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# Opportunities and impacts of the new global hydrogen economy for MENA countries

**Charlène BARNET**, **Nadia MAÏZI** and **Sandrine SELOSSE**

# SUMMARY

# 1

# STATE OF PLAY: CLIMATE AND ENERGY CHALLENGES IN THE MENA REGION

# LOW DEGREE OF ECONOMIC DIVERSIFICATION FOR NET HYDROCARBONS EXPORTERS

1

## 7 out of 13 OPEC members

Net oil and gas exporters whose economies are highly dependent on hydrocarbons (from 10% to 100% of export revenues).

## Carbon-intensive electricity mix

Electricity generated in the region is 90% hydrocarbon-based.

2


3

## Vulnerability to climate change

A region with an often arid climate and high water stress.

## Socio-economic inequalities

Some of the world's richest countries exist alongside countries in conflict and/or extreme poverty.

4



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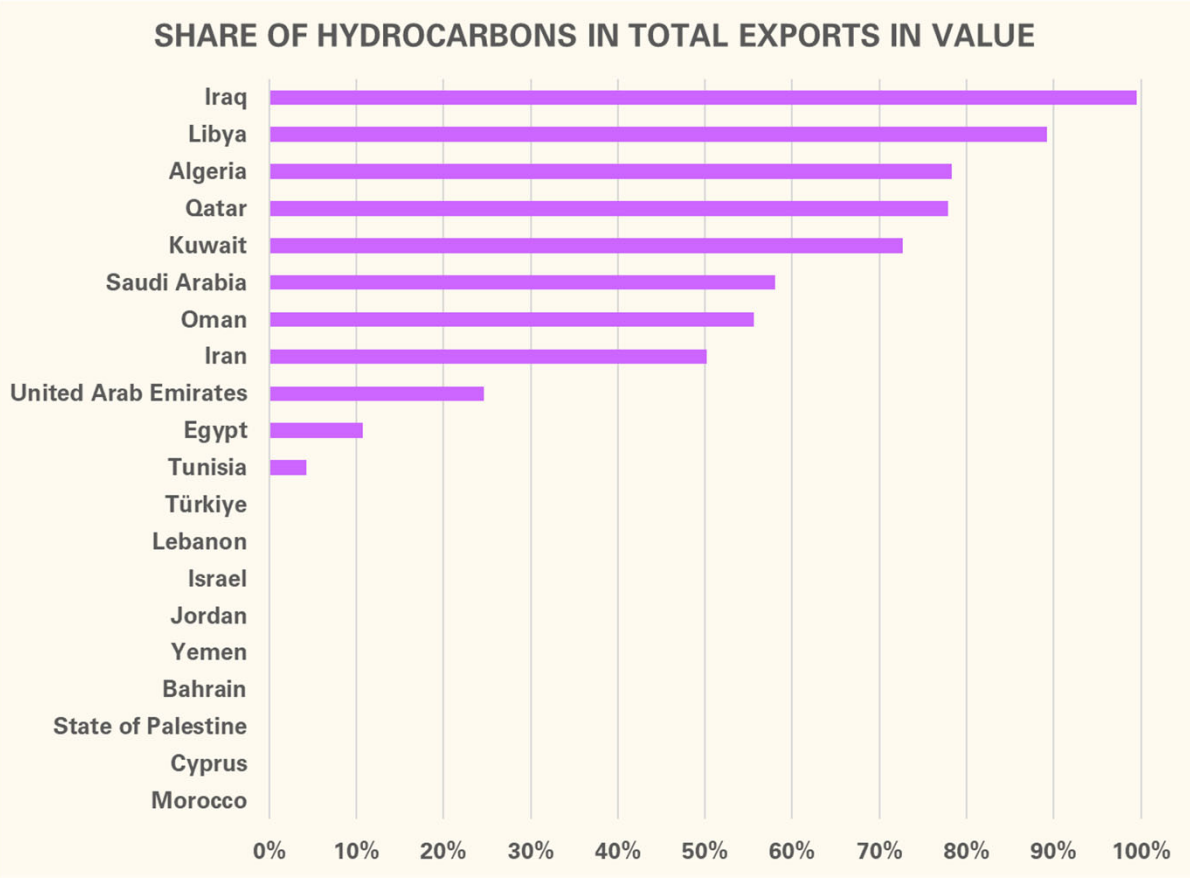
# LOW DEGREE OF ECONOMIC DIVERSIFICATION FOR NET HYDROCARBONS EXPORTERS




→ **Hydrocarbons account for 25 to almost 100% of their export earnings and a significant share of their GDP and tax revenues.**

→ Example of Saudi Arabia (2012-2015) :

- Oil sector = **24% of its GDP**
- **86%** of the government **budget**

→ Example of Oman (2020)

- **60% of total export** revenues
- **25%** of **GDP**

*Source: UN Comtrade Database (mean on the 2015-2020 period)*

# CARBON-INTENSIVE ELECTRICITY MIX

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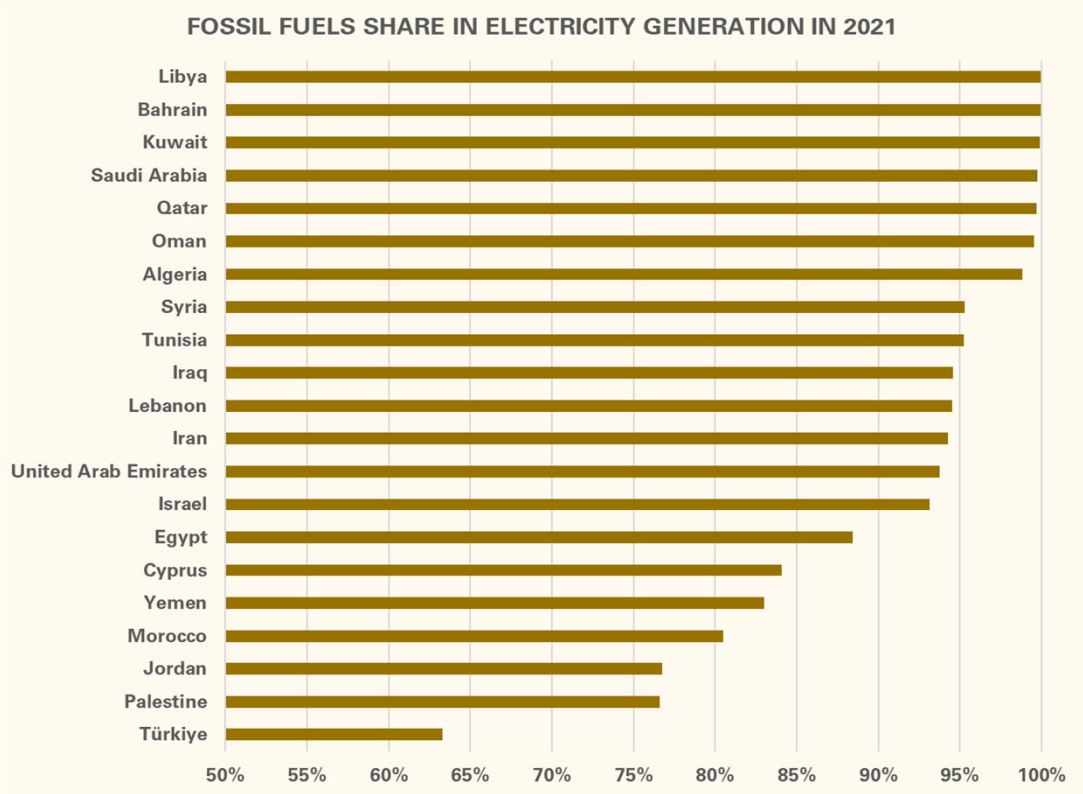



**Five out of the six GCC (Gulf Cooperation Council) members are among the ten countries in the world with the highest per capita GHG score.**

*Source: U.S Information Administration*



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# VULNERABILITY TO CLIMATE CHANGES

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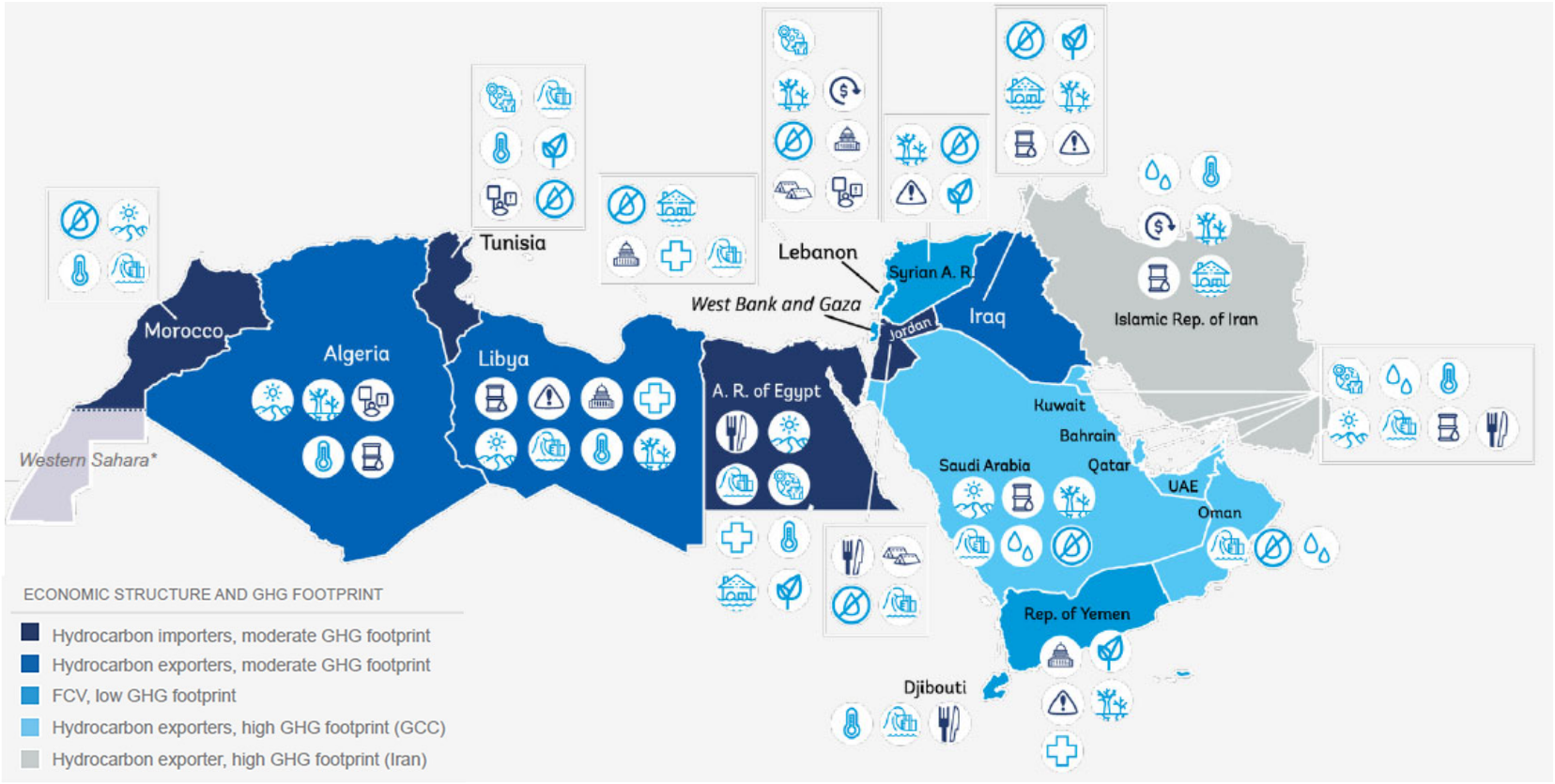
# VULNERABILITY TO CLIMATE CHANGE





*Source: World Bank, 2020*



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# SOCIO-ECONOMIC INEQUALITIES

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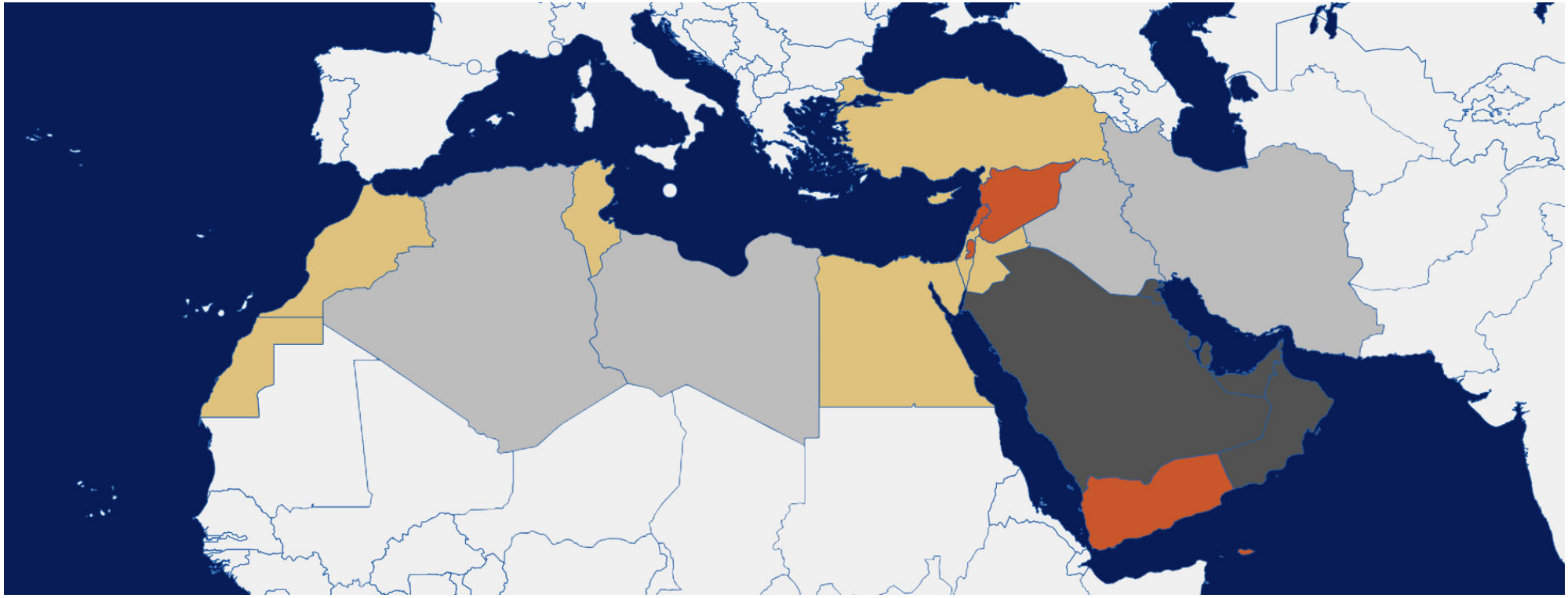
# TYPOLOGY OF MENA COUNTRIES

NET HYDROCARBONS EXPORTERS – HIGH INCOME

NET HYDROCARBONS EXPORTERS – LOW-MEDIUM INCOME

NET HYDROCARBONS IMPORTERS

FRAGILE AND CONFLICT STATES





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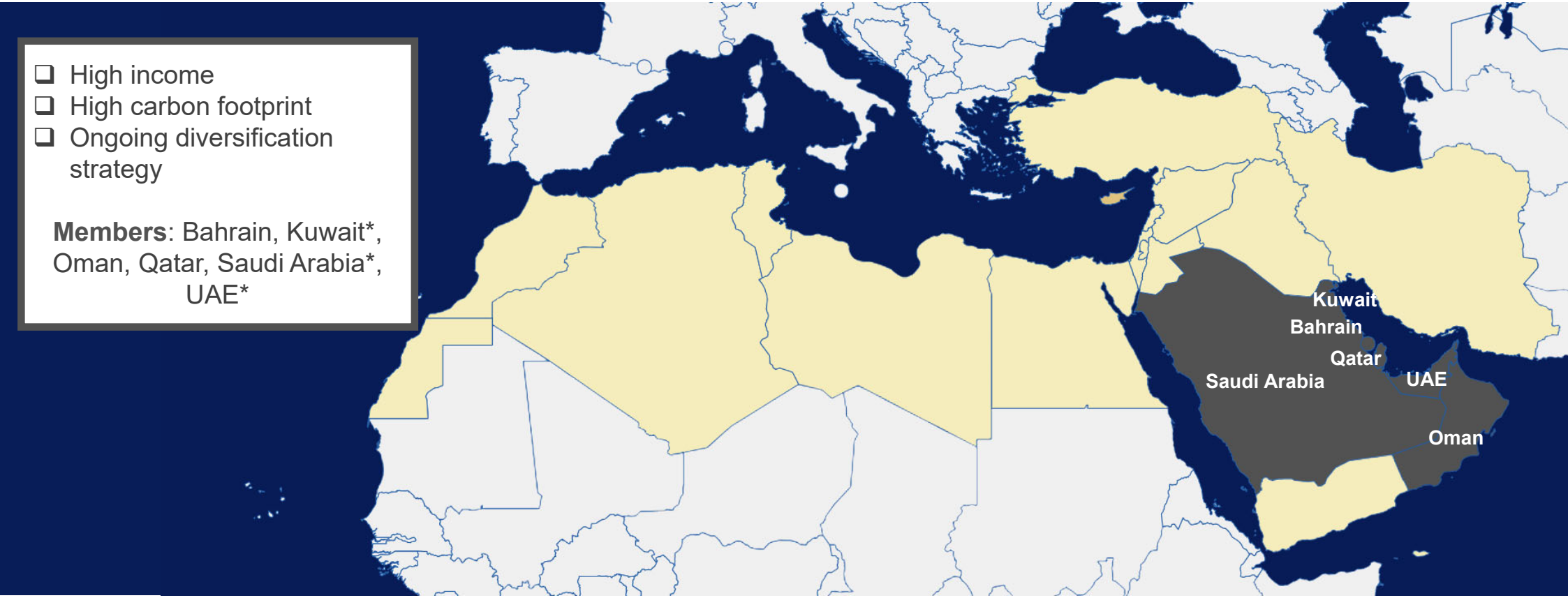
# NET HYDROCARBONS EXPORTERS - HIGH INCOME

- ❑ High income
- ❑ High carbon footprint
- ❑ Ongoing diversification strategy

**Members**: Bahrain, Kuwait*, Oman, Qatar, Saudi Arabia*, UAE*

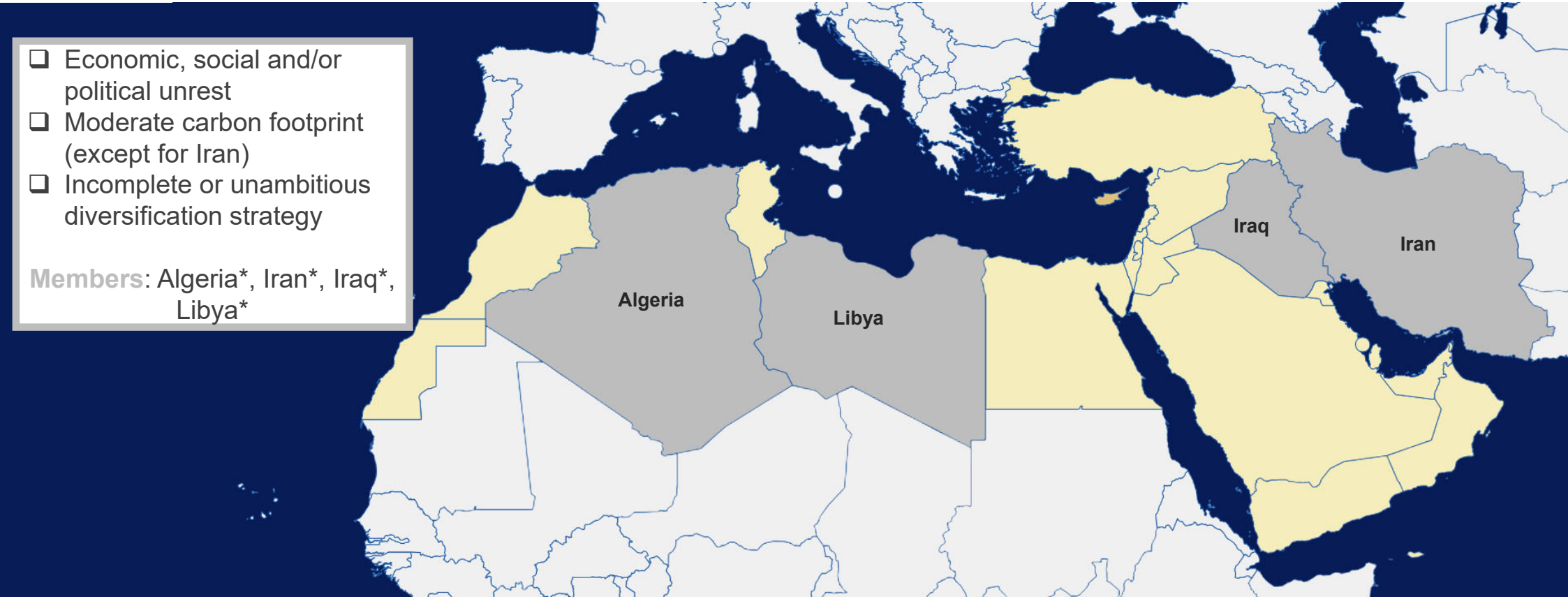



* OPEC members

# NET HYDROCARBONS EXPORTERS – LOW TO MEDIUM INCOME

- Economic, social and/or political unrest
- Moderate carbon footprint (except for Iran)
- Incomplete or unambitious diversification strategy

**Members**: Algeria*, Iran*, Iraq*, Libya*

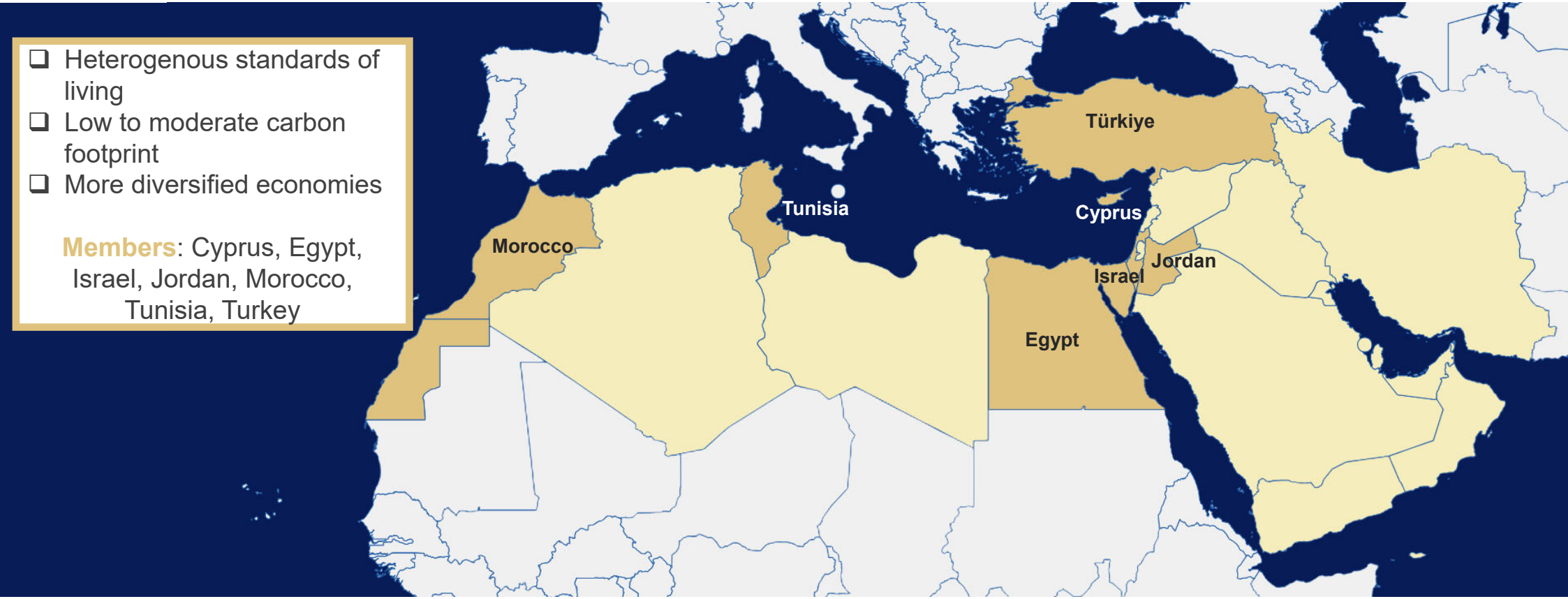



* OPEC members

# NET HYDROCARBONS IMPORTERS

- Heterogenous standards of living
- Low to moderate carbon footprint
- More diversified economies

**Members**: Cyprus, Egypt, Israel, Jordan, Morocco, Tunisia, Turkey



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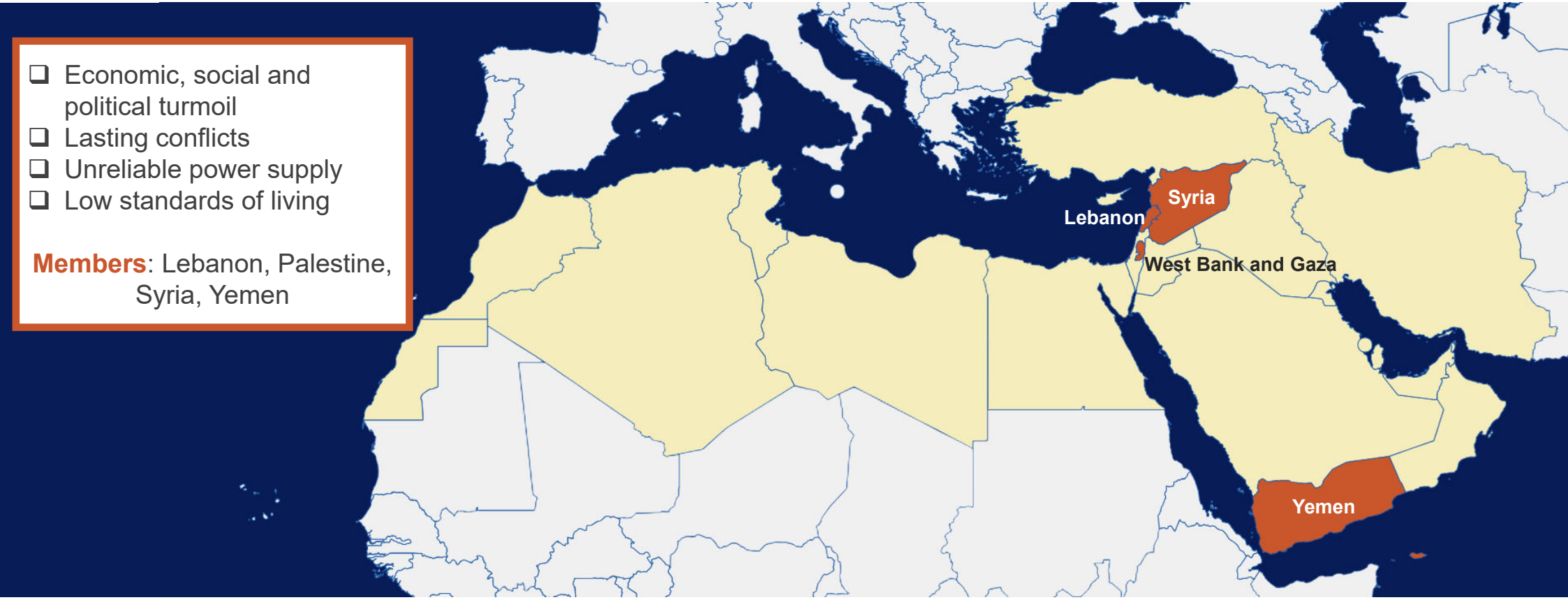
# FRAGILE AND CONFLICT STATES

- Economic, social and political turmoil
- Lasting conflicts
- Unreliable power supply
- Low standards of living

**Members**: Lebanon, Palestine, Syria, Yemen



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# 2

# THE ENERGY TRANSITION AND THE HYDROGEN OPPORTUNITY IN THE MENA REGION

# HYDROGEN IN THE MENA: CURRENT SITUATION AND OPPORTUNITIES

## SITUATION

→ **5 to 6 MT of grey hydrogen (from SMR) are produced each year in GCC countries** (Khan et al., 2023), mainly for:

- → oil refining
- → the steel industry (4MT yearly output)
- → ammonia production (fertilizers)

→ **Egypt is also producing around 2 MT of grey hydrogen annually (Habib, 2021):**

- → 13% of Egypt's gas use is dedicated to hydrogen production
- → Ammonia production, methanol, steel, oil refining.

→ In 2020, **70 MW of electrolysis capacities** existed in the MENA region and two blue $H_2$ facilities became operational.

## OPPORTUNITIES

→ **Decarbonation of the economy:**

- → **Iron and steel industry**: through green H2 DRI-EAF route. For GCC countries and Egypt.
- → **Fertilizers production:** Morocco is one of the world's top 4 fertilizer producers. It currently imports grey ammonia, which could be replaced by domestic production of green ammonia.
- → **Transportation:** Road transportation (GCC mainly), aviation (big research program in GCC)
- → **Refineries**: green hydrogen-based conventional fuels for the European market

→ **Export product:** new source of commercial power.

→ **Diversification strategies:** new fiscal revenues, diversification of companies of the energy sector.

→ **Job creation**

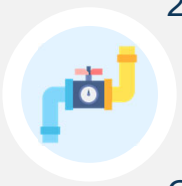
→ **Industrial value chain creation:** technological mastery, soft power through patents.

# THE STRENGHS AND ASSETS OF THE MENA FOR HYDROGEN DEVELOPMENT

## ABUNDANCE OF SOLAR AND WIND RESOURCES

→ Abundance and low cost of its renewable production potential.

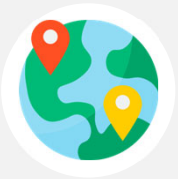
→ Among the 15 countries with the highest practical PV energy potential 9 are located in MENA (ESMAP, 2020).



## EXISTING INFRASTRUCTURES

→ Gas pipelines connecting North Africa to Europe through Italy and Spain.

→ Extensive gas infrastructures in the GCC, ports and liquefaction facilities and carriers ships.



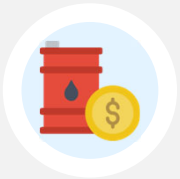
## STRATEGIC GEOGRAPHIC PROXIMITY TO KEY IMPORTING MARKETS

→ Ideal location between future major hydrogen consumption hubs: South-East Asia and Europe.

## FINANCING CAPACILITIES

→ Strong funding capabilities for the GCC countries.

→ Possibility for financial support from the EU in North Africa.



## EXPERTISE IN ENERGY PRODUCTS PRODUCTION, TRANSPORT AND TRADE

→ Vast reserves of low-cost natural gas (in GCC mainly): first mover advantage for entering the hydrogen economy through blue molecules.

→ Strong expertise in energy products trade (LNG, ammonia).

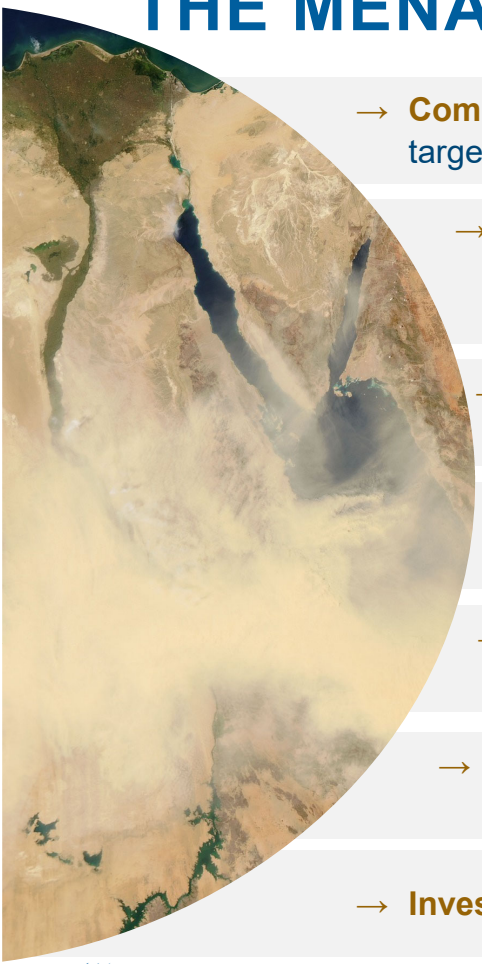
→ Full ecosystem of private and national companies and institution dedicated to energy products trade.

→ Long-standing commercial relations with international customers and partners.

# HYDROGEN AMBITIONS AND STRATEGIES

| | GROUP 1 | GROUP 2 | GROUP 3 |
|---|---|---|---|
| **Countries with declared ambitions** | Saudi Arabia, UAE, Oman, Qatar | Algeria | Morocco, Tunisia, Egypt, Türkiye |
| **Export orientation** | ▪ Strongly oriented towards exports<br>▪ Europe and South East Asia are targeted | ▪ Strongly oriented towards exports<br>▪ Europe is targeted | ▪ Strongly oriented towards exports except for Türkiye<br>▪ Europe is targeted |
| **$H_2$ color** | Blue and green | Blue and green | Green |
| **Production targets** | ▪ **SA**: 4 Mt/yr by 2035<br>▪ **UAE**: 1.4 Mt/yr by 2031, 15 Mt/yr by 2050<br>▪ **Oman**: 3.75 Mt/yr by 2040 and up to 8.5 Mt/yr by 2050 | ▪ **Algeria:** 30-40 TWh by 2040 | ▪ **Egypt:** Increase of domestic production of green $H_2$ by 60% in 2030 and 400% in 2040. |
| **Export targets** | ▪ **SA**: capture 10% of world demand by 2030<br>▪ **UAE**: capture 25% of world demand by 2030 | ▪ **Algeria**: Meet 10% of UE clean $H_2$ needs by 2040 | ▪ **Morocco**: up to 4% of global demand by 2030 and 1% by 2050.<br>▪ **Tunisia**: 6 Mt/yr exports to EU by 2050<br>▪ **Egypt**: 25% of production for exports |

# WEAKNESSES AND HURDLES FOR HYDROGEN ADOPTION IN THE MENA



→ **Competition with domestic energy systems decarbonation**: most of these are already struggling to meet their current targets for the penetration of renewable energy in the electricity mix.

→ **Infrastructure requirements**: the need for new or retrofitted infrastructure is big. In the short term, retrofitted pipelines could meet the requirements but in the longer term new infrastructures are needed. In addition, port facilities, liquefaction units and adequate carriers ships must be anticipated.

→ **High production costs**: blue and green hydrogen production costs are still high and they will require further research and, above all, widespread adoption in order to become competitive.

→ **Need for demand creation**: a market must be created both at the world and domestic stages. Only 17% of current H2 export projects for 2030 have actual off takers (IEA,2023).

→ **Lack of well-defined roadmaps and strategies**: so far, hydrogen targets are revealed mainly from announcements ; comprehensive and publicly displayed strategies are lacking.

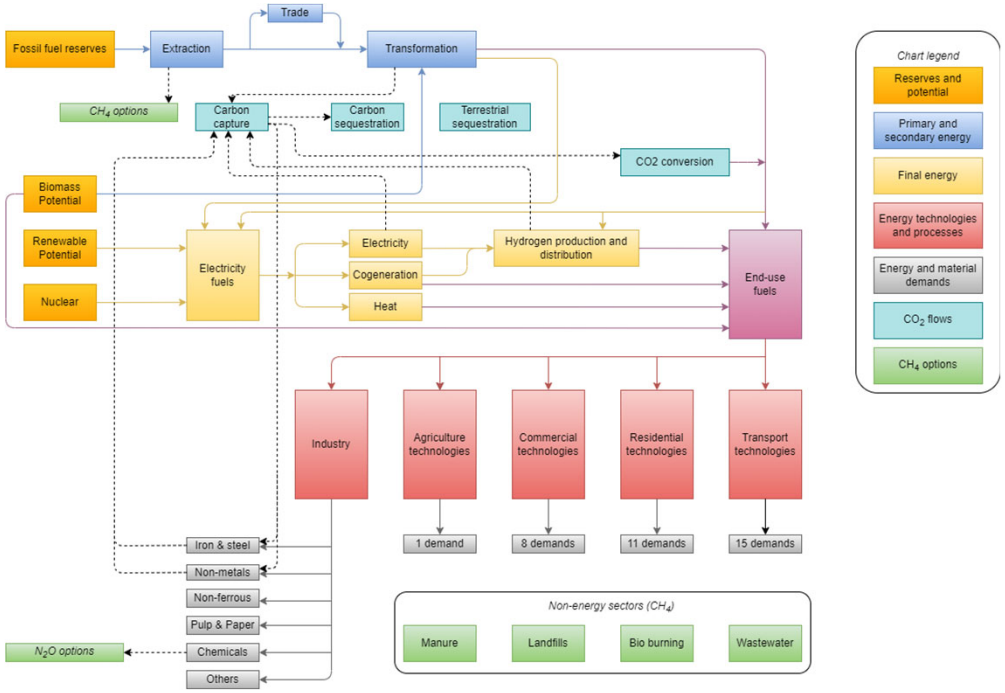
→ **Water requirements**: the MENA region is already under great pressure regarding water use and availability. This situation should worsen in the future. Green hydrogen production is water intensive.

→ **Investment and business environment**: great disparities do exist between countries.

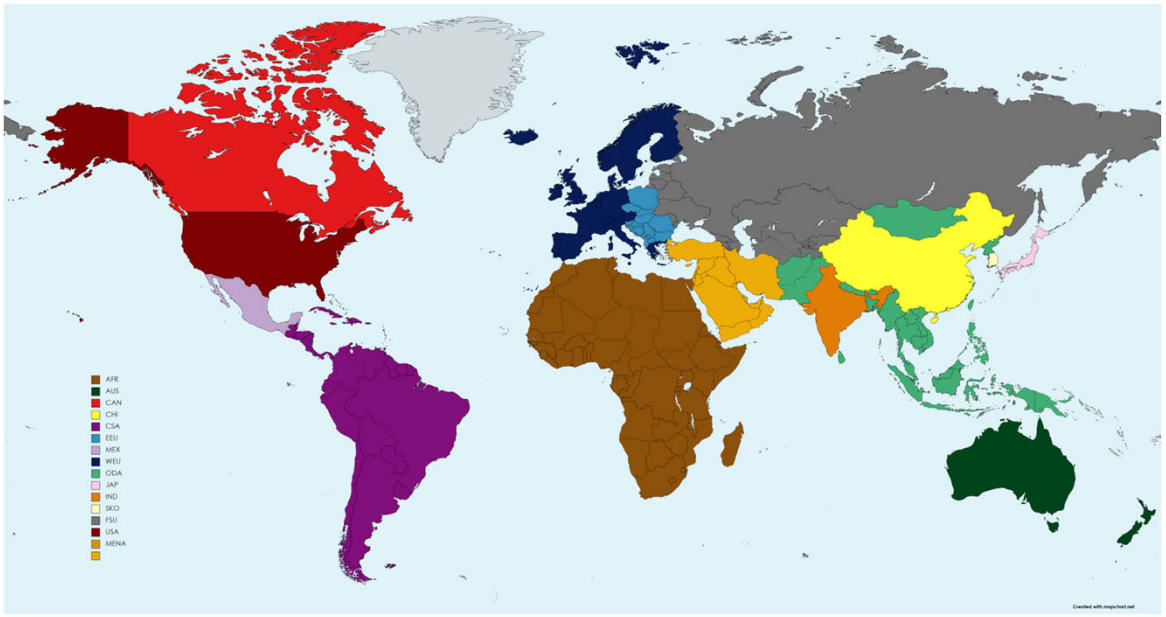
# 3

# METHODOLOGY: THE TIAM-FR MODEL

# TIAM-FR: A GLOBAL MODEL FOR BOTTOM-UP OPTIMIZATION OF ENERGY SYSTEMS




**Reference Energy System (RES) of TIAM-FR model**




**TIAM-FR regions**



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# LONG-TERM ENERGY SYSTEMS MODELING: HYDROGEN AND THE MENA

## LESSONS FROM THE LITERATURE REVIEW

- ❑ **Relative <u>scarcity of long-term bottom-up prospective models applied to MENA</u>** energy systems.
- ❑ Most techno-economic modeling exercises **<u>focus on exports from the MENA region to Europe</u>** (i.e. the search for the best transport route and cost-optimized solutions for Europe).
- ❑ **Techno-economic <u>impacts of hydrogen strategies</u> on domestic energy systems of the MENA region are <u>poorly investigated</u>** (ElSayed et al., 2023):
  - **Virtusally no bottom-up optimization models incorporate hydrogen** ecosystem technologies.
  - **Additional renewable energy capacity requirements** and **optimization solutions** (e.g. interconnections) are insufficiently addressed in scientific literature based on bottom-up optimization models.
  - The **need for water and desalination capacity** has also been understudied to date.

**CONTRIBUTION: As part of this thesis, we would like to modify and improve TIAM-FR in order to address some of these shortcomings**

# HYDROGEN REPRESENTATION IN TIAM-FR

## HYDROGEN PRODUCTION PROCESSES

- COAL GASIFICATION
- STEAM METHANE REFORMING
- BIOMASS GASIFICATION
- COAL GASIFICATION WITH CCS
- STEAM METHANE REFORMING WITH CCS
- BIOMASS GASIFICATION WITH CCS
- ALKALINE ELECTROLYZERS
- PEM ELECTROLYZERS

## HYDROGEN TRADE OPTIONS

| | JPN | SKO | WEU |
|---|---|---|---|
| AUS | YES | YES | YES |
| CSA | YES | NO | YES |
| MEA | NO | NO | YES |

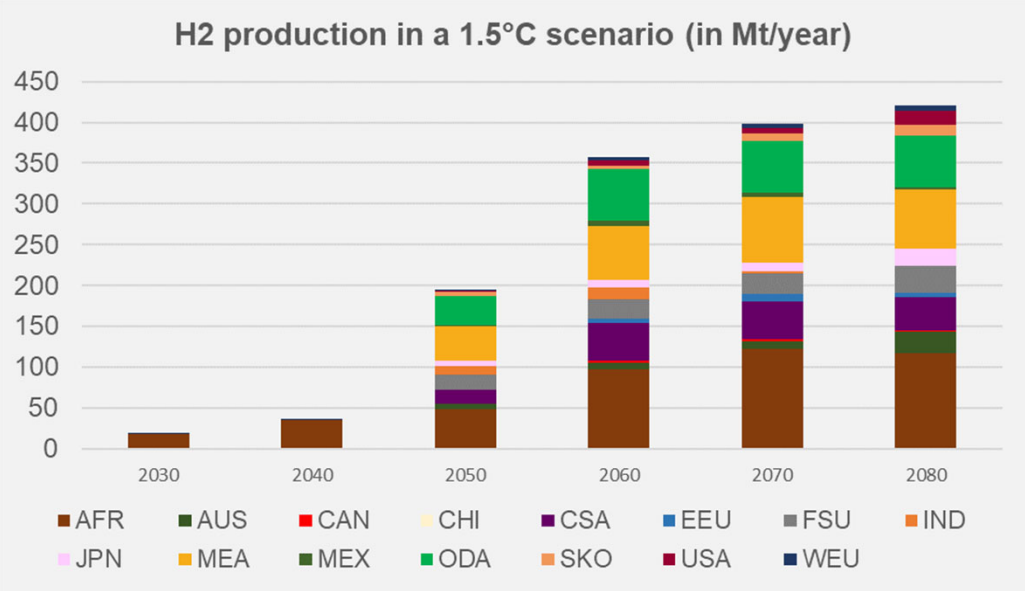
The **liquid hydrogen transportation by ship** route has been considered in TIAM-FR. Different costs assumptions has been made available to perform sensitivity analysis.

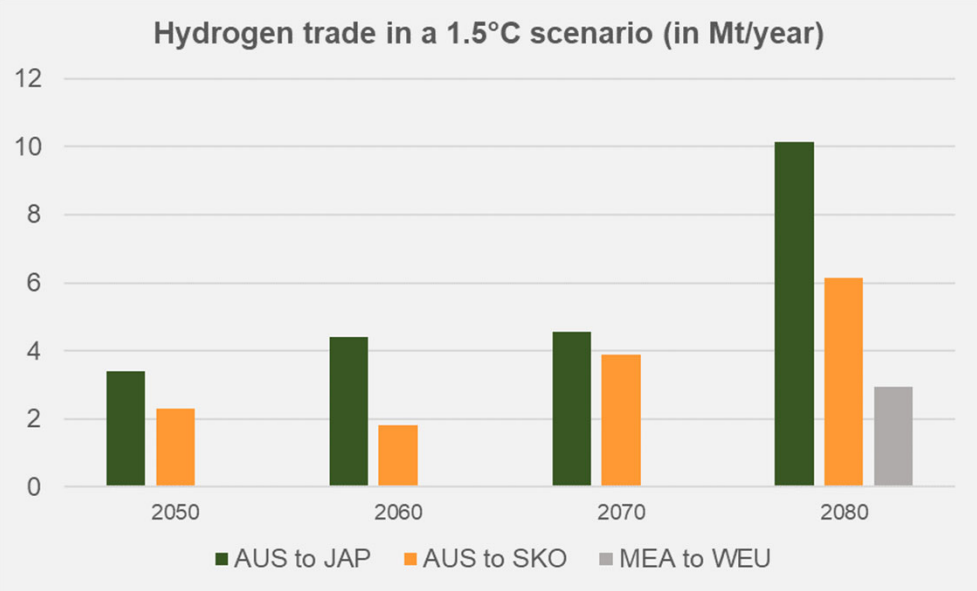
- Downstream assumptions about **storage, transportation and distribution** do exist but need further development and refinements. **Transporting liquid hydrogen by ship is the only option considered in TIAM-FR**, as transport by pipeline or in the form of ammonia has not yet been implemented.
- From the **demand side,** a single transportation technology, incorporation in iron and steel industrial processes, synthetic hydrocarbons production, methanation, conversion into methanol have been considered .

# 4

# CURRENT LIMITS OF TIAM-FR AND FUTURE EVOLUTIONS

# PRELIMINARY RESULTS ON $H_2$ TRADE IN TIAM-FR




**INCONSISTENCIES**

- **Calibration problem** for the first period,
- **Low level of global consumption in 2050** compared to other prospective scenarios: demand side must be further developed.
- **A very low level of $H_2$ exchanges** compared to the strategies and objectives announced by both importing and exporting countries: more transportations options and trade routes must be added.



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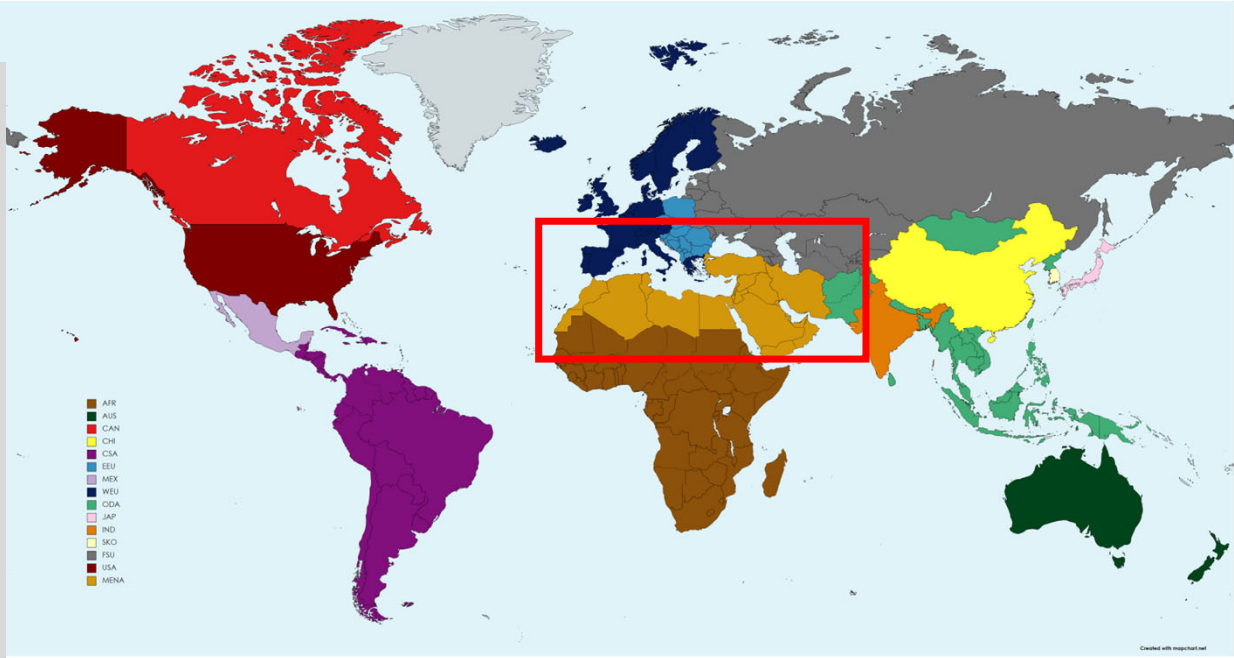
# THE GEOGRAPHIC DISAGGREGATION

- A geographical disaggregation of the MENA region would make it possible to address several points:
  - **Make hydrogen trade options more precise**: transport costs are highly dependent on distance for example.
  - **Better taking into account the electric typology of the region**: interconnection already do exist between MENA countries and further integration is discussed.
  - **Align with scientific literature on the subject**: this is a block that has already been studied as such in numerous research projects.
- But a more detailed disaggregation of the area poses difficulties in terms of data: they are often difficult to access, and sometimes non-existent.



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# FUTUR DEVELOPMENT IDEAS

## NEW GEOGRAPHIC DISAGGREGATION

North Africa/Middle East

Four zones disaggregation

Country case studies

## INCORPORATION OF HYDROGEN STRATEGIES

Integration of national hydrogen strategies regarding hydrogen production and exports

Integration of RepowerEu targets regarding hydrogen

## INTEGRATION OF THE WATER-ENERGY NEXUS

Water Consumption

Desalination technologies implementation

## CONSIDERATION OF ELECTRICITY SYSTEMS

Impact of hydrogen strategy on domestic/regional power system

Enhanced interconnection opportunities



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# Thank you for your attention


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# MENA: RENEWABLE ENERGY & NET ZERO EMISSIONS TARGETS

| Country | RE share in electric power generation target (year) | Share in 2021 (including hydro and nuclear) (EIA, 2022) | Net Zero target (year) |
|---|---|---|---|
| Algeria | 27% (2035) | 1.17% | |
| Barhain | 10% (2035) | 0.04% | Yes (2060) |
| Egypt | 42% (2035) | 11.55% | |
| Iran | 5% of installed capacities (2021) | 4.77% | |
| Iraq | 33% (2030) | 5.43% | |
| Israel | 30% (2030) | 14.42% | Yes (2050) |
| Jordan | 50% (2030) | 23.26% | |
| Kuwait | 15% (2030) | 0.07% | |
| Lebanon | 30% (2030) | 5.48% | |
| Lybia | 10% (2025) | 0.02% | |
| Morocco | 52% (2030) | 19.88% | |
| Oman | 30% (2030) | 0.43% | Yes (2050) |
| Qatar | 20% (2030) | 0.30% | |
| Saudi Arabia | 50% (2030) | 0.26% | Yes (2060) |
| Syria | | 4.69% | |
| Tunisia | 35% (2030) | 4.75% | |
| Turkiye | 38.8% (2023) | 36.71% | Yes (2053) |
| UAE | 44% (2050) | 4.94% | Yes (2050) |
| Palestinian Territories | 20-33% (2040) | 23.38% | |
| Yemen | 15% (2025) | 16.98% | |

# HYDROGEN AMBITIONS AND STRATEGIES

| | COUNTRY | STRATEGY ? | ROADMAP ? | MAIN TARGETS | EXPORTS ORIENTATION |
|---|---|---|---|---|---|
| GROUP 1 | **SAUDI ARABIA** | UC | YES (2023) | ▪ Annual production target of 1.9 Mt/year of clean H2 by 2030 and 4 Mt/year by 2035.<br>▪ Capture 10% of global demand by 2030 | ▪ Strongly export-oriented<br>▪ MoU with Japan, the Netherlands, China, Germany |
| | **UNITED ARAB EMIRATES** | YES (2023) (not publicly released) | YES (2021) | ▪ Production target of 1.4 Mt/year by 2031 and 15 Mt/year of $H_2$ by 2050.<br>▪ Two hydrogen production hubs by 2031.<br>▪ Capture 25% market of global trade of $H_2$ in 2030.<br>▪ Blue, green and nuclear powered $H_2$. | ▪ Strongly export-oriented<br>▪ MoC with Japan and cooperation of agreement with Russia<br>▪ Domestic market: iron and steel and sustainable kerosene |
| | **OMAN** | YES (2022) | NO | ▪ Annual production target of 1 Mt of green $H_2$ by 2030, 3.75 Mt by 2040 and up to 8.5 Mt by 2050.<br>▪ Creation of a state-owned entity, HYDROM, entitled to handle and implement the national $H_2$ strategy. | ▪ Strongly export-oriented<br>▪ Domestic market for refining |

# HYDROGEN AMBITIONS AND STRATEGIES

| | COUNTRY | STRATEGY ? | ROADMAP ? | MAIN TARGETS | EXPORTS ORIENTATION |
|---|---|---|---|---|---|
| GROUP 2 | Algeria | | YES (2023) (not publicly released) | ▪ Meet 10% of UE clean $H_2$ needs by 2040.<br>▪ Produce and export 30-40TWh of gaseous and liquid $H_2$ and $H_2$ derivatives by 2040.<br>▪ Blue and green $H_2$.<br>▪ Develop a national demand in iron and steel sectors. | ▪ Strongly export-oriented.<br>▪ Target markets are Germany and Austria.<br>▪ Use of retrofitted pipelines throughout Italy and Spain. |

# HYDROGEN AMBITIONS AND STRATEGIES

| | COUNTRY | STRATEGY ? | ROADMAP ? | MAIN TARGETS | EXPORTS ORIENTATION |
|---|---|---|---|---|---|
| GROUP 3 | **MOROCCO** | YES (2021) | YES (2021) | ▪ Capture up to 4% of global demand for green molecules by 2030 (10 to 22 TWh) and up to 1% by 2050 (115 to 230 TWh).<br>▪ Focus on green $H_2$. | ▪ Strongly export-oriented.<br>▪ Joint agreement with Portugal and Germany, MoU with EU.<br>▪ Decarbonation of fertilizers production with green ammonia. |
| | **TUNISIA** | UC (2024) | TBR (2023) | ▪ Exportation of 6 million tones of green hydrogen to Europe by 2050.<br>▪ Focus on green hydrogen. | ▪ Strongly export-oriented.<br>▪ Pipeline connection via Italy.<br>▪ Cooperation with GIZ Germany for national hydrogen strategy development. |
| | **EGYPT** | UC | | ▪ Increase of domestic production of green $H_2$ by 60% in 2030 and 400% in 2040.<br>▪ Account for 5% of global renewable $H_2$ production, with 25% reserved for exports. | ▪ MoU with EU on Strategic Partnership for Renewable Hydrogen<br>▪ Decarbonation of industry, |
| | **TÜRKIYE** | YES (2023) | YES (2023) | ▪ Green $H_2$ production costs target: \$2.40/kg by 2035 and < \$1.20/kg by 2053.<br>▪ Electrolyzers capacities target: 2GW of by 2030, 5GW by 2035 and 70GW in 2053.<br>▪ Blue, turquoise and green $H_2$. | ▪ Focus is on domestic hard-to-abate sectors (chemicals, steel, glass, ceramics and transportation.)<br>▪ Surplus production will be exported. |

# CLIMATE AND ENERGY CHALLENGES OF THE MENA REGION

1

## 7 out of 13 OPEC members

Net oil and gas exporters whose economies are highly dependent on hydrocarbons (from 10% to 100% of export revenues).

## Carbon-intensive electricity mix

Electricity generated in the region is 90% hydrocarbon-based.

2


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## Vulnerability to climate change

A region with an often arid climate and high water stress.

## Socio-economic inequalities

Some of the world's richest countries exist alongside countries in conflict and/or extreme poverty.

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