HYDROGEN ENERGY IN VIETNAM, POTENTIAL, OPPORTUNITY AND CHALLENGE UNDER CHEMICAL-ENGINEERING PERSPECTIVE

Dr. Tran, Hoang Phi

Department Of Chemical Engineering

Faculty of Physics & Chemical Engineering – K11

phith@lqdtu.edu.vn

AGENDA

LE QUY DON Technical University

Climate change in Vietnam

Benefit & Drawback of Wind & Solar Energy

Hydrogen, A new Centre of Energy system

Hydrogen, For Energy Storage and Carrier

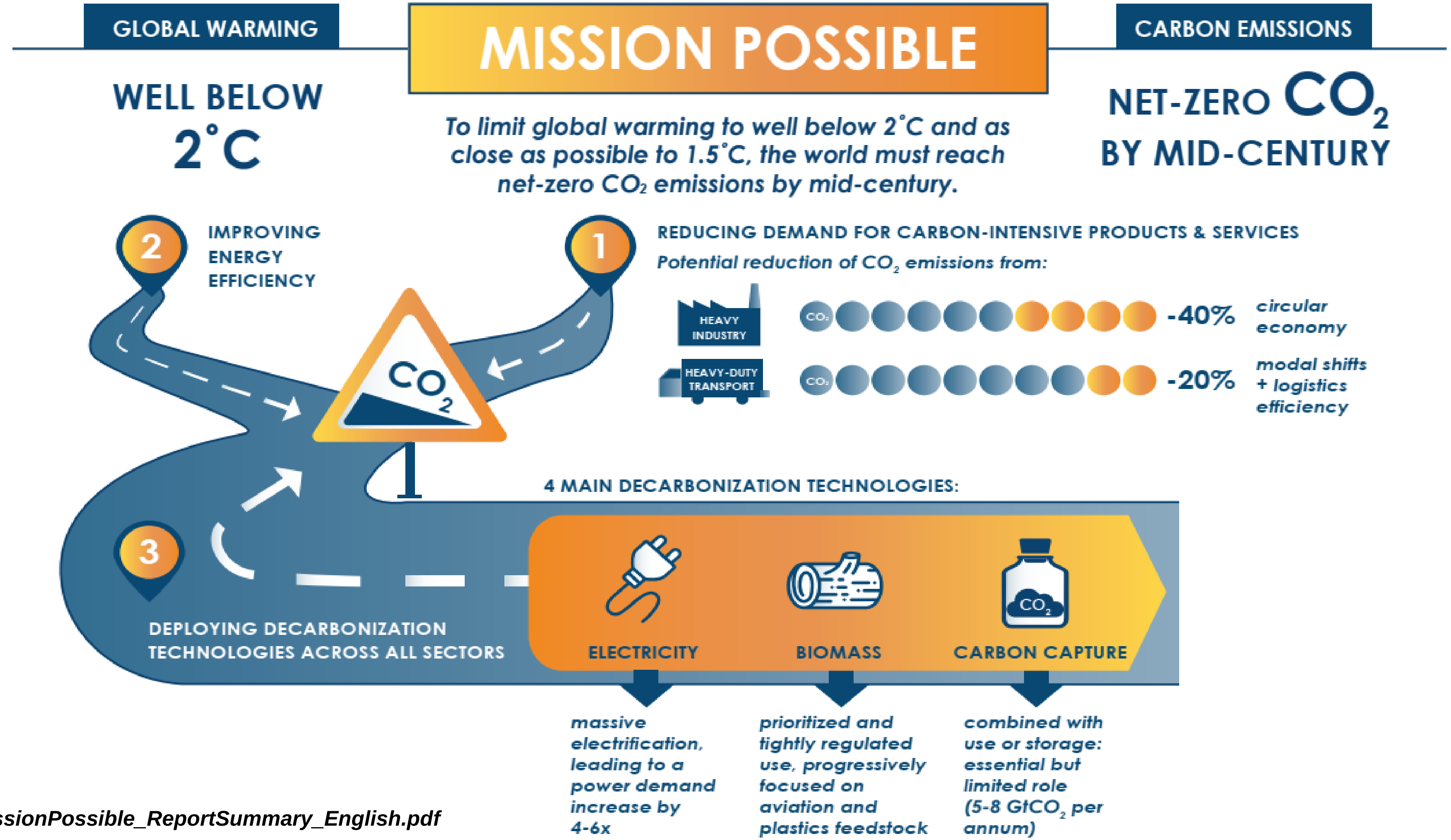
Hydrogen Generation: Electrolyser

Conclusion

I. CLIMATE CHANGE IN VIETNAM

November 03, 2016, the Vietnam Government has ratified the Paris Agreement

Three main routes for decabonization:



http://www.energy-transitions.org/sites/default/files/ETC_MissionPossible_ReportSummary_English.pdf

I. CLIMATE CHANGE IN VIETNAM

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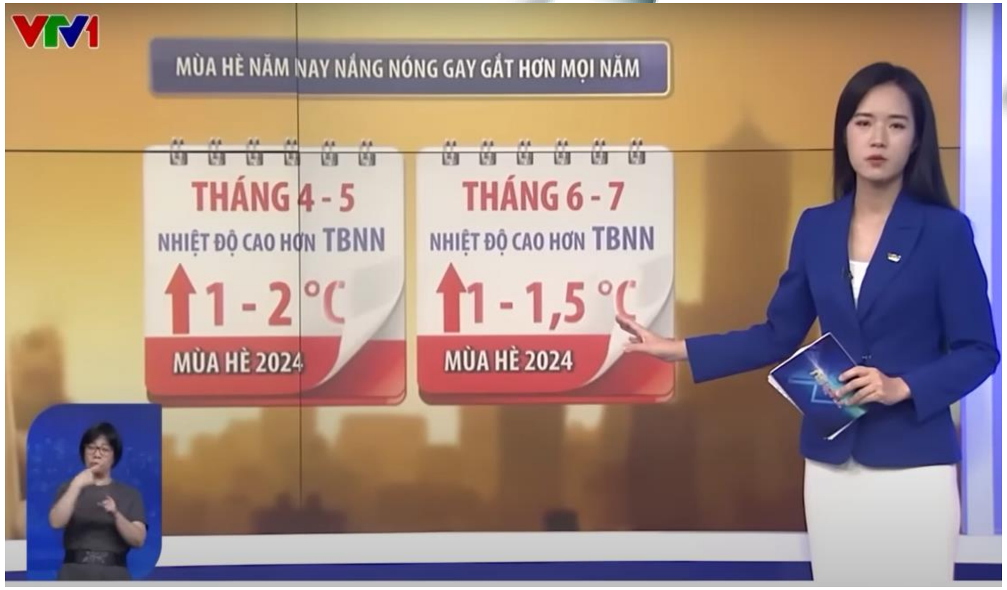


#. Thiên Tân: 5,2 cm
#. Jakata: 3,4 cm
#. Hồ Chí Minh: 2,8 cm

Vietname's Prime Minister, Pham Minh Chinh, announced net-zero target at COP26

I. CLIMATE CHANGE IN VIETNAM

Solar

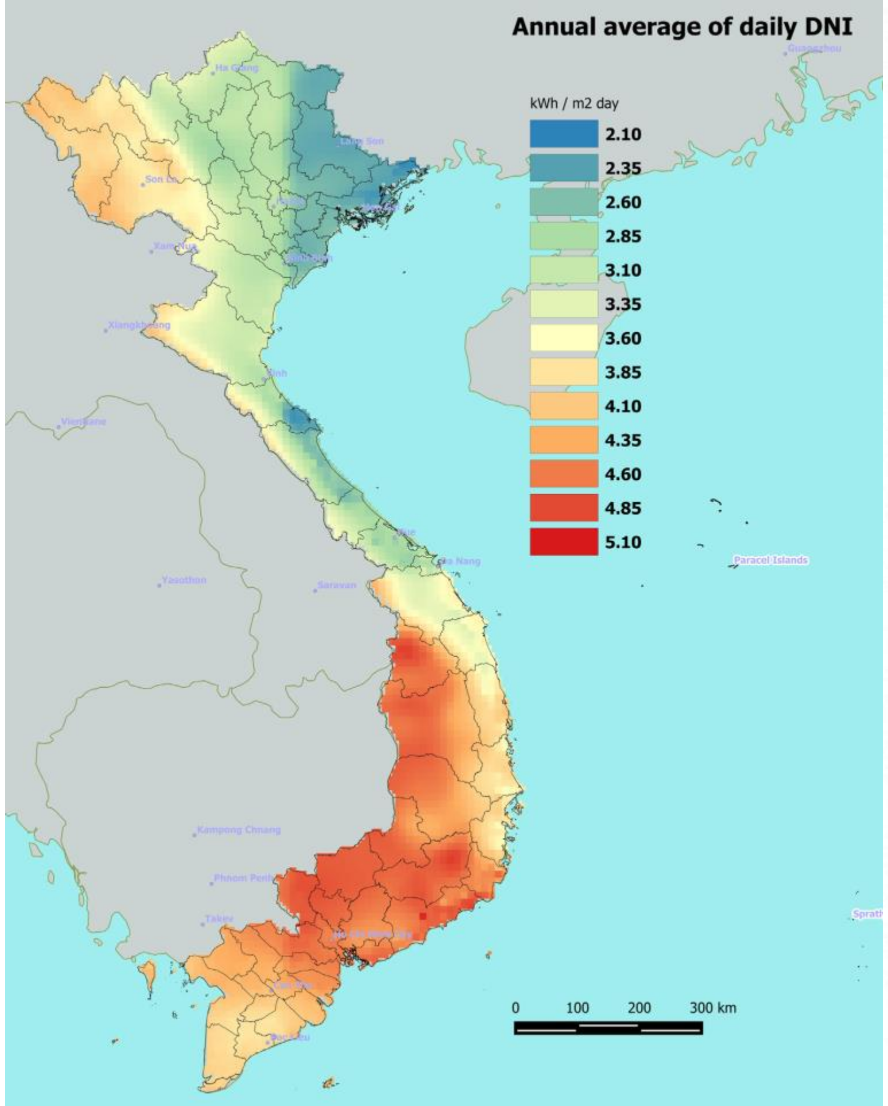
Wind

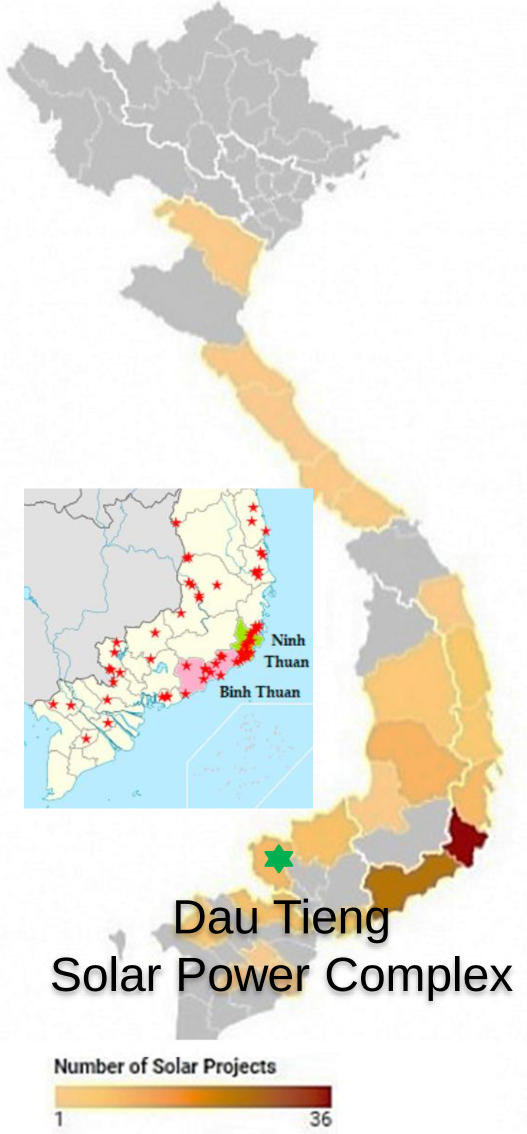
Hydropower

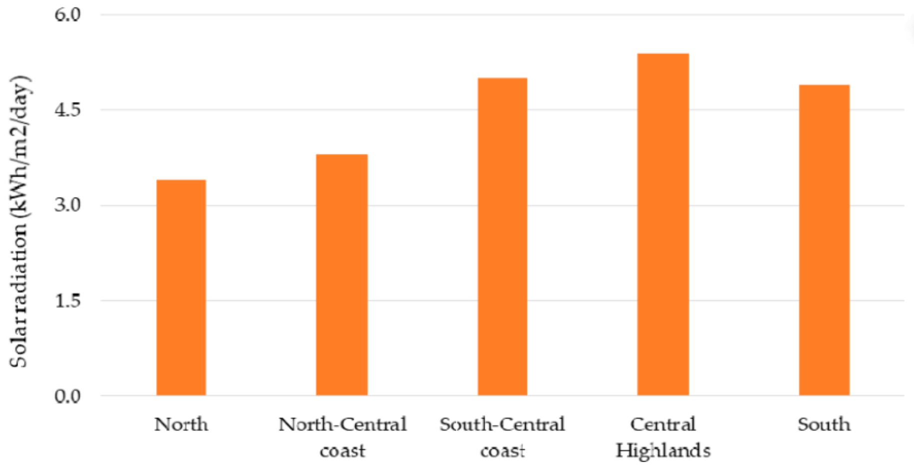
Electricity

Most renewable energy comes in form of free electrons

II. BENEFIT & DRAWBACK OF UNLIMITED ENERGIES





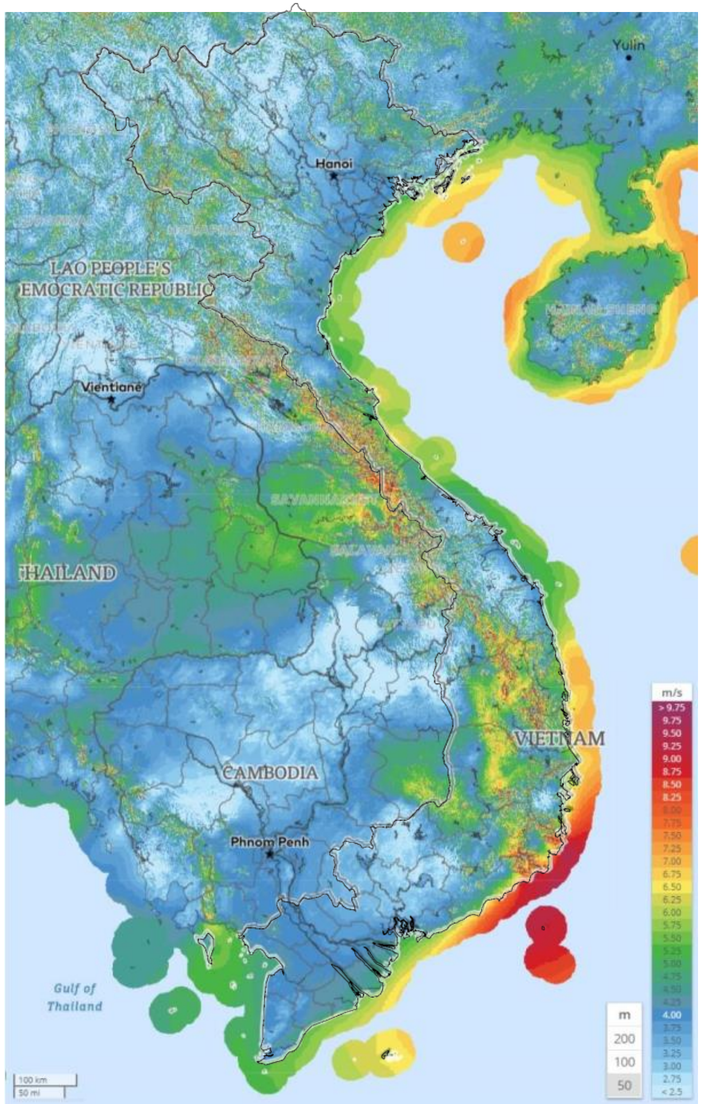


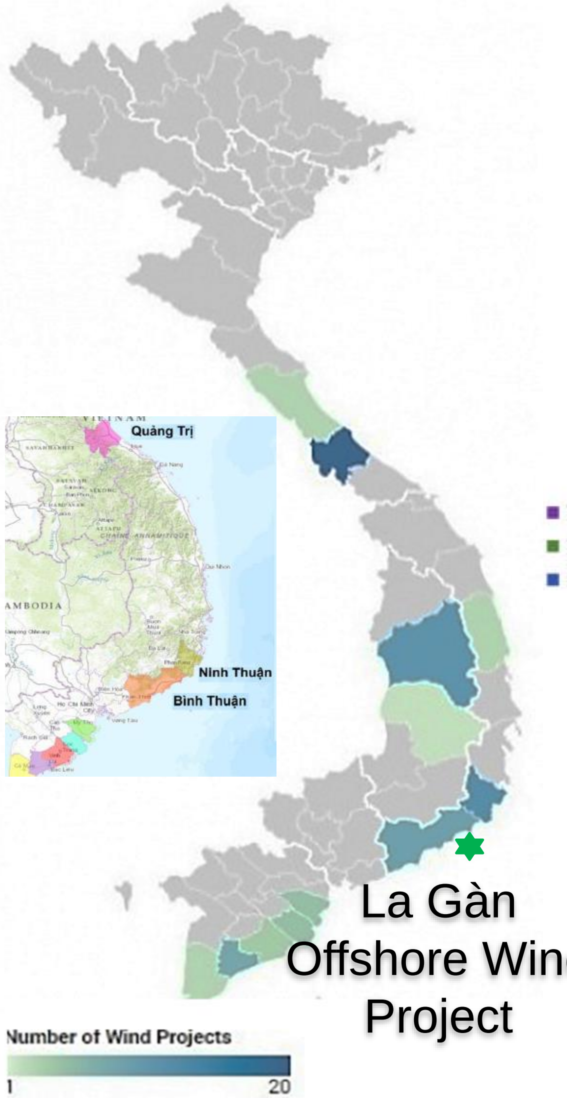
Vietnam: locate at the equator & tropical climate.
~ 2,500 hours of sunshine per year
⇒ solar radiation is stable over 4 seasons.

Vietnam showed the greatest potential for solar energy development in Southeast Asia.

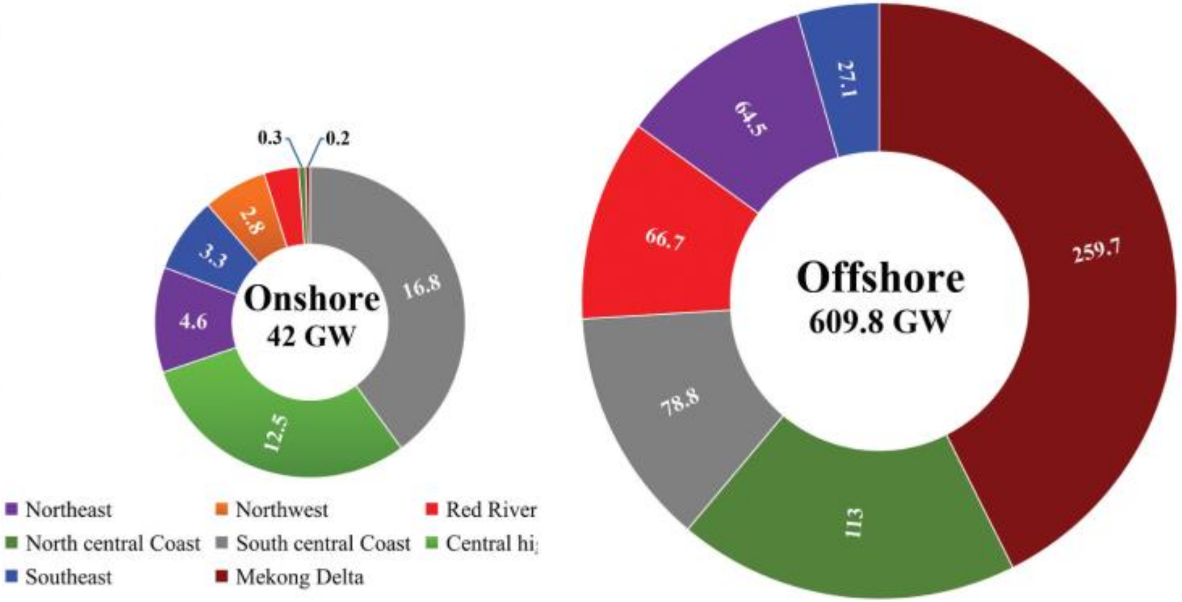
World Bank: Vietnam can reach 85 GW of solar power by 2030 and 214 GW by 2050

II. BENEFIT & DRAWBACK OF UNLIMITED ENERGIES





La Gàn Offshore Wind Project



Coastline > 3,200 km & many coastal areas & Yearly average windspeeds of 9 to 10 m/s

Vietnam have the best wind resources in Southeast Asia, especially nearshore/offshore and onshore coastal regions in the south.

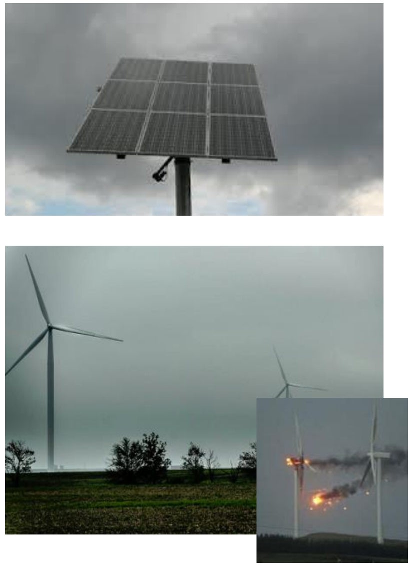
World Bank: Vietnam's offshore wind potential > 500 GW, onshore wind potential > 40 GW

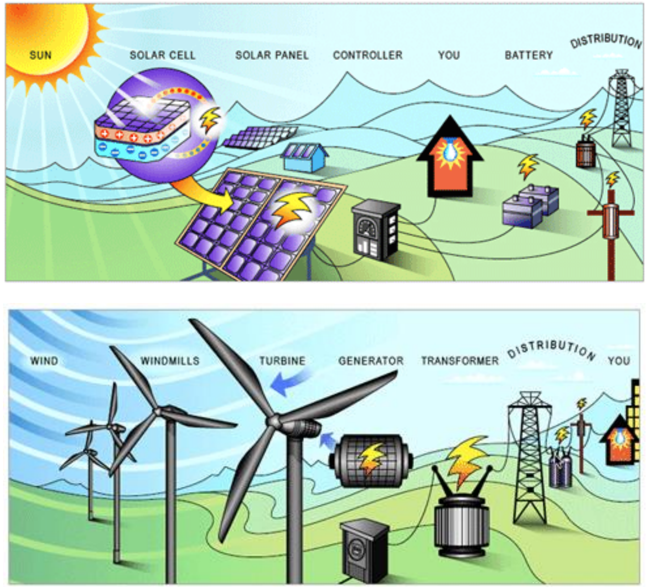
https://www.rvo.nl/sites/default/files/2019/02/Wind-Energy-Potential-Vietnam.pdf

Disadvantage of wind and solar energy

① Reliability of supply

② Long distance between generation & consumption

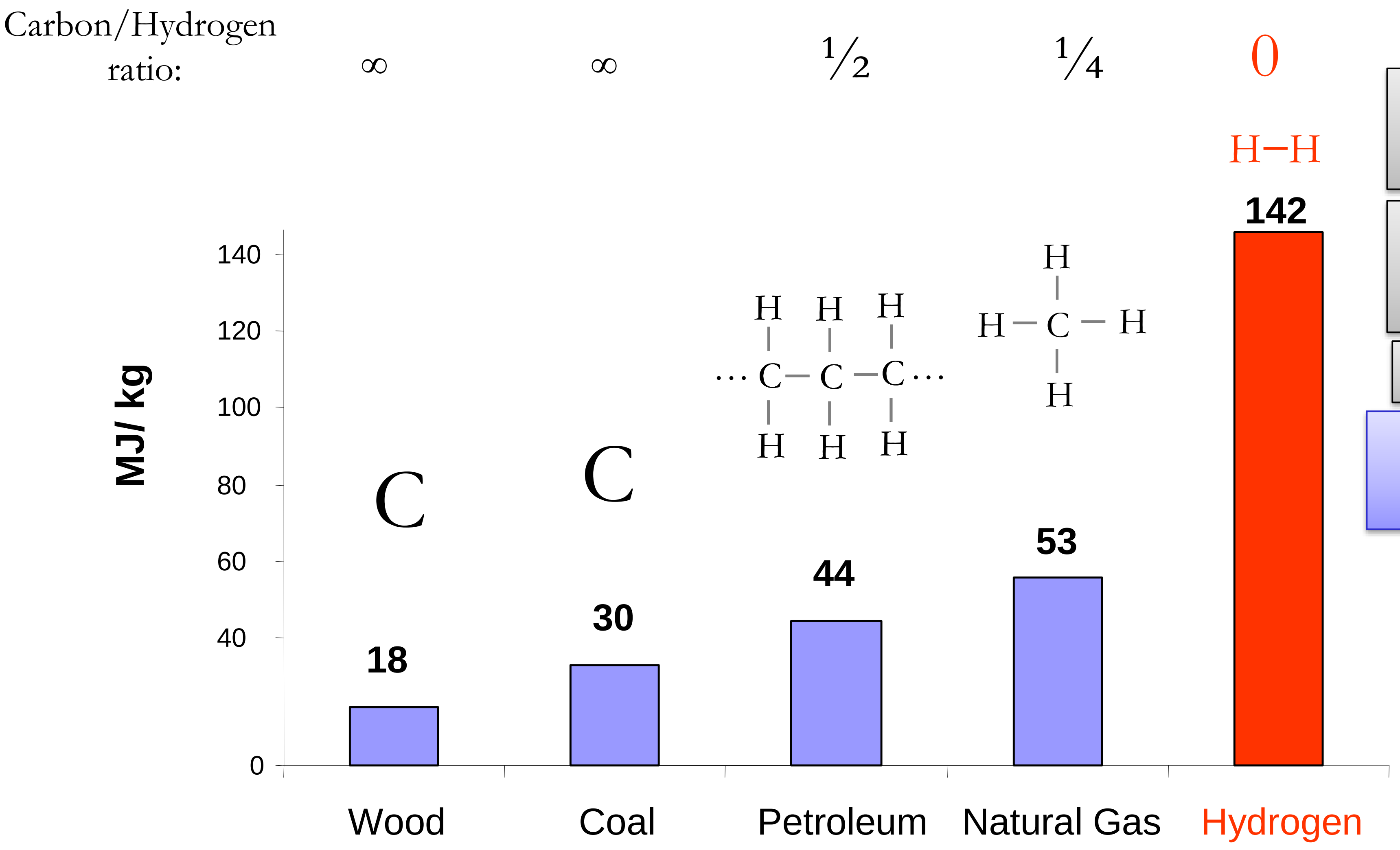




New energy carrier & storage system

- Renewable energy relies on the weather for its source of power: unpredictable, intermittent
- Long distance between generation and consumption: power line, pylon, power dissipation
- We need a new energy carrier and storage system

III. HYDROGEN, NEW CENTRE OF ENERGY SYSTEM

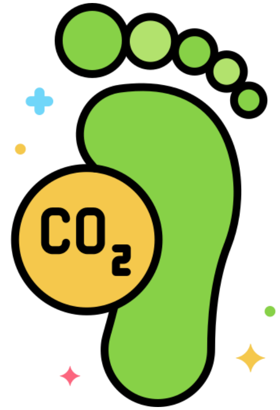


Hydrogen offers much higher energy content than fossil fuels

Hydrogen – the most abundant atom in the universe

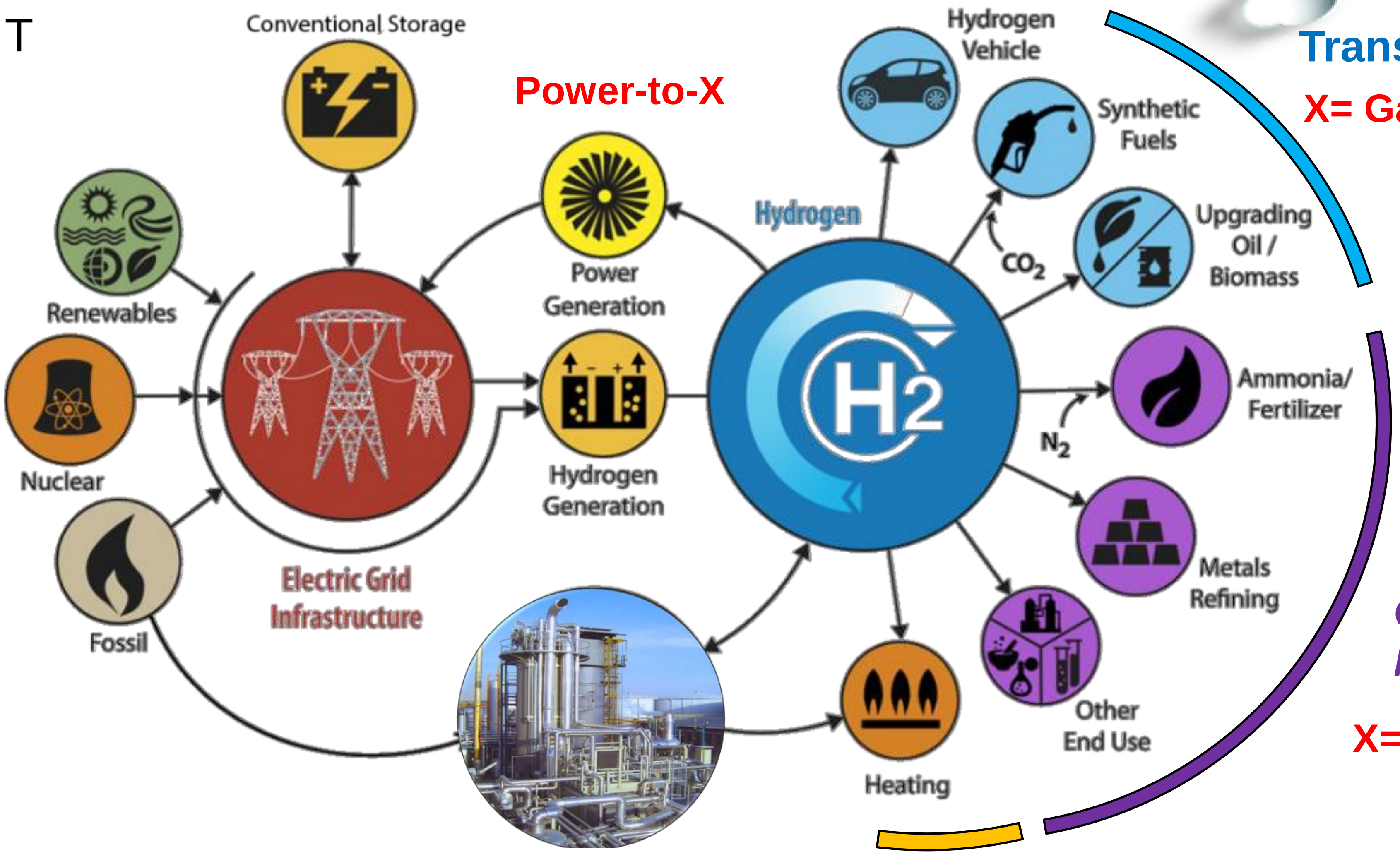
& no Carbon footprint

⇒ leads to **hydrogen** as ultimate energy carrier



T

Power-to-X



Transportation

X= Gas, Liquid

Chemical /Industrial

X= Chemical

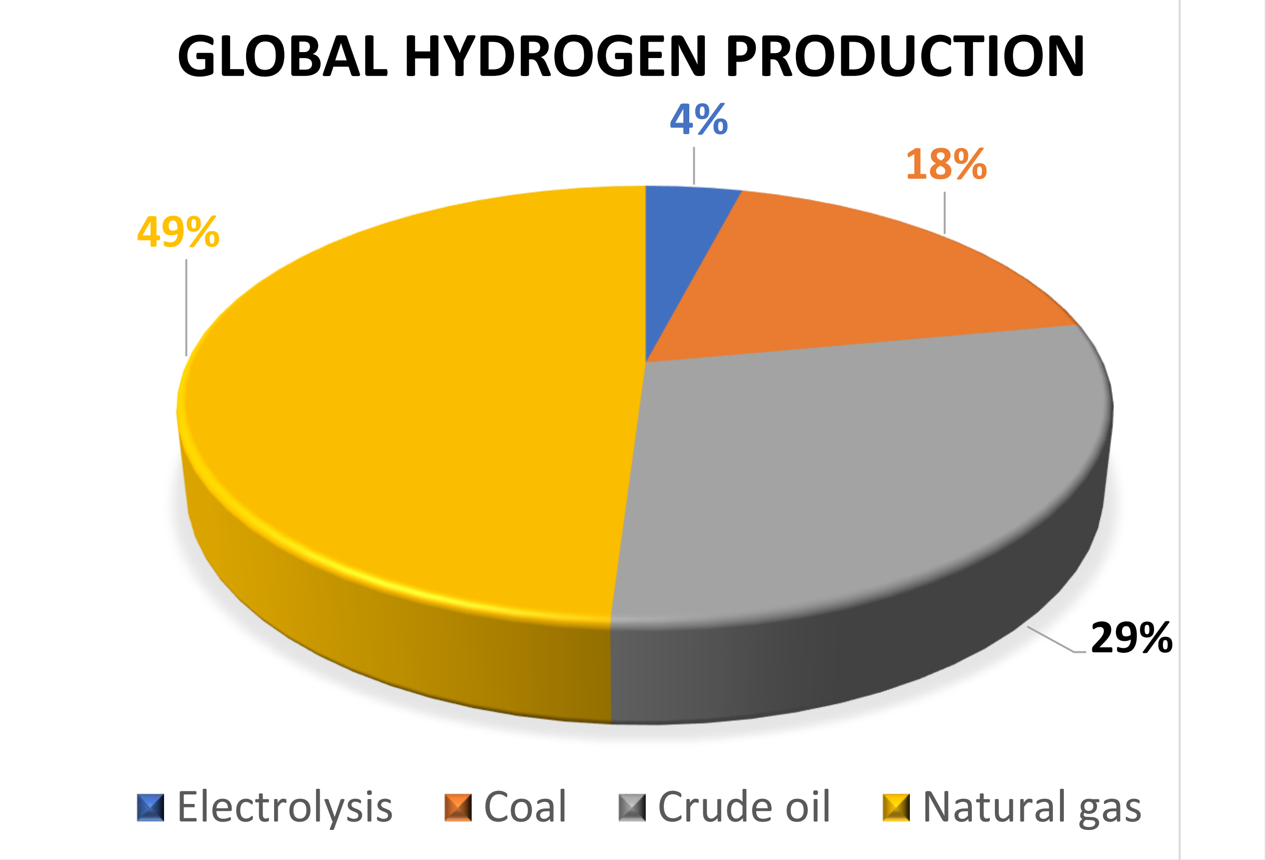
Traditional fossil thermal routes

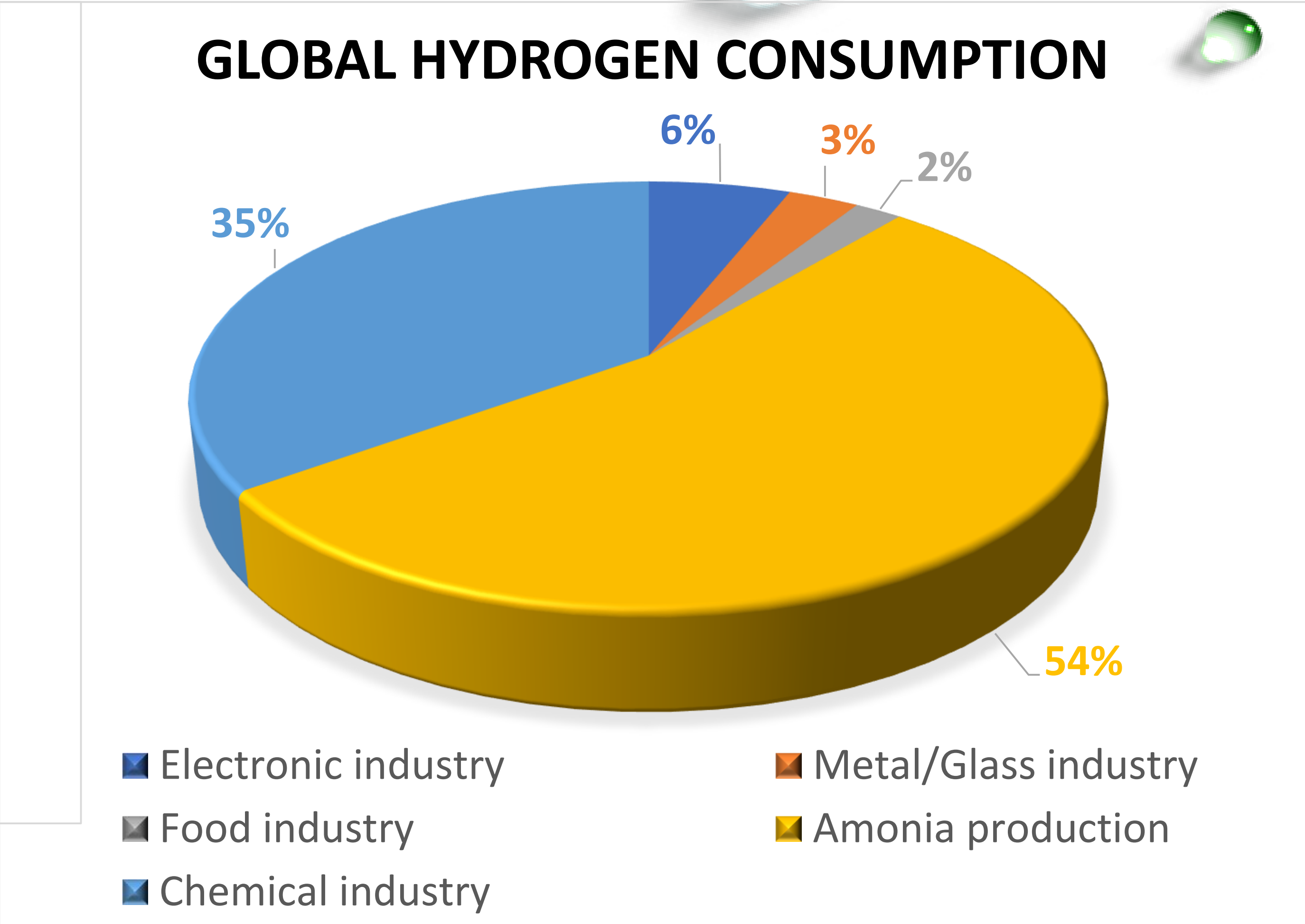
Buildings(heating)

X= heat

Green Hydrogen production and application

Clean Hydrogen Strategy and Roadmap, 2023
https://www.energy.gov/eere/fuelcells/h2scale





- ***4%-5%*** Hydrogen produced from electrolysis,
- ***Only 1%*** of global hydrogen output produced with renewable energy

https://www.sembcorpenergy.co.uk/blog/hydrogen-and-the-path-to-net-zero/

https://www.researchgate.net/publication/321781364

III. HYDROGEN, NEW CENTRE OF ENERGY SYSTEM

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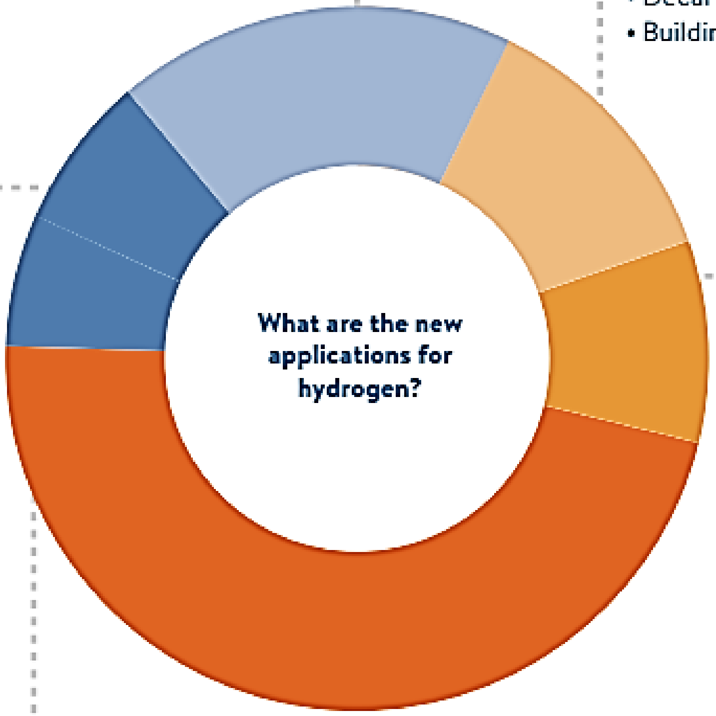
What is hydrogen used for in 2040?

STORAGE - 18,3%
- Seasonal energy storage 9,3%
- Intermittent renewables integration 7%
- Buffer to increase system resilience 2%

HEAT - 12,5%
- Decarbonise industrial heat 6,5%
- Building heating 6%

POWER - 13%
- Residential & Building CHP 7%
- Portable power 4,6%
- Stationary power 1,6%



INDUSTRY ENERGY USE - 9,3%
- Green ammonia 7%
- Low carbon steel 2,3%

MOBILITY - 46,9%
- Passenger cars 21,6%
- Heavy duty transport 9,5%
- Trains 4,9%
- Aviation 4,9%
- Material handling 2,3%
- Maritime applications 2,3%
- Buses 1,4%

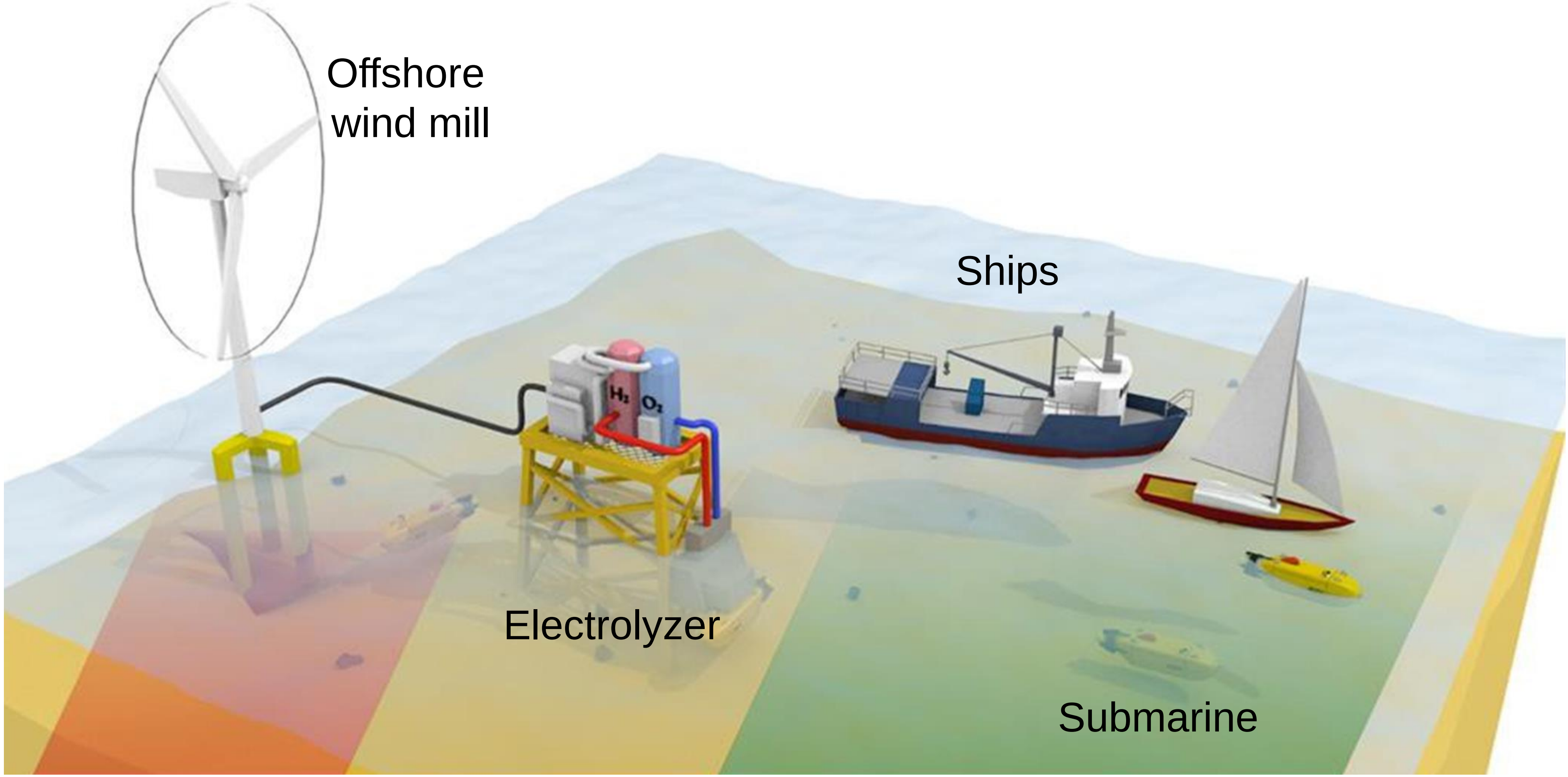
Main Application

Mobility
- Fast refueling/recharging
- Longer lifespan than battery
- Zero CO_2 emission

Heat
- Unlimited supply
- Decarbonization of heat
- Flexible to scaleup

Power system
- Seasonal storage of energy
- Flexible and scalable
- Long term: replacing natural gas with H_2 for power generation

IV. ENERGY STORAGE & CARRIER

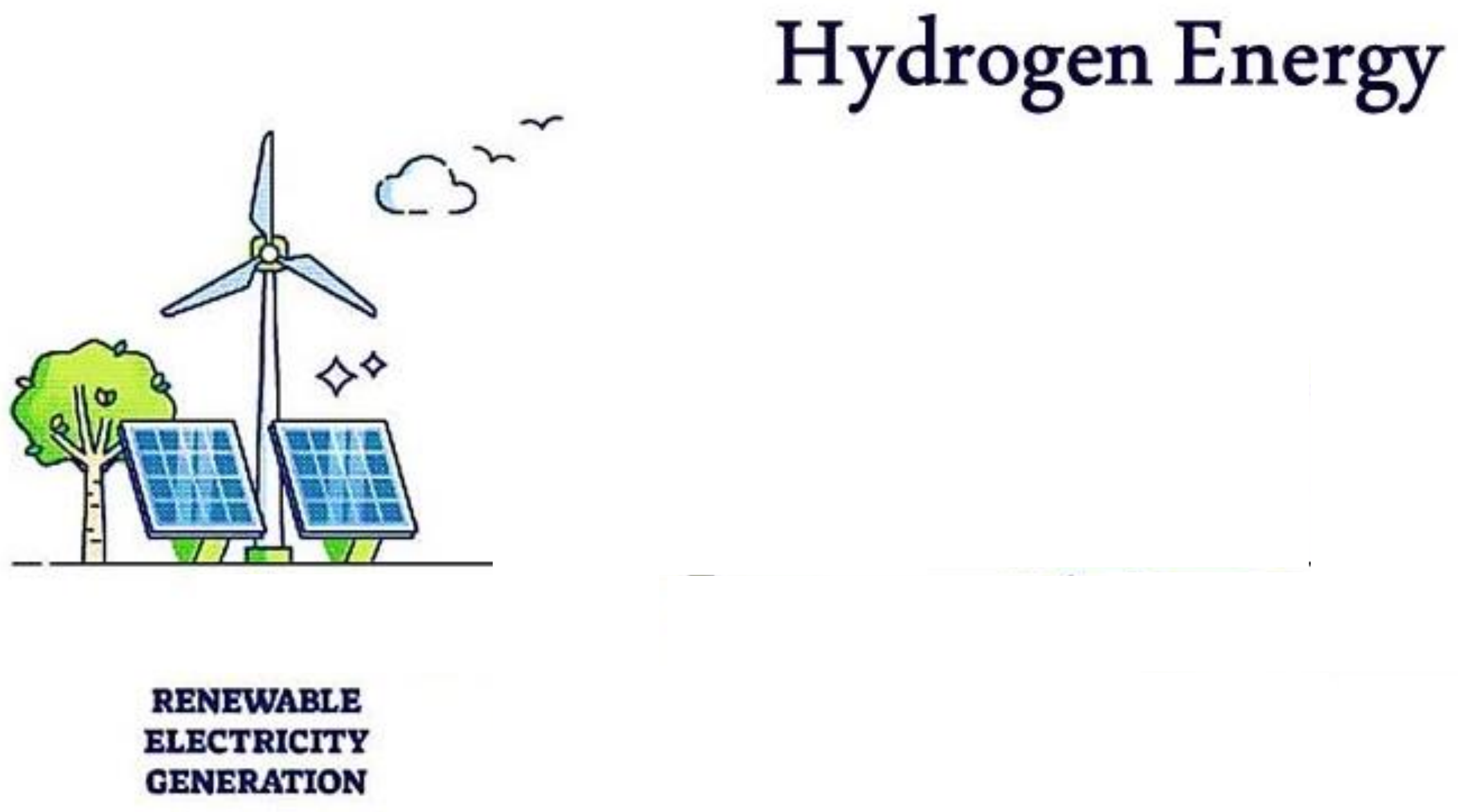


Energy generation

Conversion to H_2

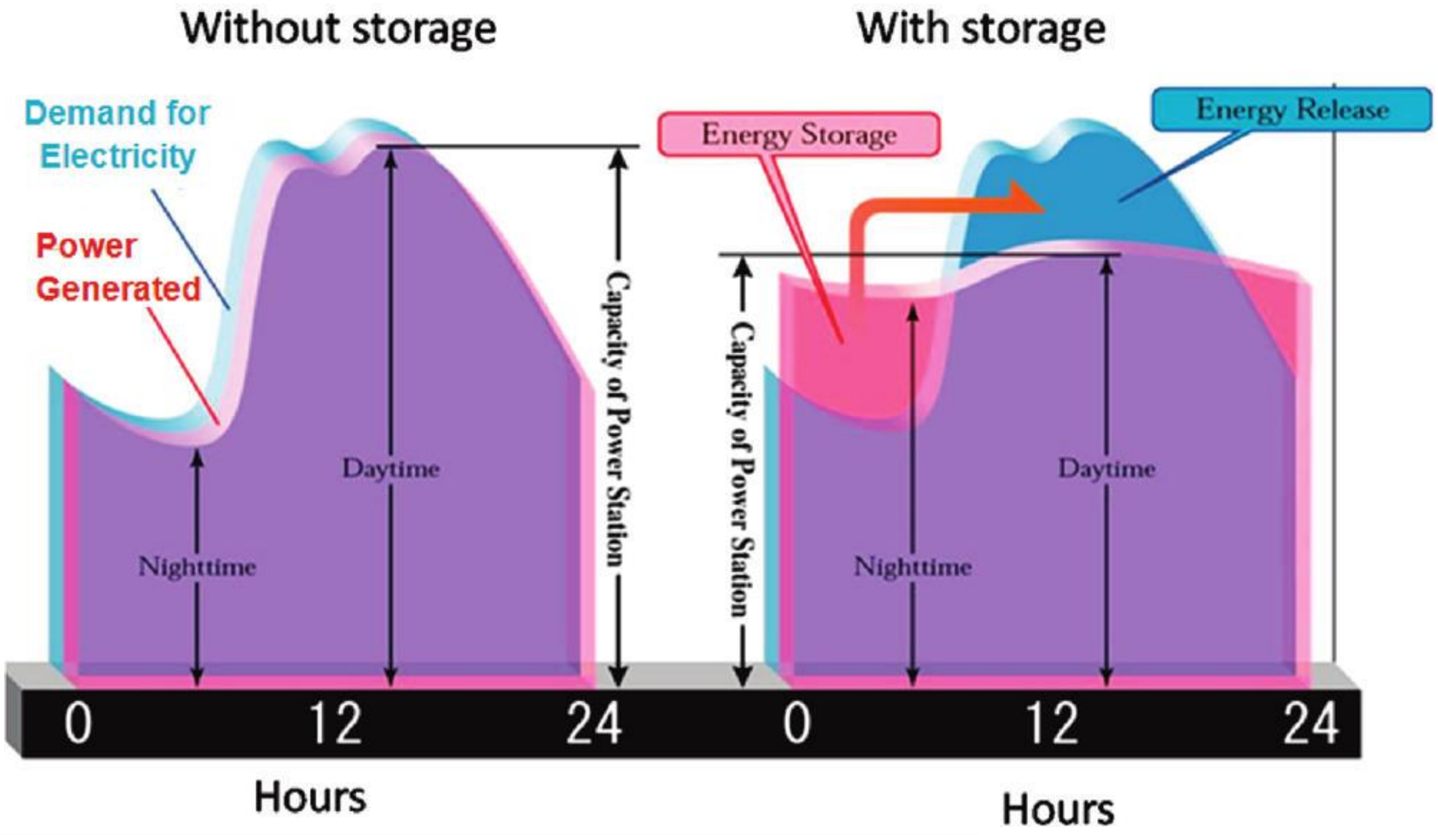
Transportation, Storage and distribution

Electrochemical Hydrogen Conversion with renewable electricity



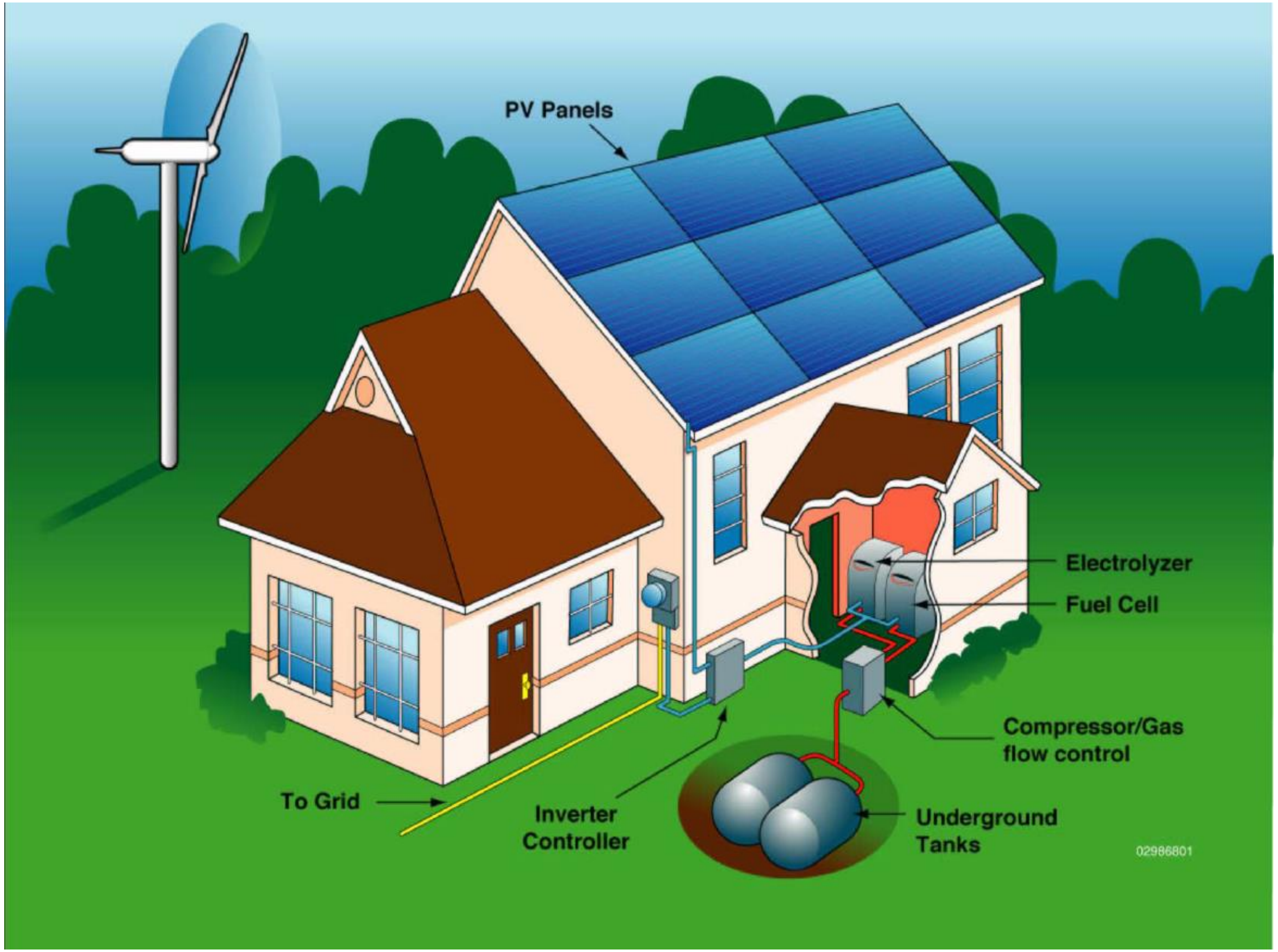
IV. ENERGY STORAGE & CARRIER

Intermittency challenge: PV power over one day / with and without energy storage



- Hydrogen can be liquified and keep in a proper tank
- Larger scale, hydrogen can be stored in Salt Caverns, to used in winter

IV. ENERGY STORAGE & CARRIER



Getting hydrogen into homes?

In US, Department of Energy attempts to reduce the cost of hydrogen to $1 for one kilogram, in one decade.

Hydrogen could be transported through our existing gas network and easily stored with conventional technology

IV. ENERGY STORAGE & CARRIER

Lack of Government policy

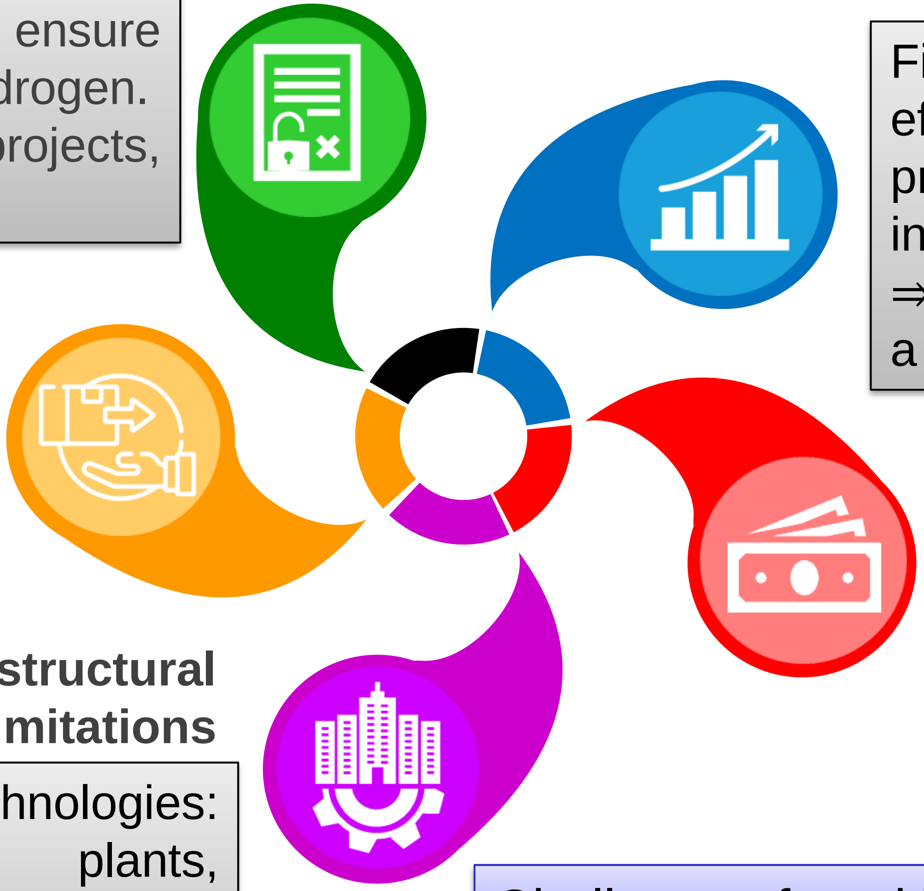
Applying taxes or other mechanism set the price of carbon high enough to ensure cost competitiveness for green hydrogen.
⇒ More investigation, R&D projects, policy-related changes.

Storage and distribution

Low energy density, flammability and low boiling point (-253^{0}C) of H_2, require specified materials for safety use.

Technology and infrastructural limitations

Many of the relevant technologies: compressors, conversion plants, storage tanks, transportation,… are not yet commercially ready.



Economy scale production

Final price depends on the efficiency and management of production as well as refueling infrastructure.
⇒ the need is to invest in building a robust hydrogen infrastructures

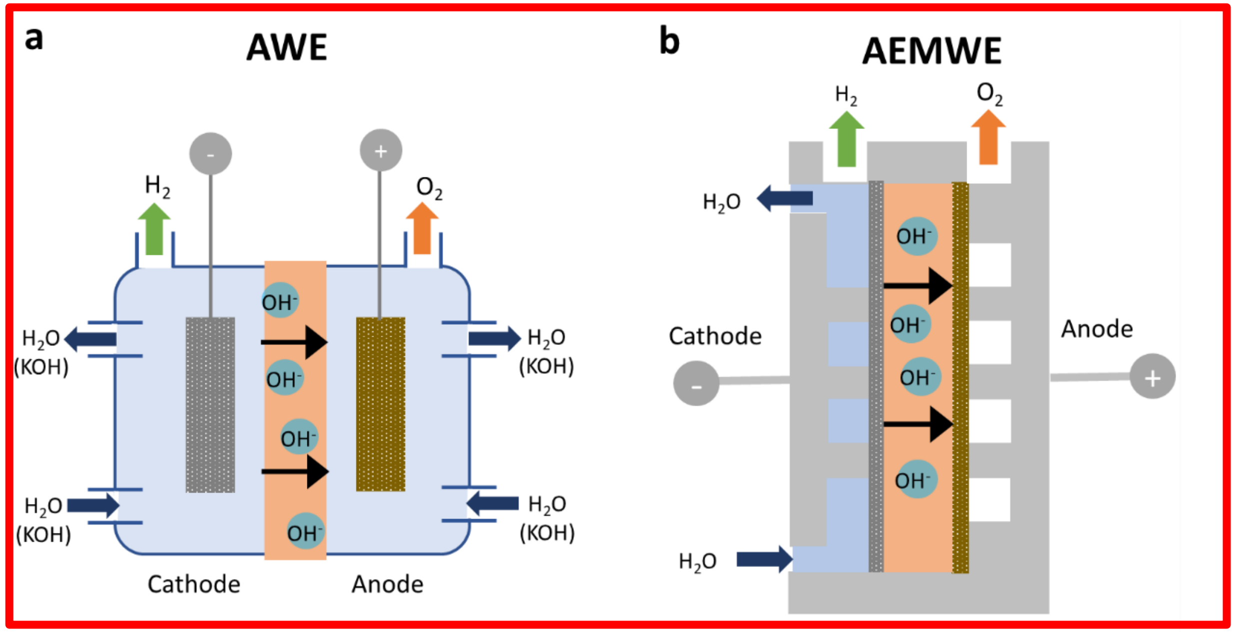
High cost

Cost for hydrogen is 5-6 $/kg. (target 1-2 $/kg ~ 30 $/MWh)
Caused by membrane/electrode and precious metallic catalysts

Challenges faced by Hydrogen as The Future Fuel

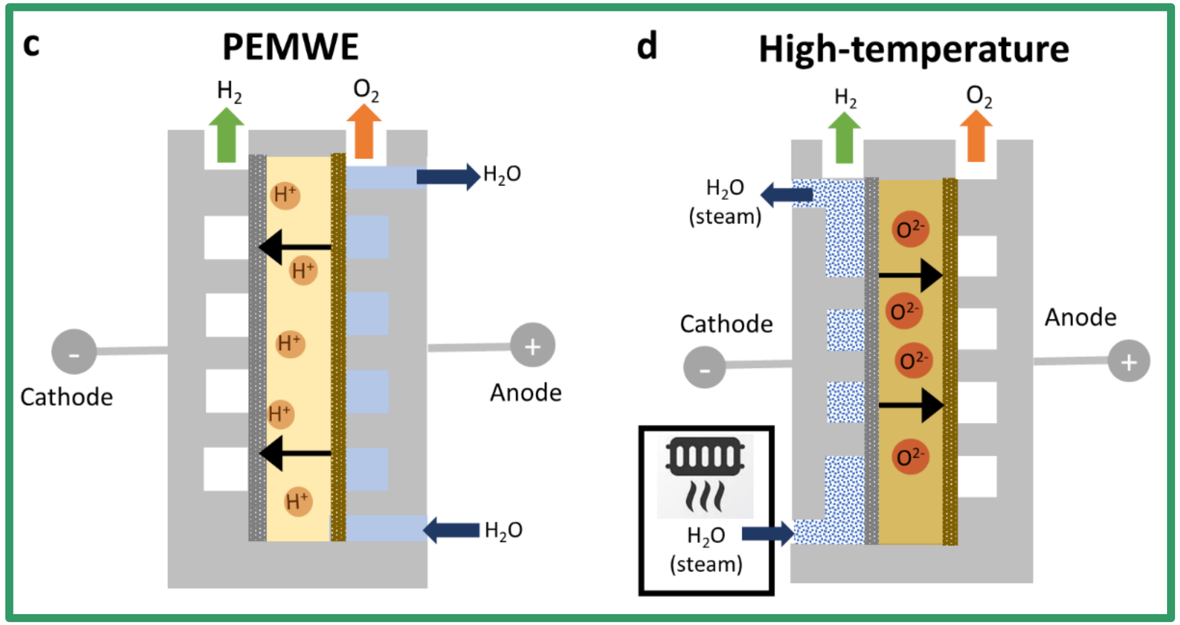
Nature Energy, **2020**, 5, 367–377

Dominating commercial electrolyser technologies:



- **Advantage:**
  - AEL long investigated technology
  - Mature diaphragm *(Zirfon)*
  - Non-noble catalyst
- **Disadvantage:**
  - Low current densities (300 mA cm^{-2})
  - High KOH concentrations (32 wt%)

Emerging electrolyzer technologies:



- **Advantage:**
  - Mature **p**roton **e**xchange **m**embrane *(Nafion)*
  - High current densities (2 - 10 A cm^{-2})
- **Disadvantage:**
  - Require ultra-purified water
  - Noble metal catalysts

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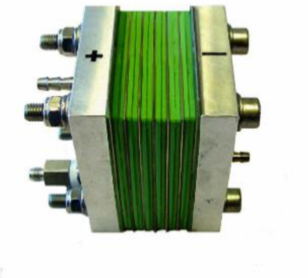
Acid PEM Water electrolyzers – Hydrogen from Electricity and ultraclean water

PEM stack

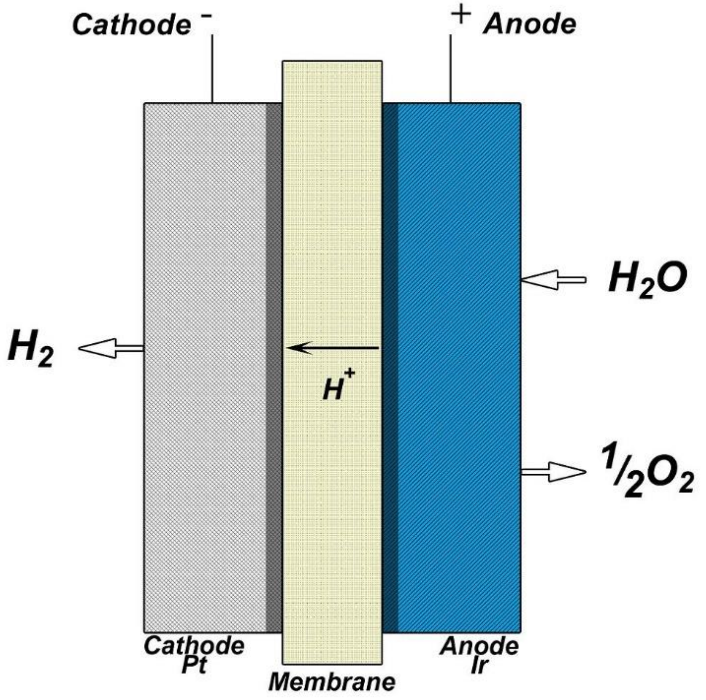


Cathodic Reaction

Hydrogen Evolution Reaction (HER)

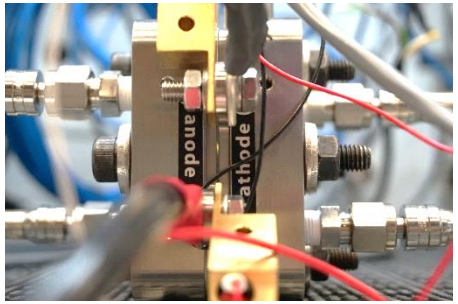
$$2H^+ + 2e^- \rightarrow H_2$$

- **Pt/C is commercialized**



$$H_2O \longrightarrow 2H^+ + \tfrac{1}{2}O_2 + 2e^- \quad \text{Anode}$$
$$2H^+ + 2e^- \longrightarrow H_2 \quad \text{Cathode}$$
$$H_2O \longrightarrow H_2 + \tfrac{1}{2}O_2 \quad \text{Total Reaction}$$

Single PEM cell



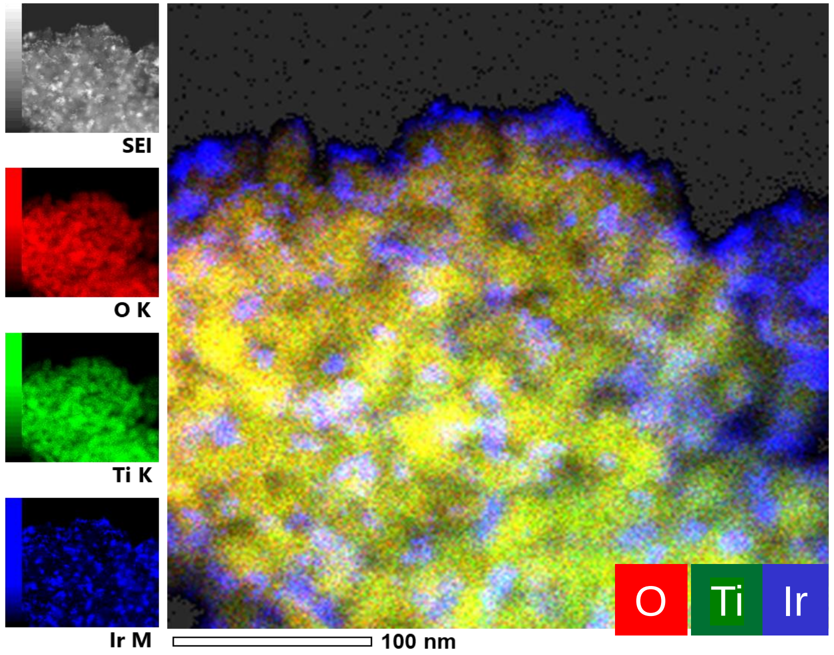
Anodic Reaction

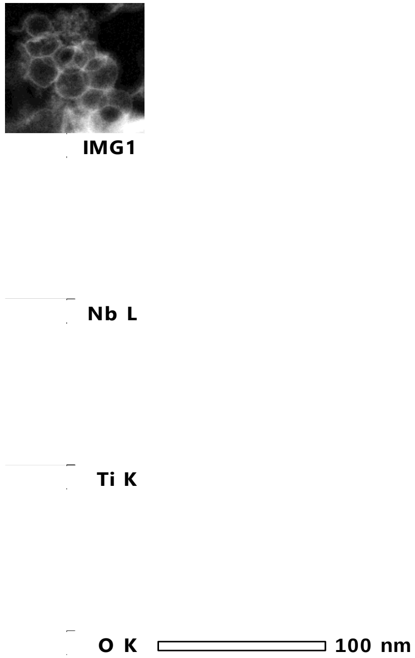
Oxygen Evolution Reaction (OER)

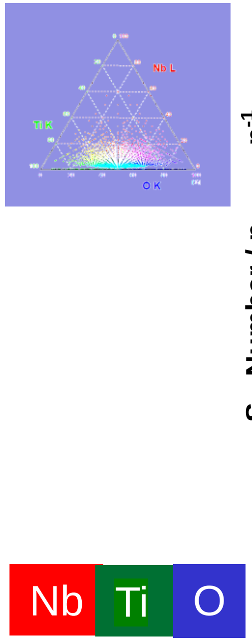
$$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$$

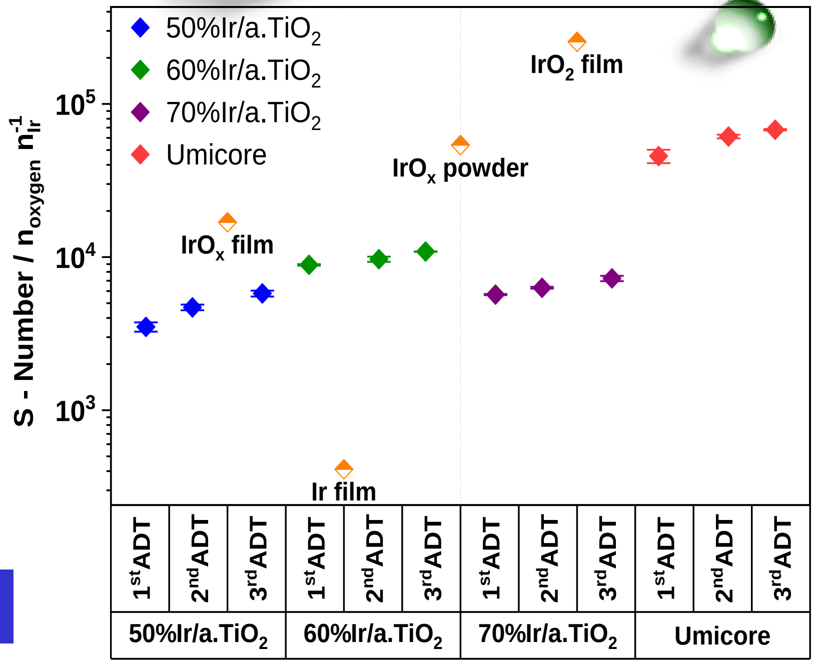
- **Replacement of Iridium ($0.5 g_{Ir}/kW$ to $0.01\ g_{Ir}/kW$)**
- **Increase efficiency (reduce Voltage losses)**

V. HYDROGEN GENERATION BY ELECTROLYSIS









- Synthesis of supported catalysts for reducing noble metal loading.
- Catalyst’s structure design of supported catalysts
- Stability and activity of the catalysts, in comparison to the commercial materials

ACS Catal. 2023, 13, 23, 15375–15392

Chem. Mater. 2022, 34, 21, 9350–9363

Zeitschrift für Physikalische Chemie, *234*(5), 787-812

Nature, 587, 408–413 (2020)

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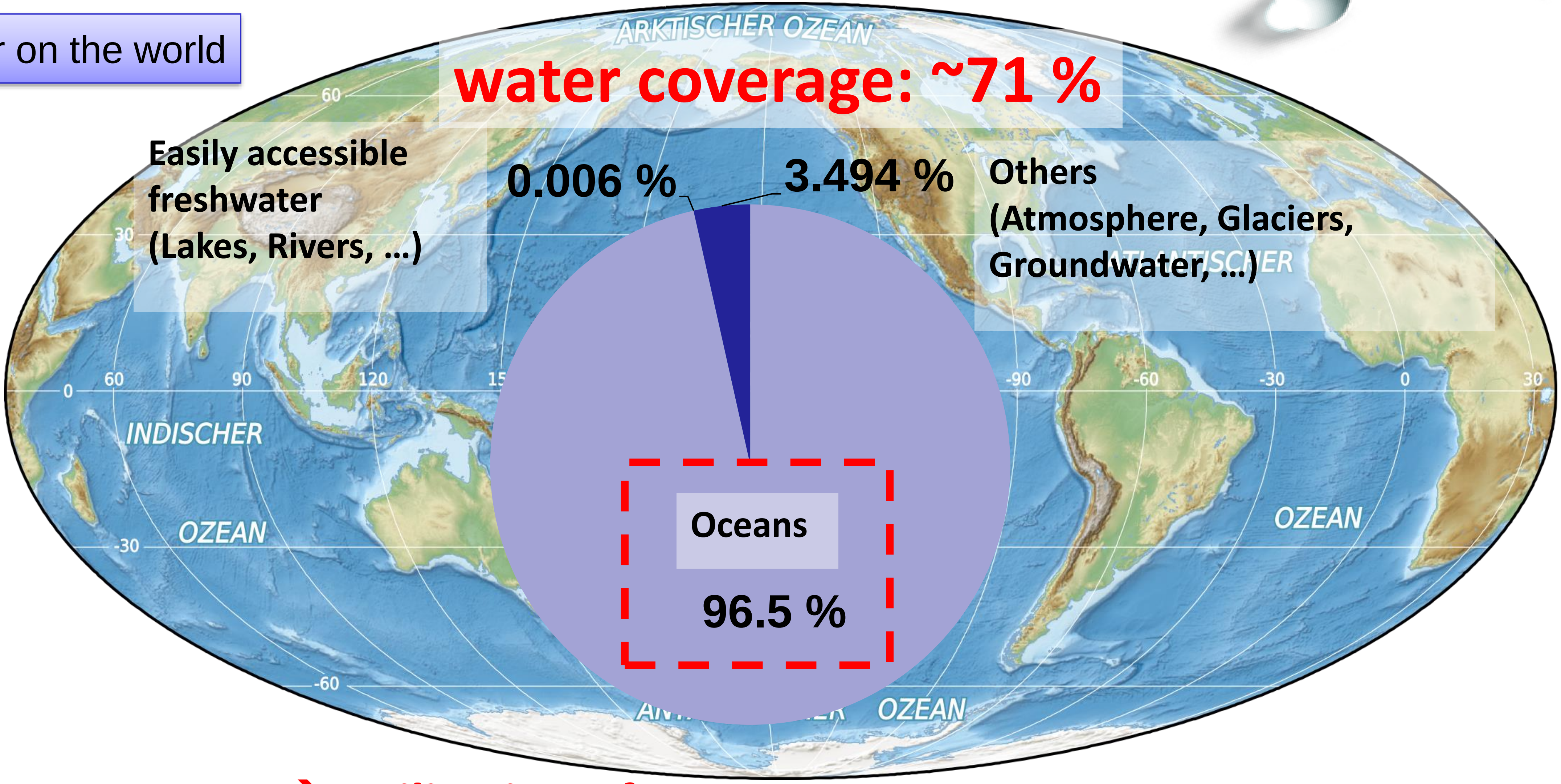
Water on the world

water coverage: ~71 %



→ Utilization of seawater as water resource

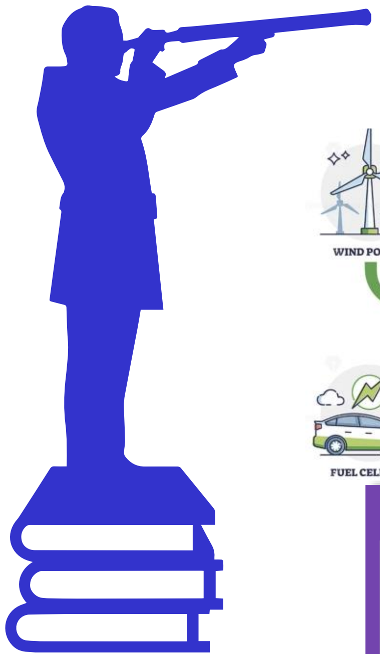
Source: *https://upload.wikimedia.org/wikipedia/commons/6/6a/World_oceans_map_mollweide_de.png*

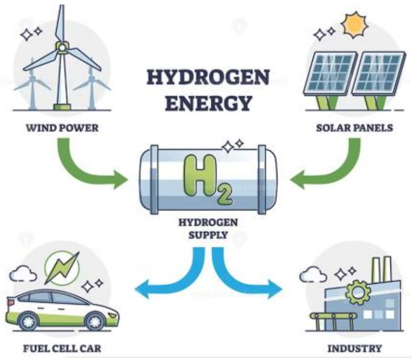
Source: *https://water.usgs.gov/edu/earthwherewater.html*

VI. CONCLUSION

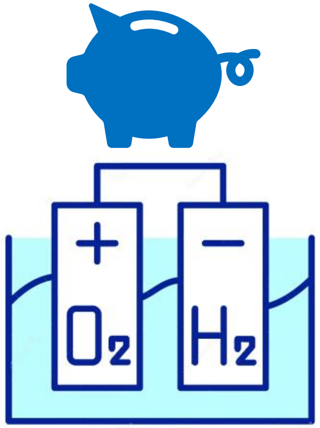
To unlock hydrogen economy:

- Demand for clean hydrogen must be stimulated
- Infrastructure must be developed to enable end-user access to H_2
- Cost competitiveness, by mass-production of clean H_2





Recognizing Hydrogen as Energy transition Solution

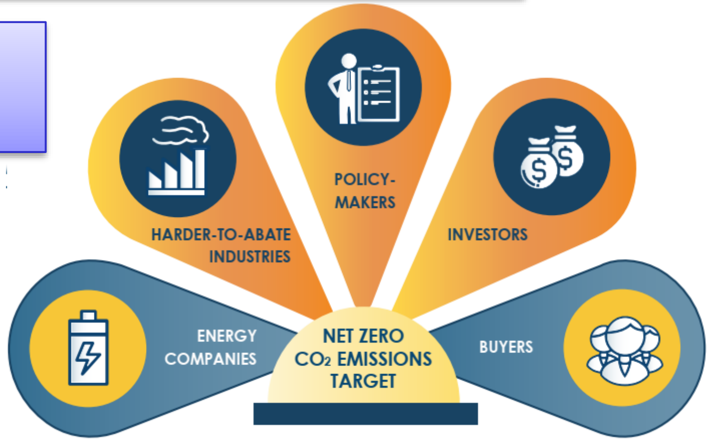


Investigating on R&D for higher cost effectiveness

Changing policy & Developing Infrastructure

Unlocking production pathways & building hydrogen market

HYDROGEN ECONOMY



Thank you for your attention