carry a blend of natural gas and hydrogen (up to 15% hydrogen) may require only modest modifications to the pipeline
- Converting existing natural gas pipelines to deliver pure hydrogen (100% hydrogen) require more substantial modifications including new compressors, storage facilities
- Blending hydrogen will reduce the mixture heating value, which means higher gas/hydrogen volumes to meet the same energy needs.
- Furthermore, blending may require to change/modify the equipment/households appliances connected to the hydrogen network

(new gas heating and cooking appliances in Europe are certified to handle 23% hydrogen blend)

Hydrogen in the Arab region: success potentials



01 Availability of massive gas networks in place and transcontinental pipelines.

02 Unique geographical location with proximity to potential demand centers like Asia and Europe.

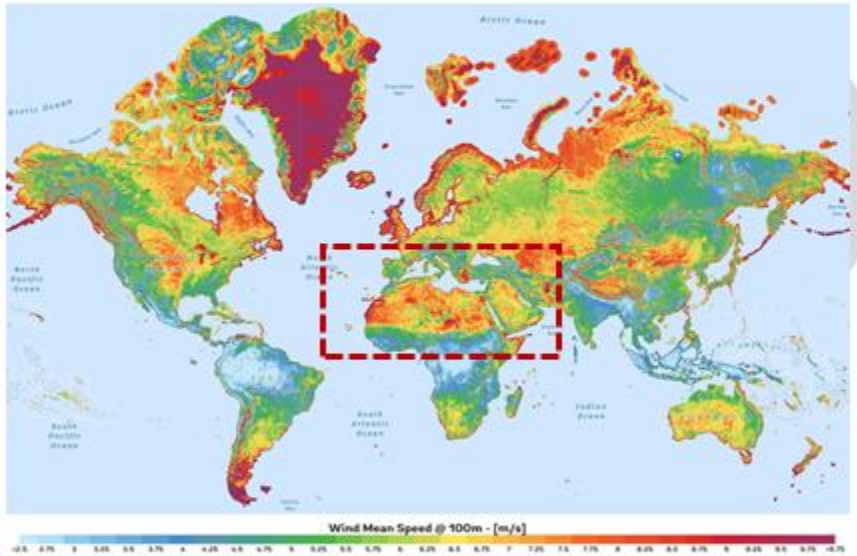
03 Long established strategic ties between Arab NOCS and IOCS.

04 Availability of renewable energy resources

Hydrogen in the Arab region: success potentials

Arab region has optimal PV /Wind resources for green hydrogen production due to expected **higher capacity factor of electrolyzers and low cost of electricity generated**

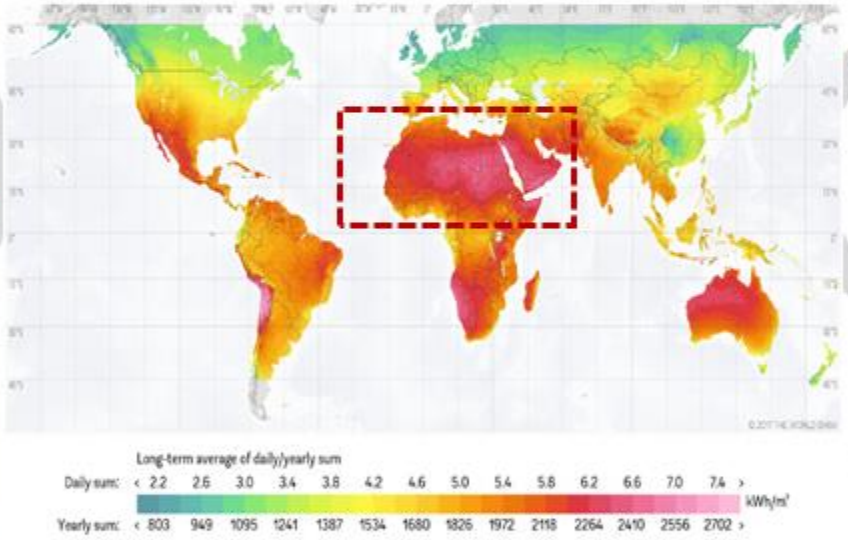
wind atlas of the world



9-11 m/s

Wind speed

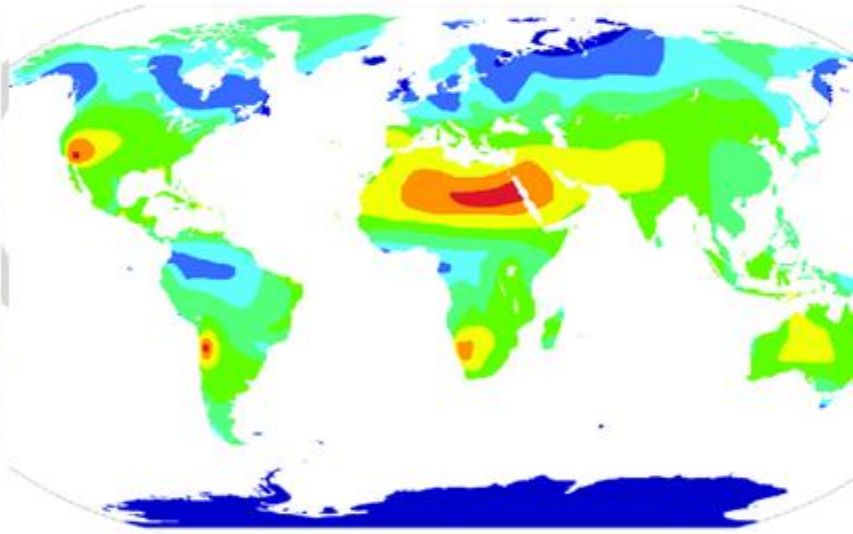
solar radiation atlas of the world



2200-2500 KW/m²

Solar radiation

Annual sunshine map of the world

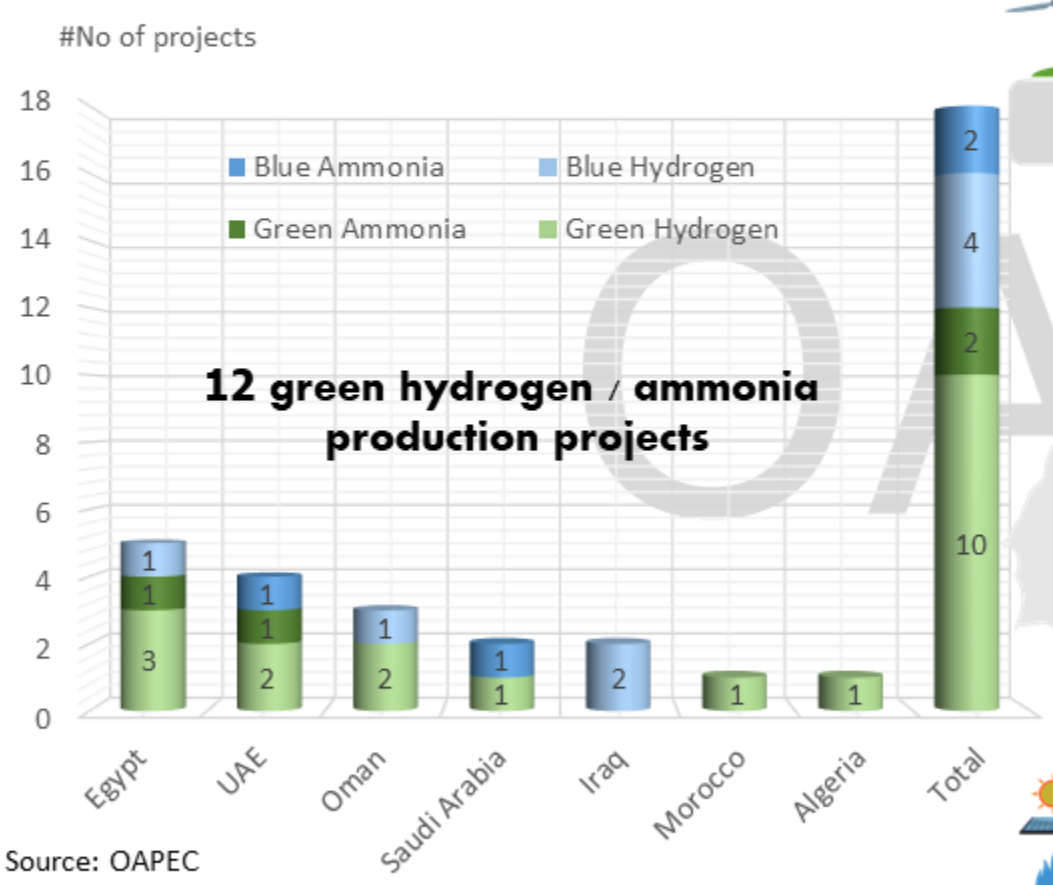


3900 hours

Sunshine hours

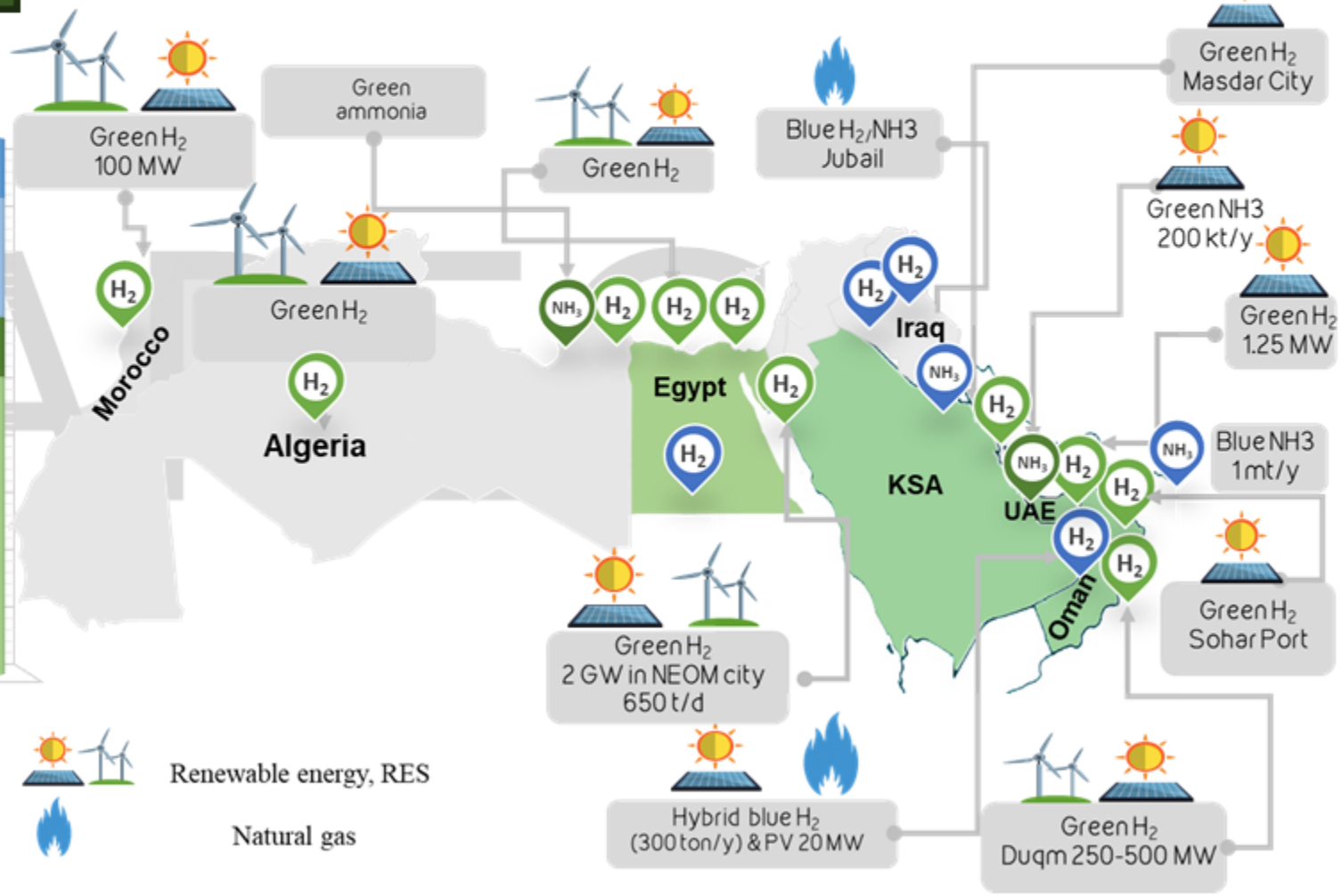
Planned hydrogen production/export projects in the Arab region

Planned hydrogen production/export projects in the Arab region



Source: OAPEC

Majority of planned projects are at very early stage of planning

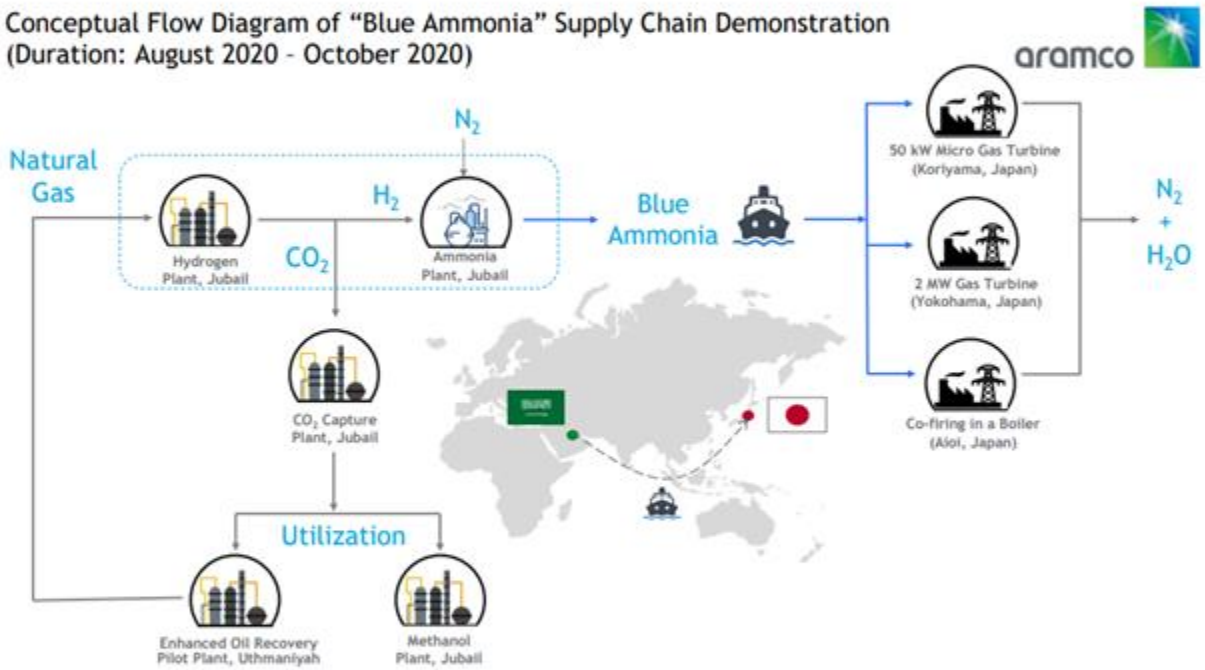


Successful production and shipping of blue ammonia cargoes

Aramco and the Institute of Energy Economics, Japan (IEEJ), in partnership with SABIC

ADNOC in partnership with Fertiglobe exported green ammonia cargoes

Conceptual Flow Diagram of "Blue Ammonia" Supply Chain Demonstration
(Duration: August 2020 - October 2020)



40 tons of blue ammonia

50 tons of CO_2 captured

3 cargoes of blue ammonia exported to three Japanese companies

Wraps-up

- For hydrogen to be a key component of a global resilient energy system, a large scale hydrogen value chain is needed with adequate storage capacity and functionality
- Hydrogen has the lowest energy density compared with other fossil fuels →Hydrogen requires very large storage area and is expensive to transport over long distances
- It is feasible (with little modifications) to use existing gas pipelines to transport hydrogen blend up to 15% while pure hydrogen requires more substantial modifications to pipelines
- Arab region has optimal PV /Wind resources for green hydrogen production with expected higher capacity factor of electrolyzers.. 70% of the planned projects are for green hydrogen/ammonia production

Key message

Arab region has the potential to be a major hydrogen exporter

For further inquiries :
Eng.Wael A.Moati
Gas Industries Expert,
OAPEC
+96555157915
Email: Whamed_eng@oapecorg.org
Linkedin : Wael Hamed Abdel Moati

Visit OAPEC website for more information

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Technical study on hydrogen role in the energy transition

Quarterly report on Hydrogen developments