From Geologic Renewable Energy to Energy Storage-a Bright Future for Sustainable Energy

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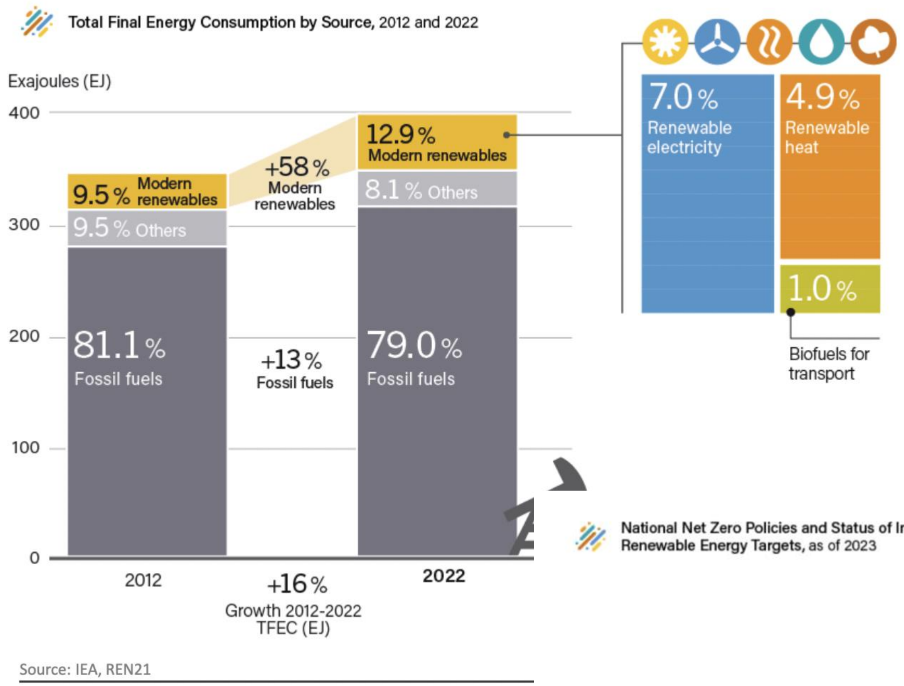
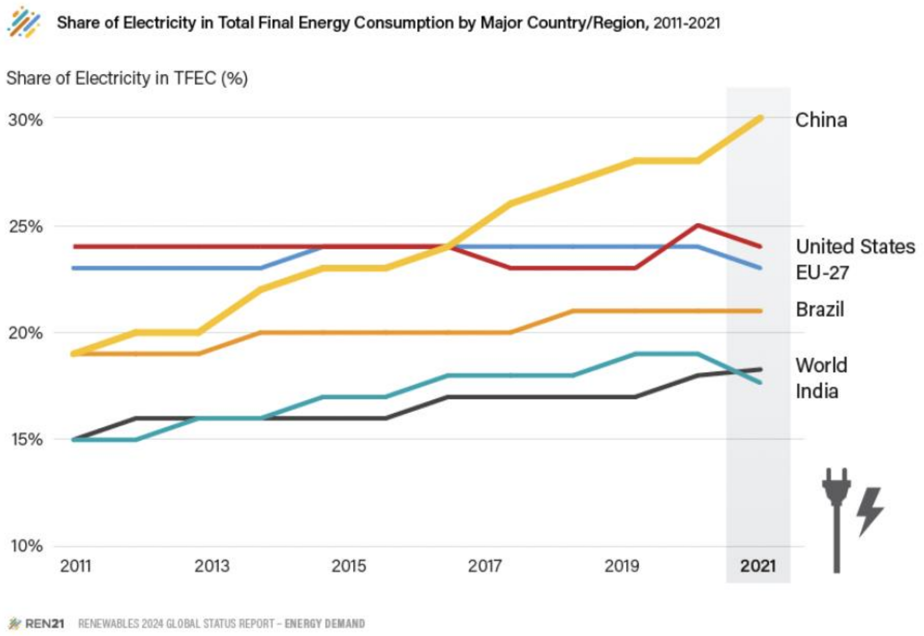
10.23.2024

- 1. Characters of Different Renewable Energy
- 2. Energy Conversion from surplus renewable
- 3. Physical and chemical to Subsurface Energy Storage Solution
- 4. Conclusions and Suggestions

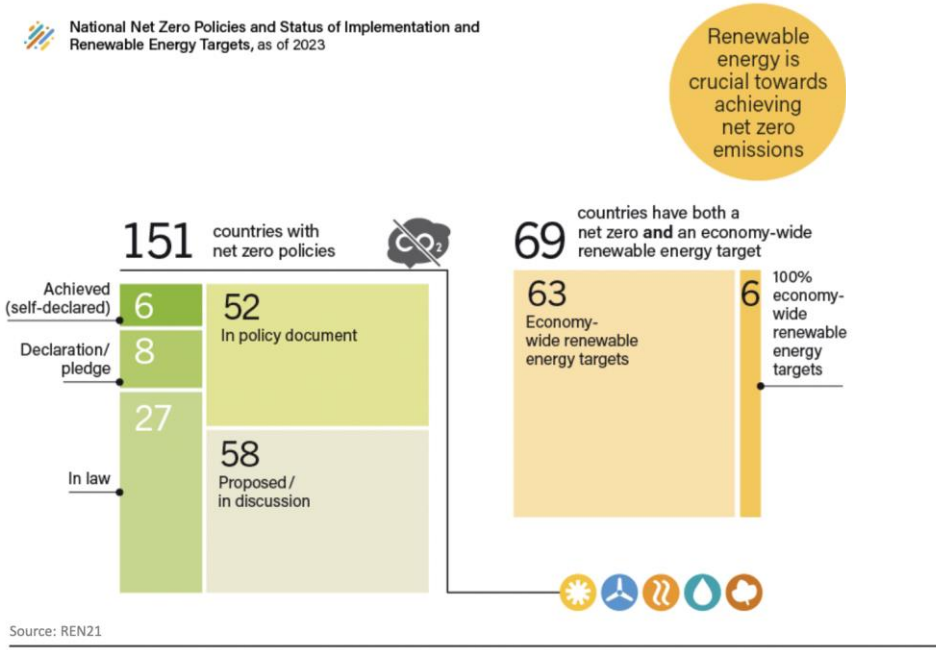
1. Characters of Different Renewable Energy





China is leading the energy consumption

Renewable is increasing, but long way to go



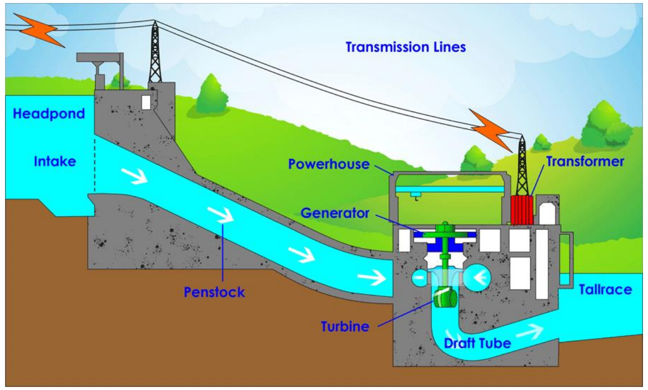
Most countries have net zero policies using renewable energy

1. Characters of Different Renewable Energy

Solar

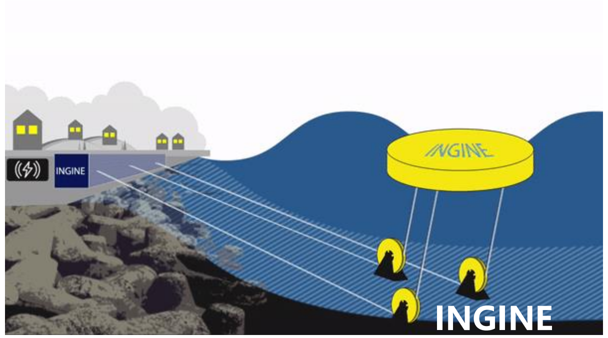
Biomass

Wind

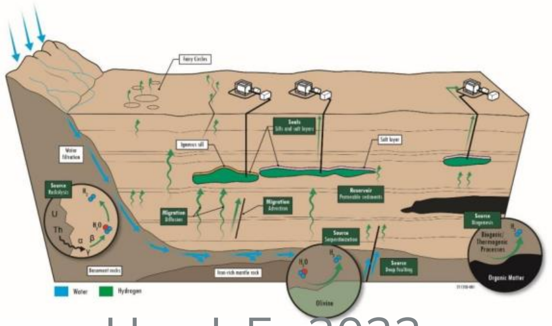


https://www.pinterest.com/pin/744149538411260886/

Hydropower

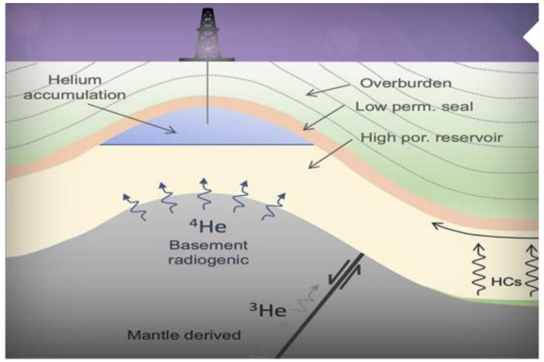


Wave



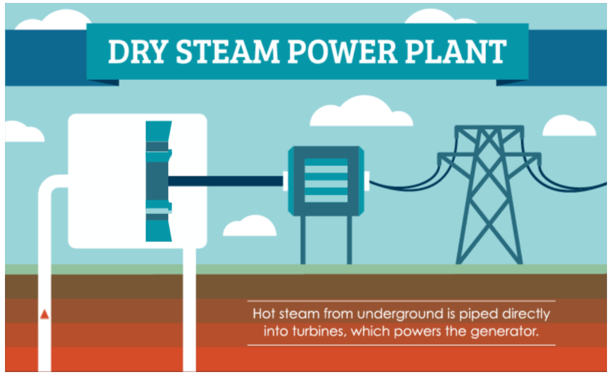
Hand, E., 2023

Hydrogen



Friedman,AAPG, 2023

Hellium



Geothermal

1. Characters of Different Renewable Energy

Advantages of Renewable Energy

1) Never run out
2) Zero Carbon Emission
3) Technology innovation
4) creates jobs

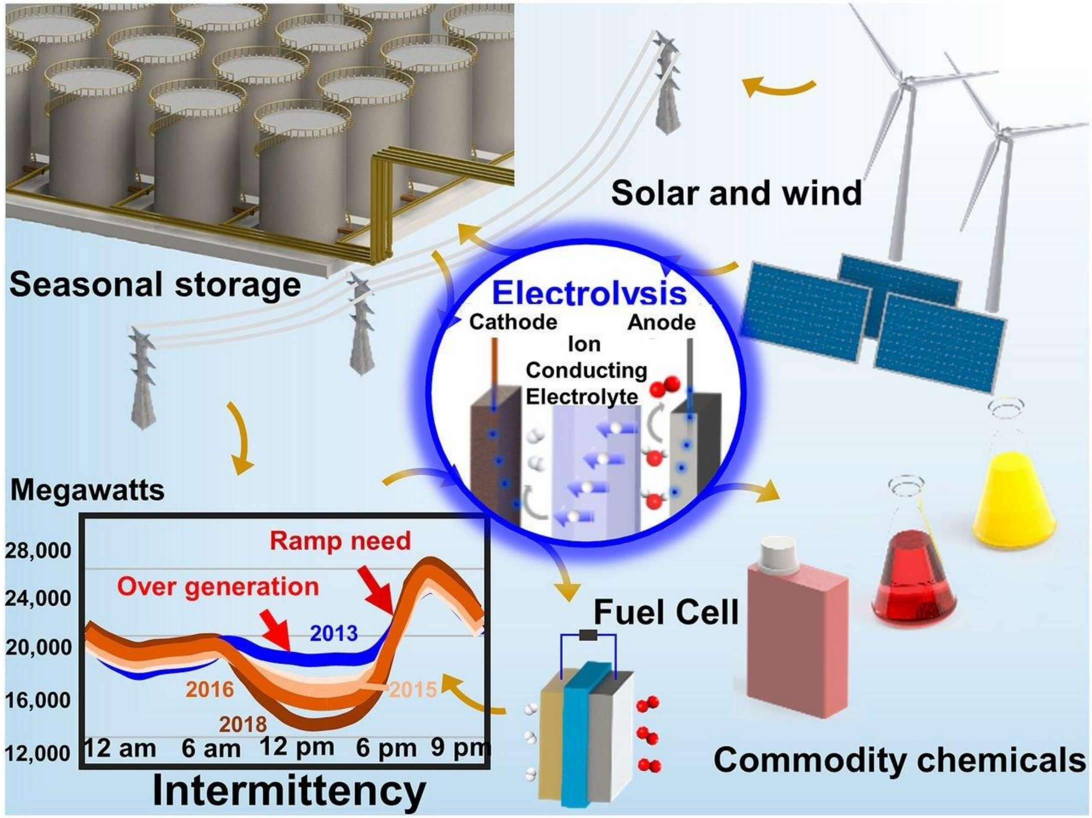
Disadvantages of Renewable Energy

1) Intermittent supply
2) Limited storage capabilities
3) Geographic limitations
4) high upfront costs

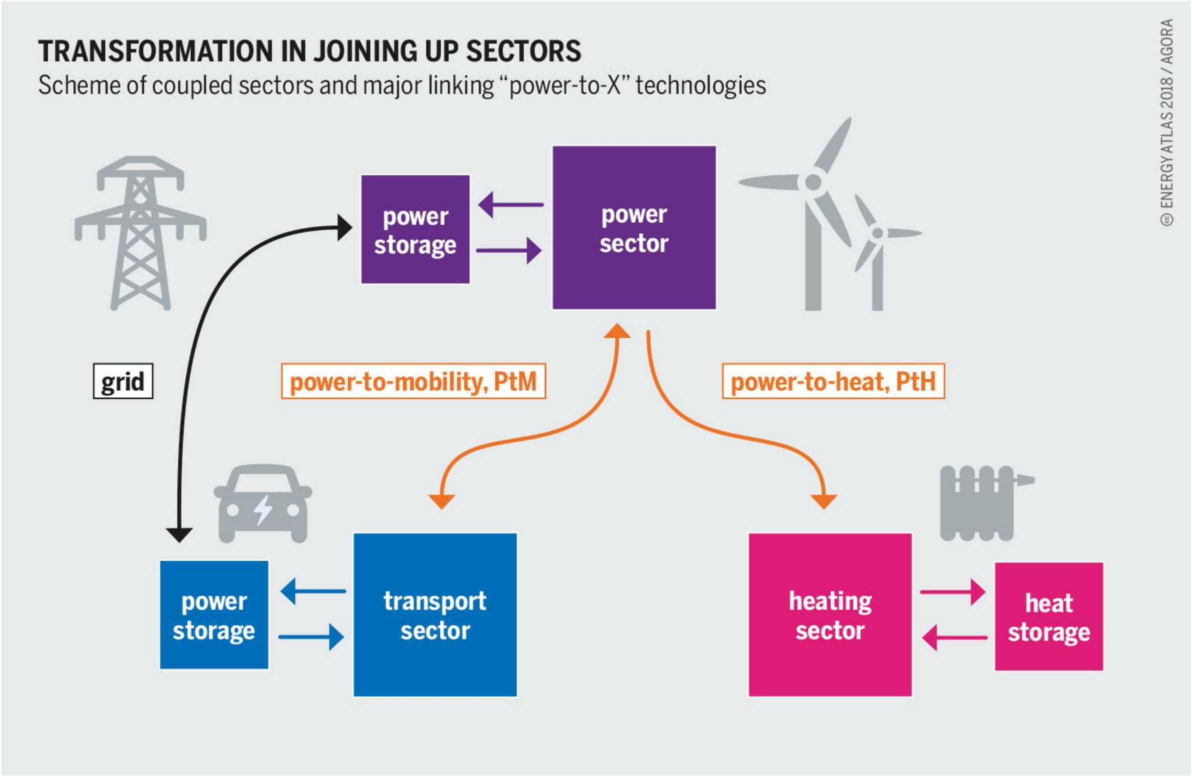
Renewable Energy Source	Advantages	Disadvantages
Solar [30]	Low running expenses, no emissions, and widespread availability	Sporadic, reliant on weather, and affected by land use
Wind [31]	Low running expenses, no emissions, and widespread availability	Intermittent, effects of land use, and possible effects on animals
Biomass [32]	Broadly accessible fuel that can be used for transit, electricity, and heating	Broadly accessible fuel that can be used for transit, electricity, and heating
Geothermal [33]	No emissions, great reliability, and the capacity to produce heat and energy simultaneously	Low supply and expensive initial expenses
Wave [34]	No emissions, steady source of electricity	Low technology growth and expensive initial expenses
Vibration/ Kinetic [35]	Numerous uses, possibly affordable	Limited technological advancement and dependability issues

Halim, 2023

2. Energy Conversion from surplus renewable



Yan et al., 2019

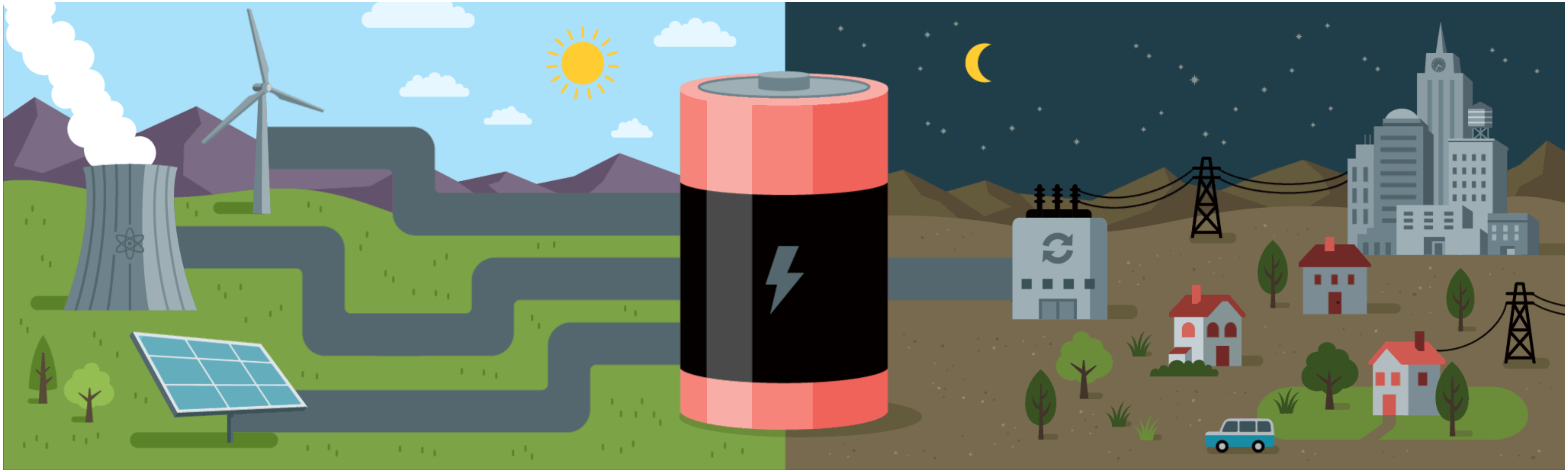


Common surplus renewable energy storage and utilization based on electrolysis

Electrical power storage to power, mobility, heat, etc

2. Energy Conversion from surplus renewable

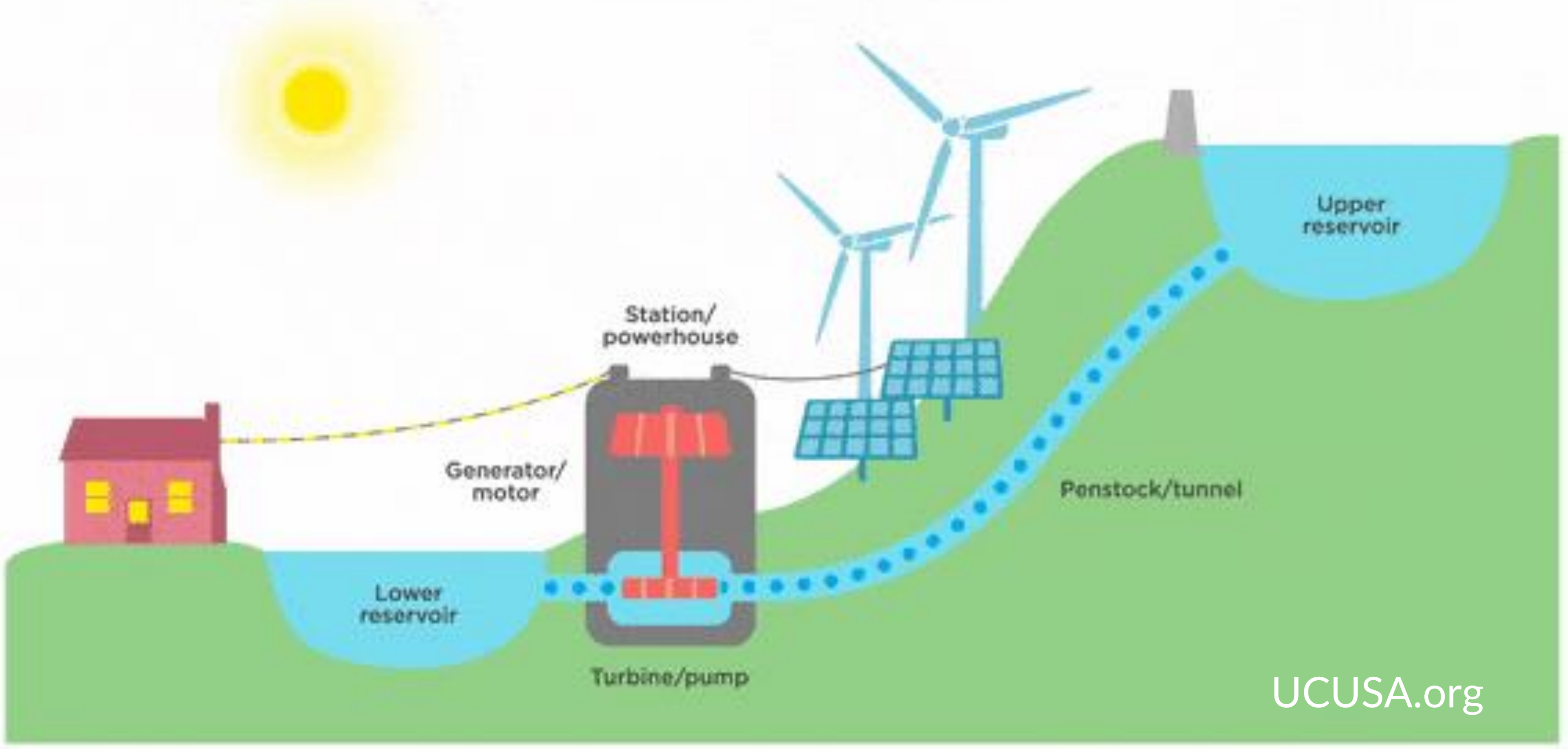
1) Renewable energy to fuel battery and grid pow



https://www.nytimes.com/2017/06/03/business/energy-environment/biggest-batteries.html

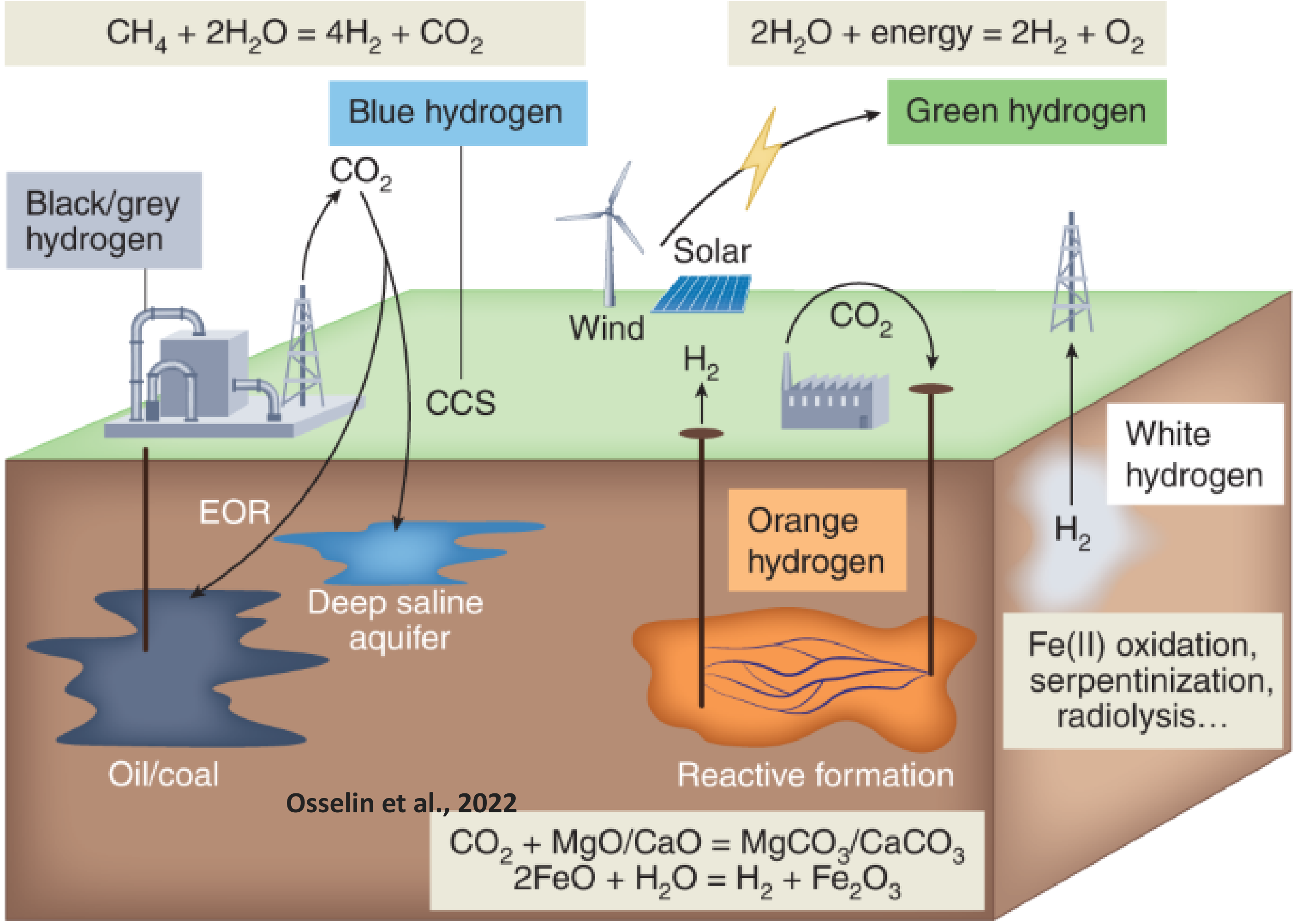
Solar, nuclear, and wind Renewable Energy Storage as power for later use

2) Surplus wind and solar to Pumped hydropower



https://galooli.com/blog/the-importance-of-energy-storage-systems-for-sustainable-operations/

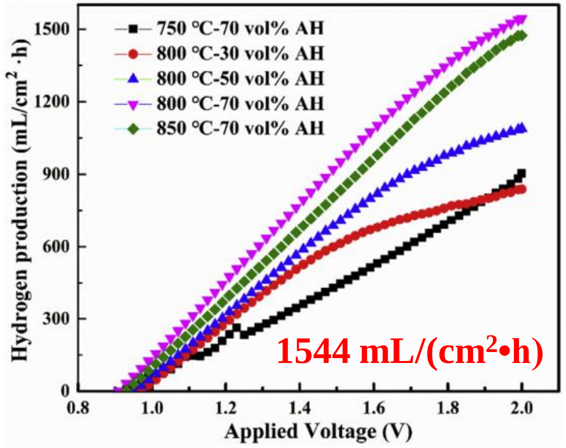
3) Fossil fuel, electrolysis, chemical reaction, etc to hydrogen



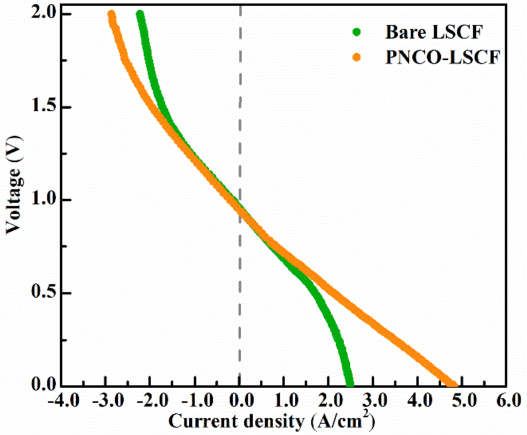
Osselin et al., 2022

4) A solid oxide electrolyzer cell (SOEC) water electrolysis hydrogen production

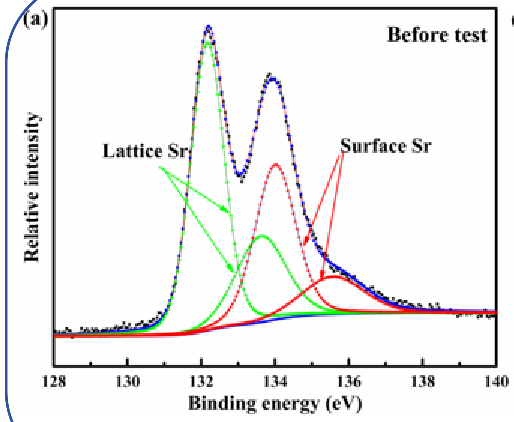
- **Green hydrogen is produced by high-temperature electrolysis, with an efficiency of ≥95%, achieving a DC energy consumption for hydrogen production as low as 4kWh/Nm3.**

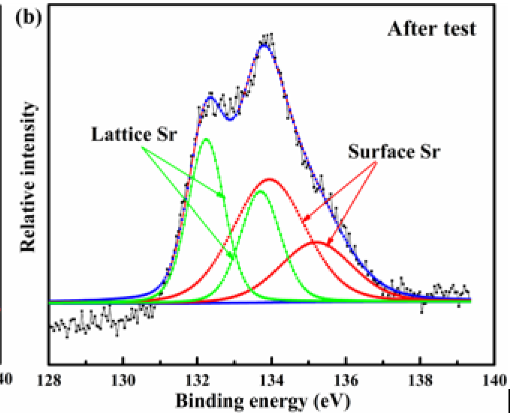


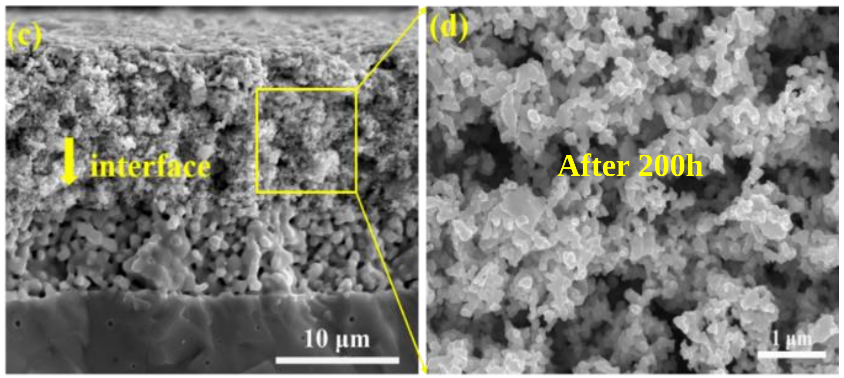
Hydrogen production rate =1544 mL/(cm²•h)

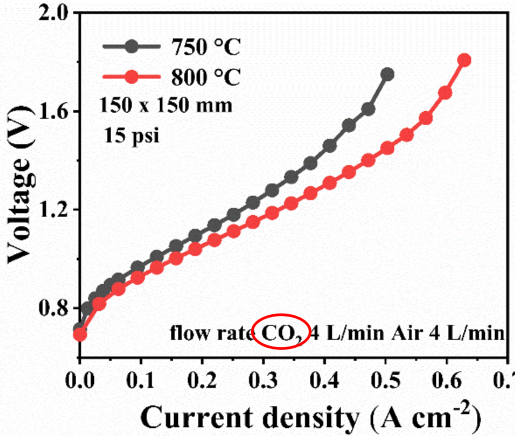


SOEC Model 800 °C I1.5v=1.718 A/cm²



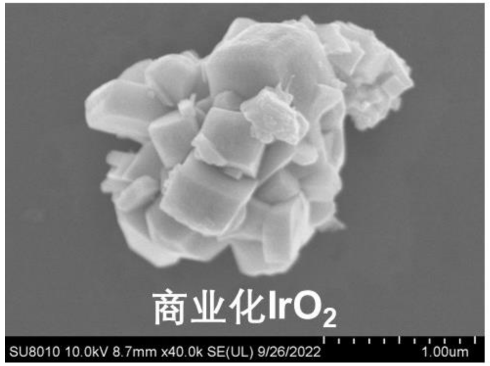


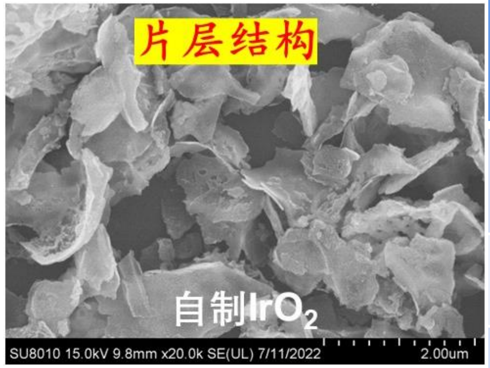




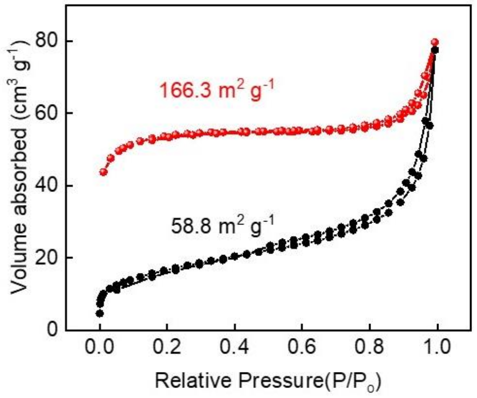
SOEC Single cell electrolysis at 800°C，1.3V 1000h，stable micro-sctructure

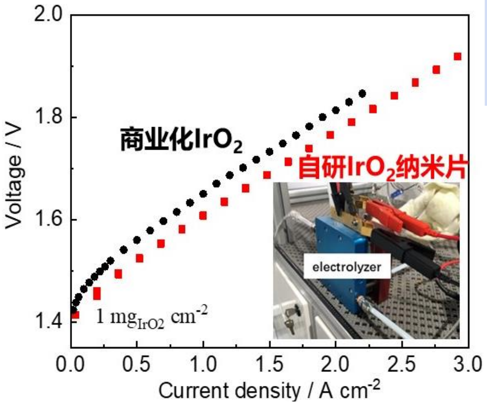
5) Iridium dioxide catalyst electrolysis water hydrogen production

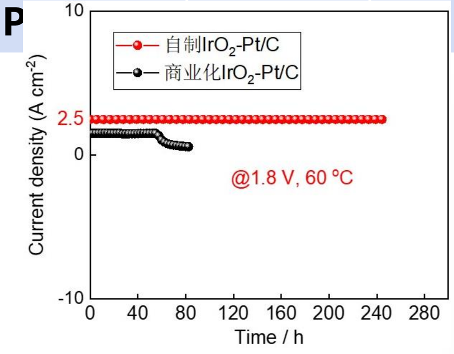


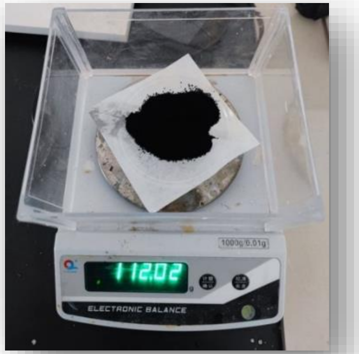


	shape	Specific Surf (m^2/g)	PEM Function (1.8 V)	Price
IrO_2 (Japan)	Grain	≤60	1.9 A cm^{-2}	≥100g，1950RMB/g
Our IrO_2	Flake	≥150	2.3 A cm^{-2}	1000RMB/g
Other Chinese P	Grain		1.7 A cm^{-2}	1400RMB/g



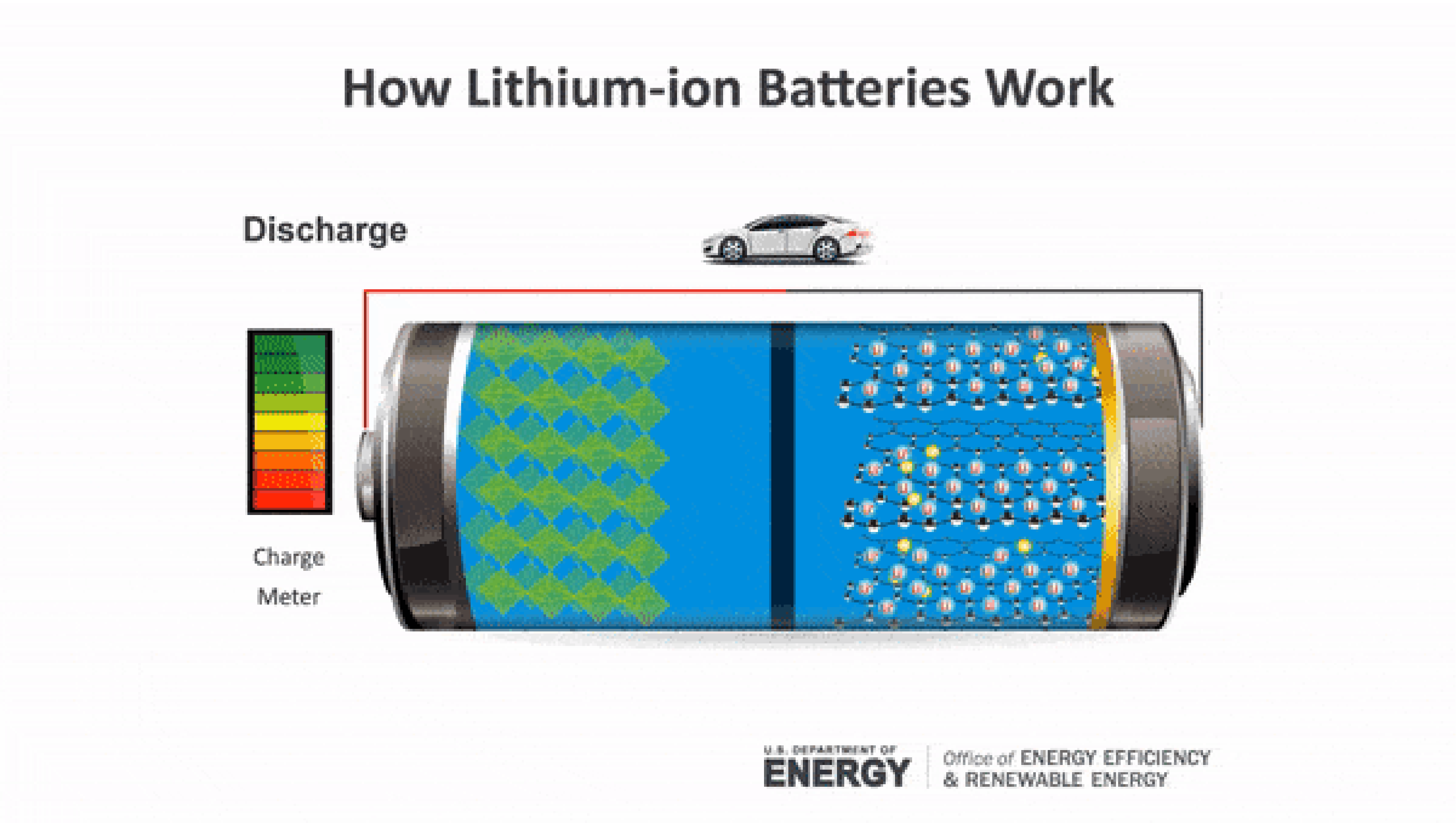




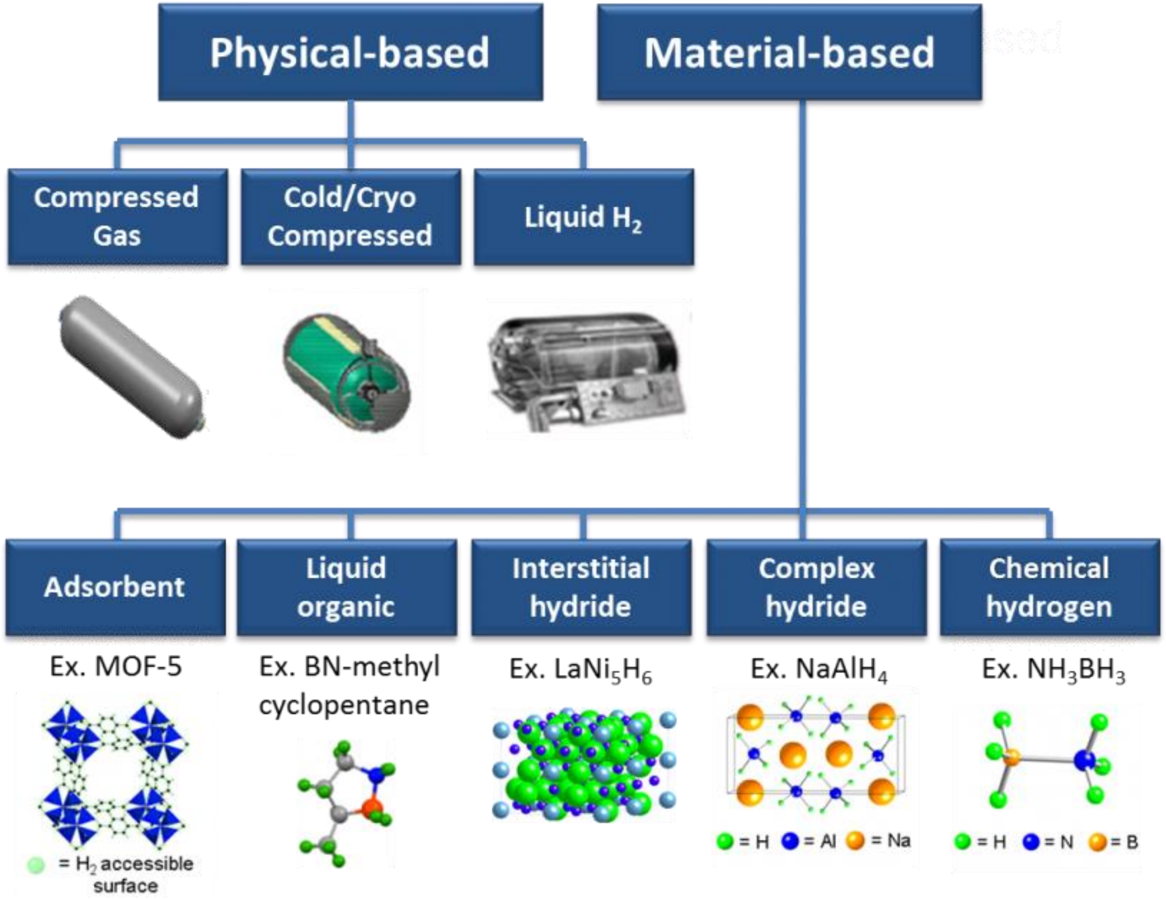


- Excellent performance (30% higher than Japanese catalysts, cycle voltage decay rate <10μV/h)
- Lower cost (↓~50%), batch process (the laboratory >10g level)

1) Chemical/Battery Energy Storage

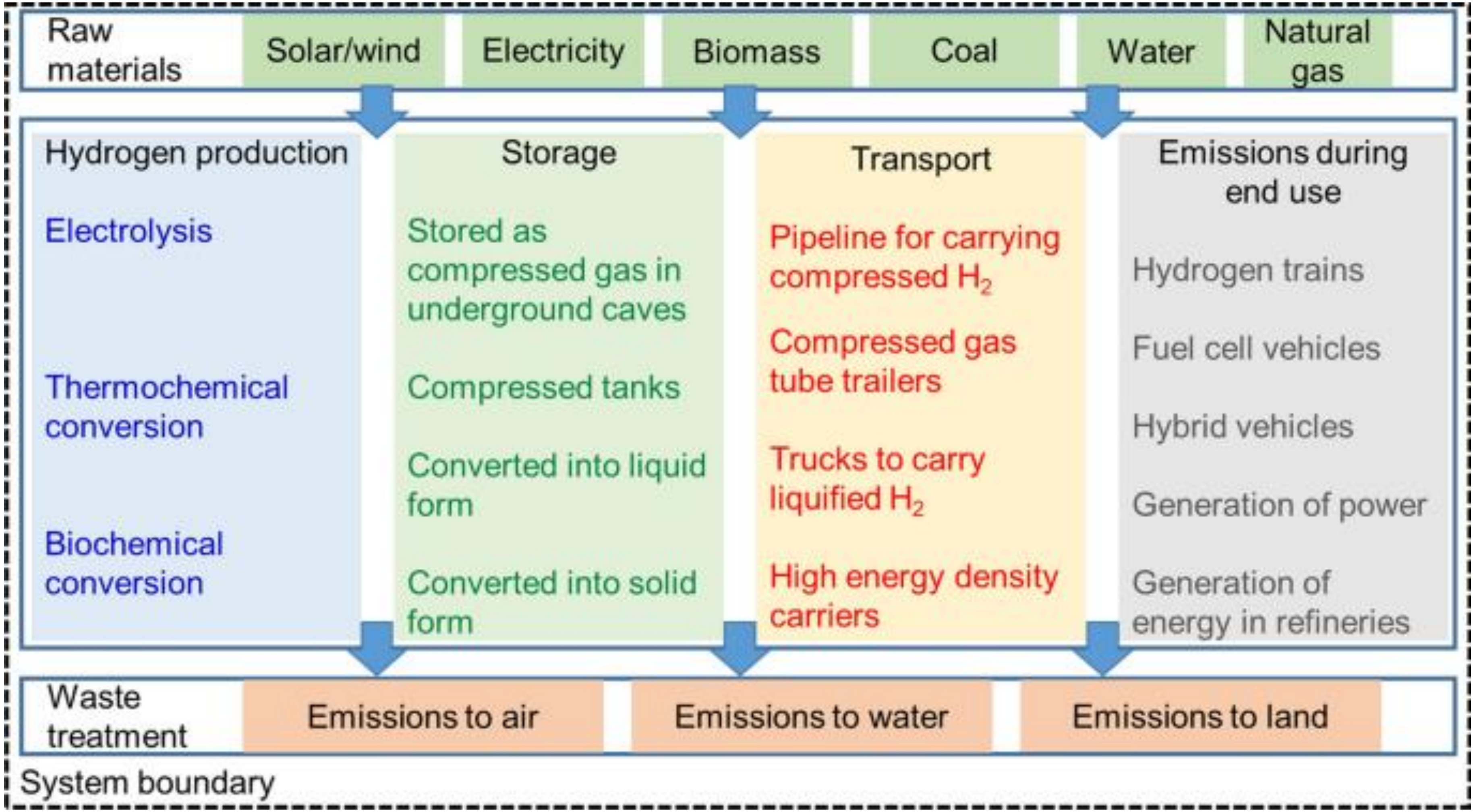


2) Physical, Chemical and Material-based Hydrogen Energy Storage

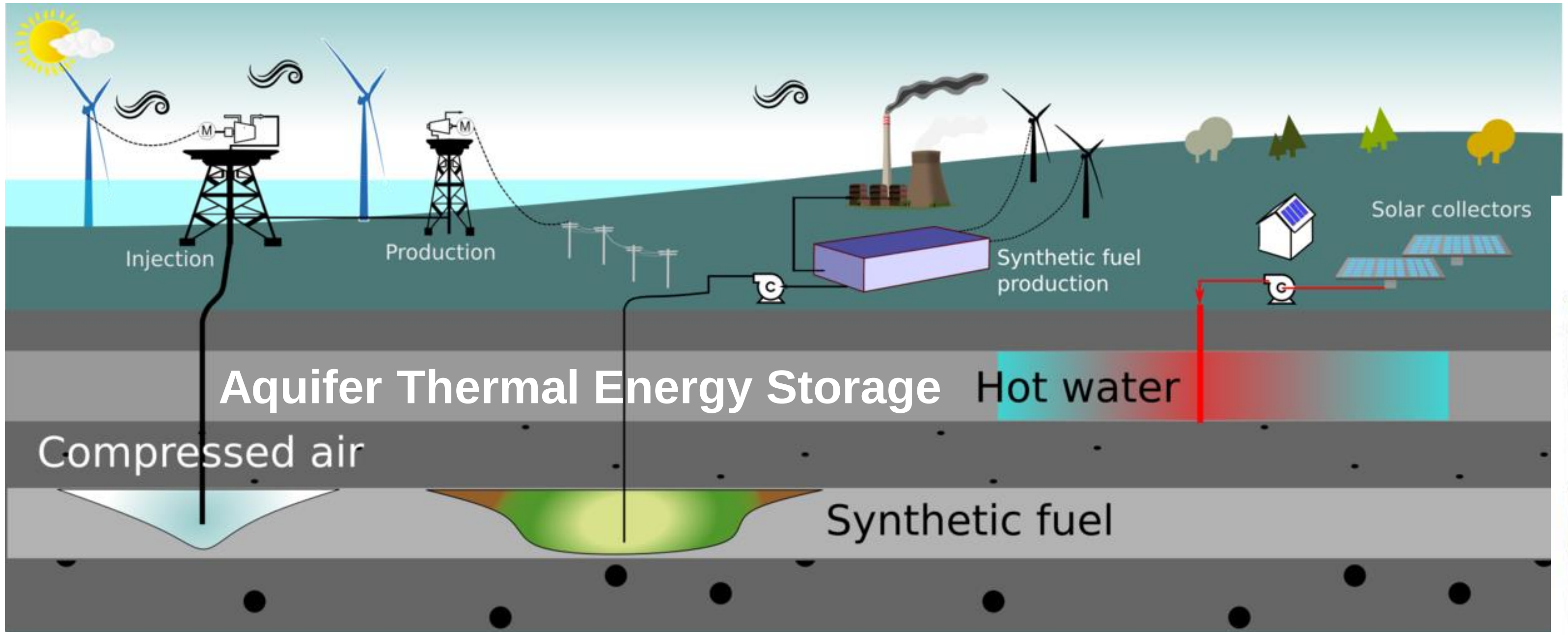


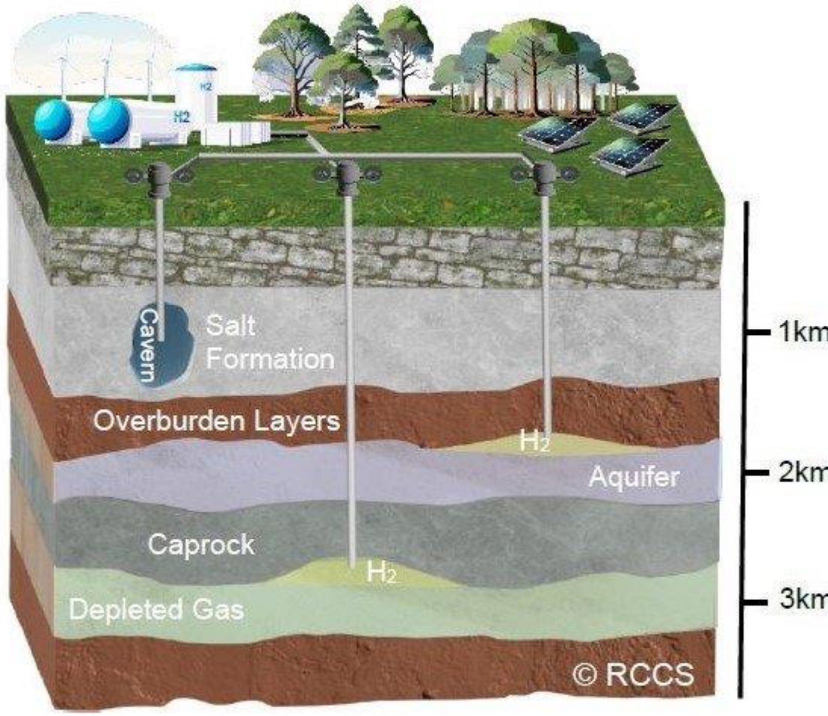
https://www.energy.gov/eere/fuelcells/hydrogen-storage

2) Comparison between different types of H_2 storage



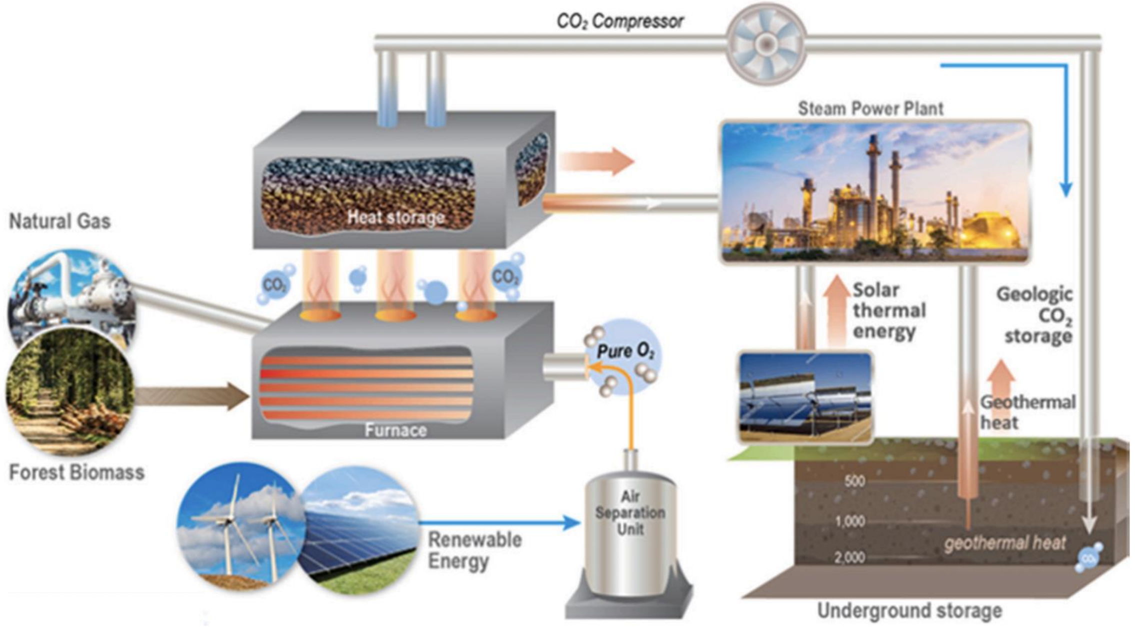
3) Types of Geologic Energy Storage



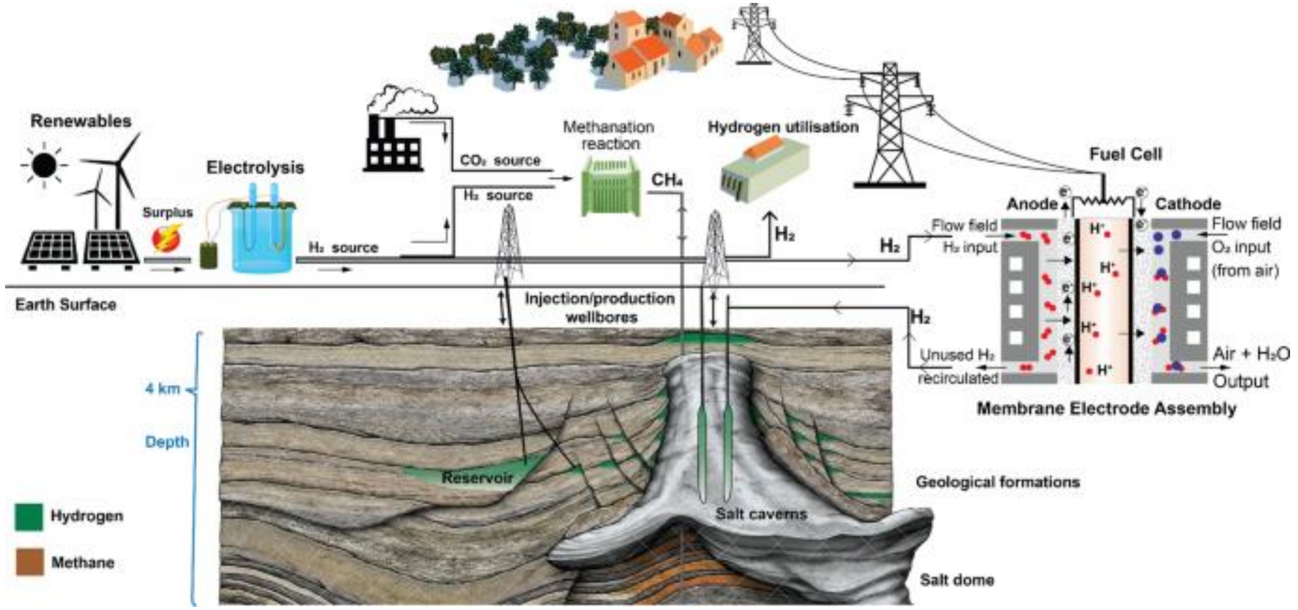


A. Geothermal energy storage
B. Hydrogen storage in the salt cavern, depleted oil and gas reservoir, and acquifer
C. Compressed air storage
D. Synthetic fuel storage

3) From Energy Conversion to Geologic Energy Storage

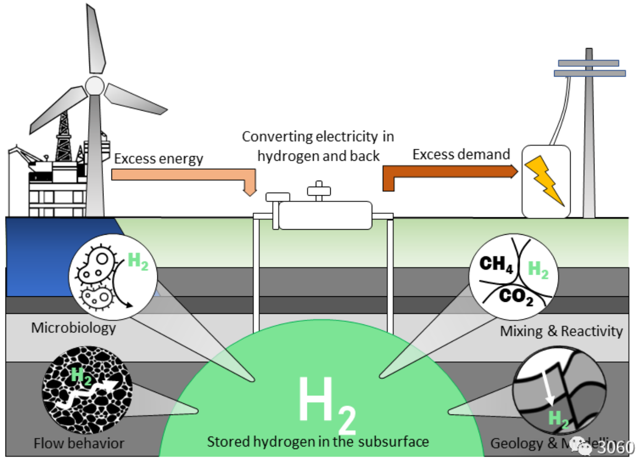


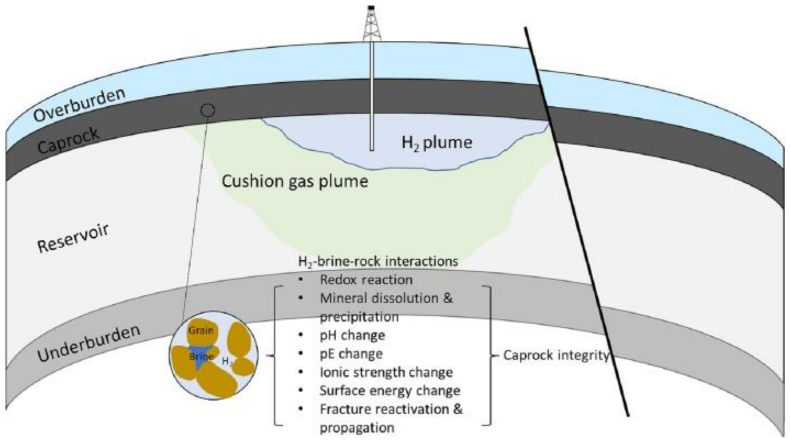
Buscheck, 2021

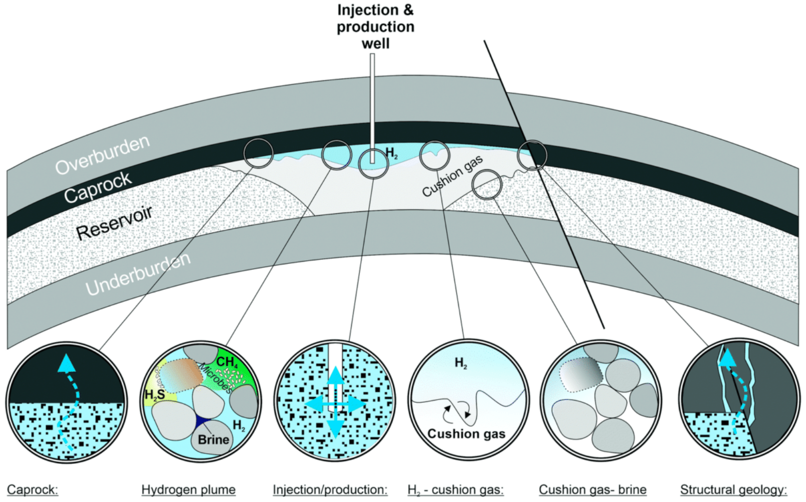


Osman et al., 2021

4) Subsurface H_2 storage



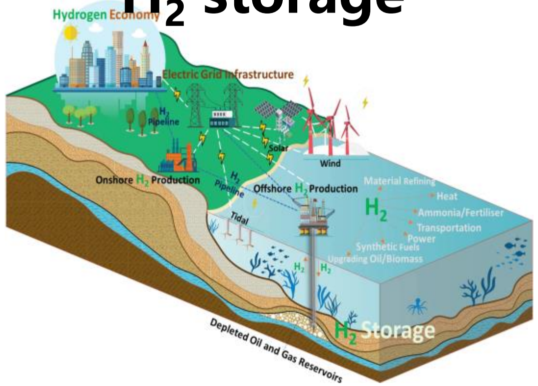




Reservoir characterization for H_2 storage

Sealing capability for H_2 storage

Monitoring

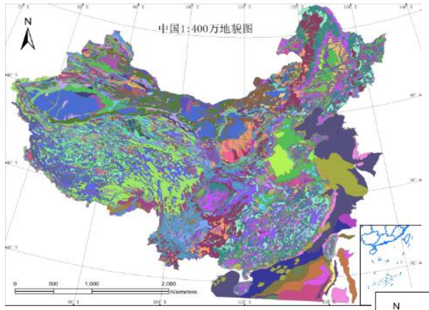


ACS Energy Lett. 2021, 6, 6, 2181-2186

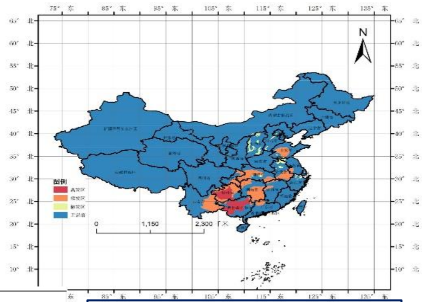
Advantage: subsurface is safe and cost-effective for a low ignition temperature and highly flammable hydrogen, and easy integration of the storage facility with the distribution pipelines.

Disadvantage: purity of hydrogen less than in a fuel cell

5) Compressed Air Storage

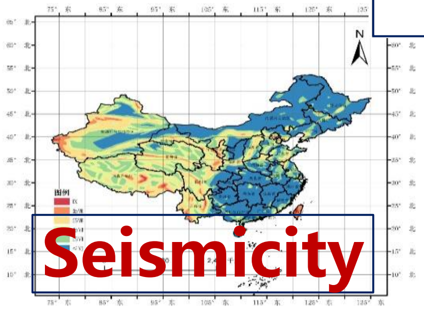


Geomorphology

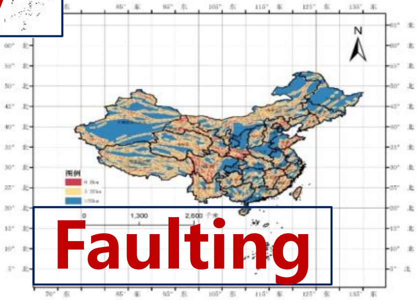


Karst

Lithology

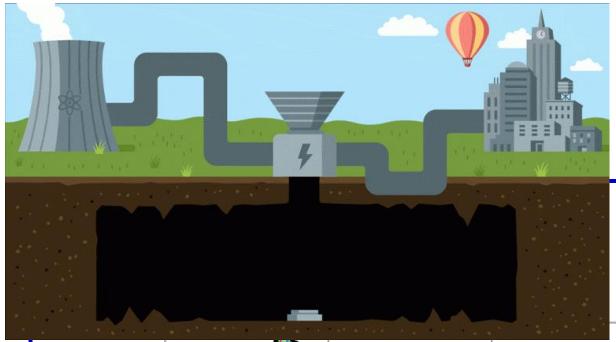


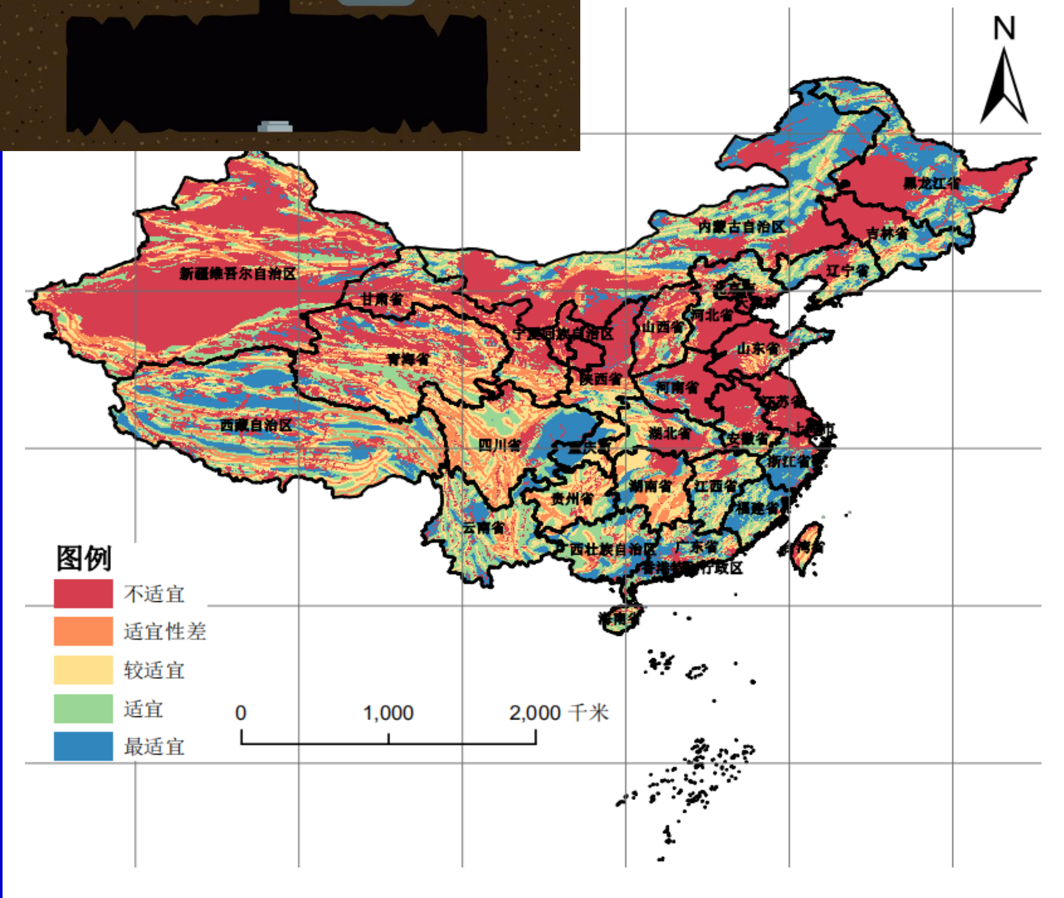
Seismicity



Faulting

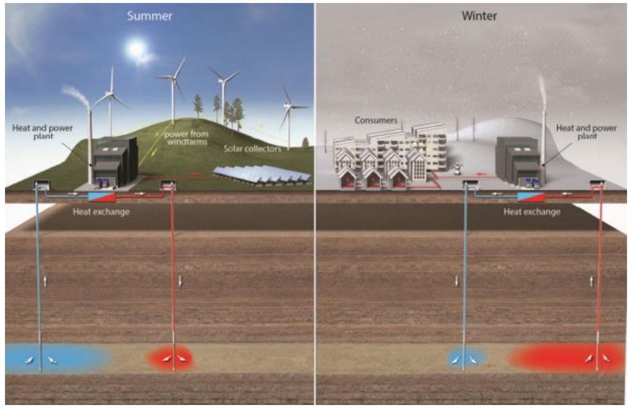
Geologic factors





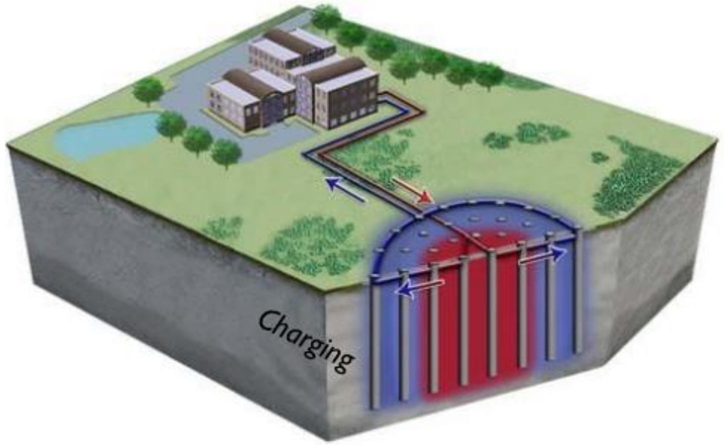
Suitability map

6) Types of subsurface thermal energy storage



Aquifer thermal energy storage (ATES)

Pit Thermal Energy Storage (PTES)



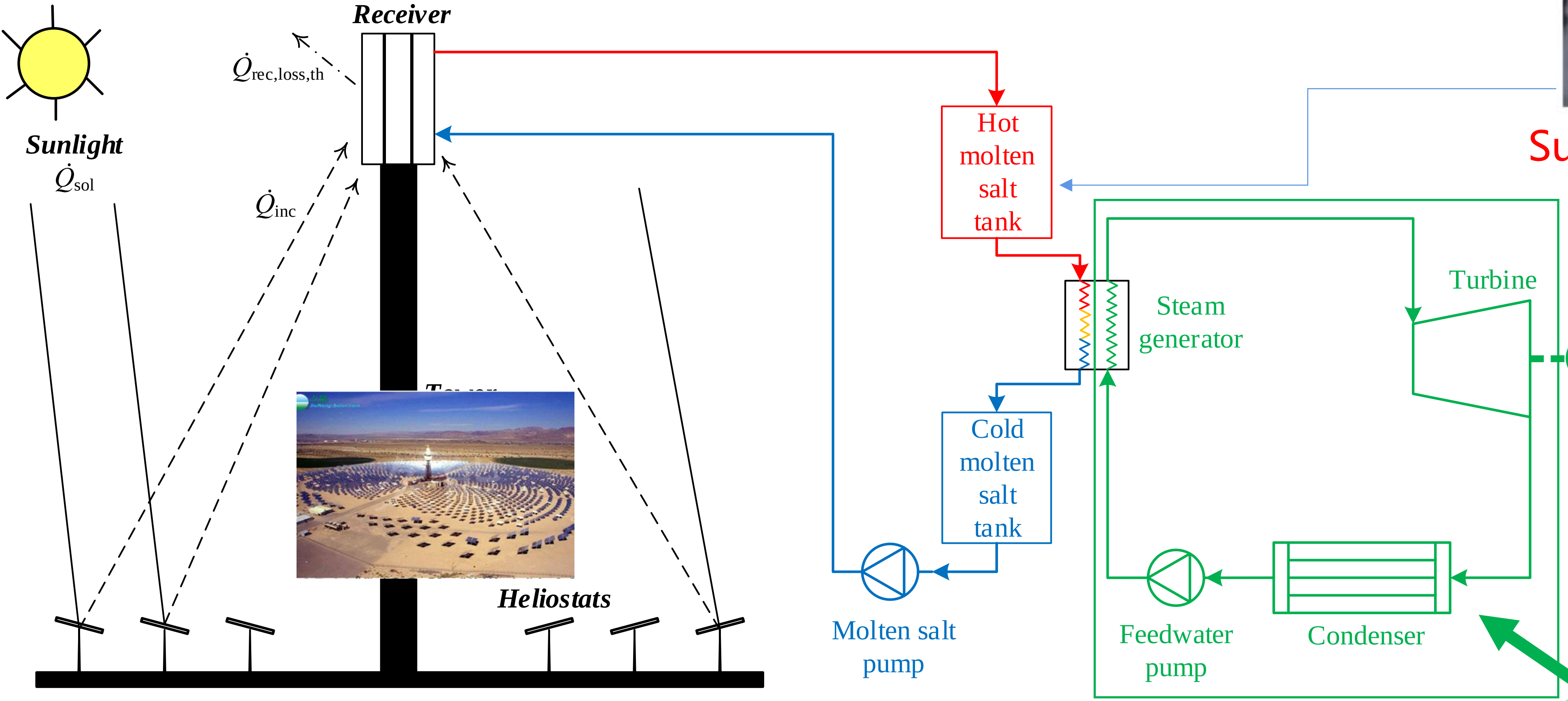
Borehole thermal energy storage (BTES)

Mine Thermal Energy Storage (MTES)

6) History of thermal energy storage in the subsurface

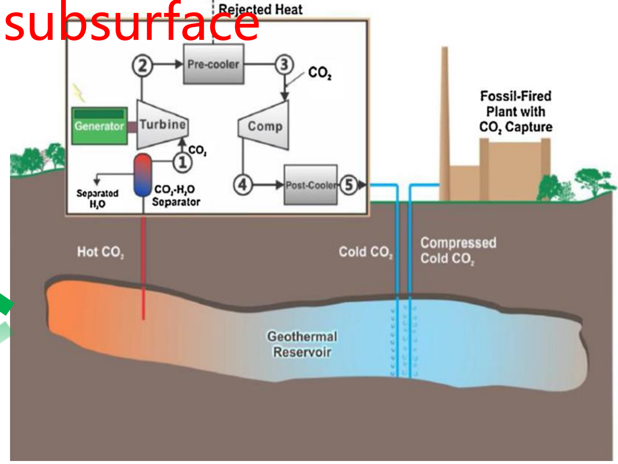
Geothermal Battery	Heat Pump and subsurface storage (EW-201135)	EU RHC-ETIP	HeatStore	CAS Type A Fund	German GeoTES
2017，NSF SedHeat,10 USD	2011-2017年, US ESTCP 5.75 million USD, aquifer and soil storage	2018-， 2022 3 billion EU dollars	2018-2022，EU GEOTHERMICA funding，50 million, 3 deep Acquifer geothermal storage	2019-2023, Wind energy to geothermal energy storage, 8 million RMB	2022-2025, Deep acquifer thermal storage,1.75 million EU dollars

6) Thermal storage for CSP (solar to geothermal energy)



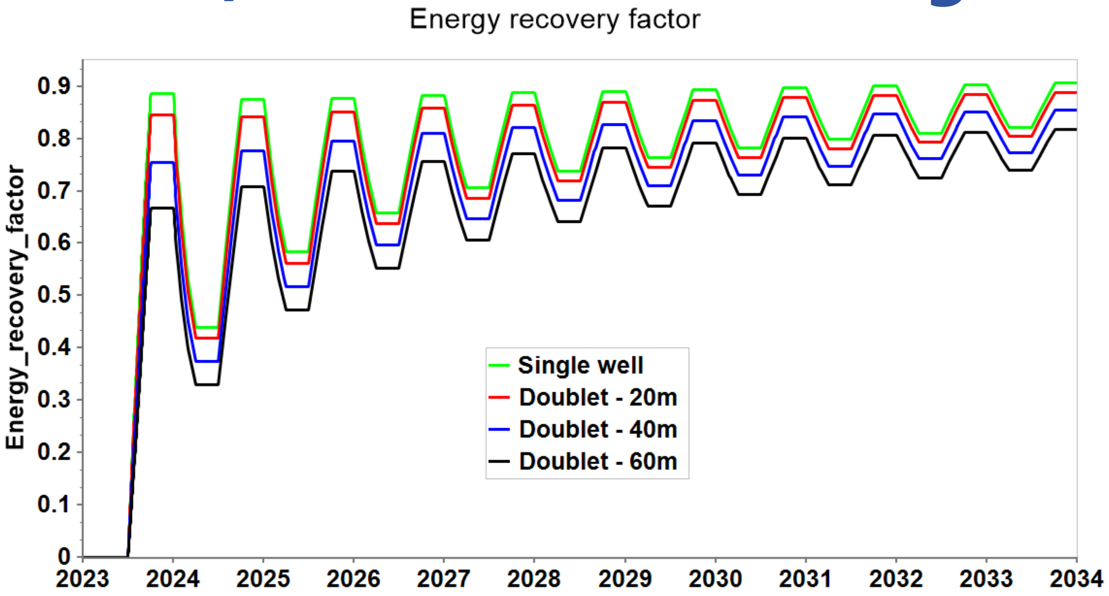
Supercritical fluids

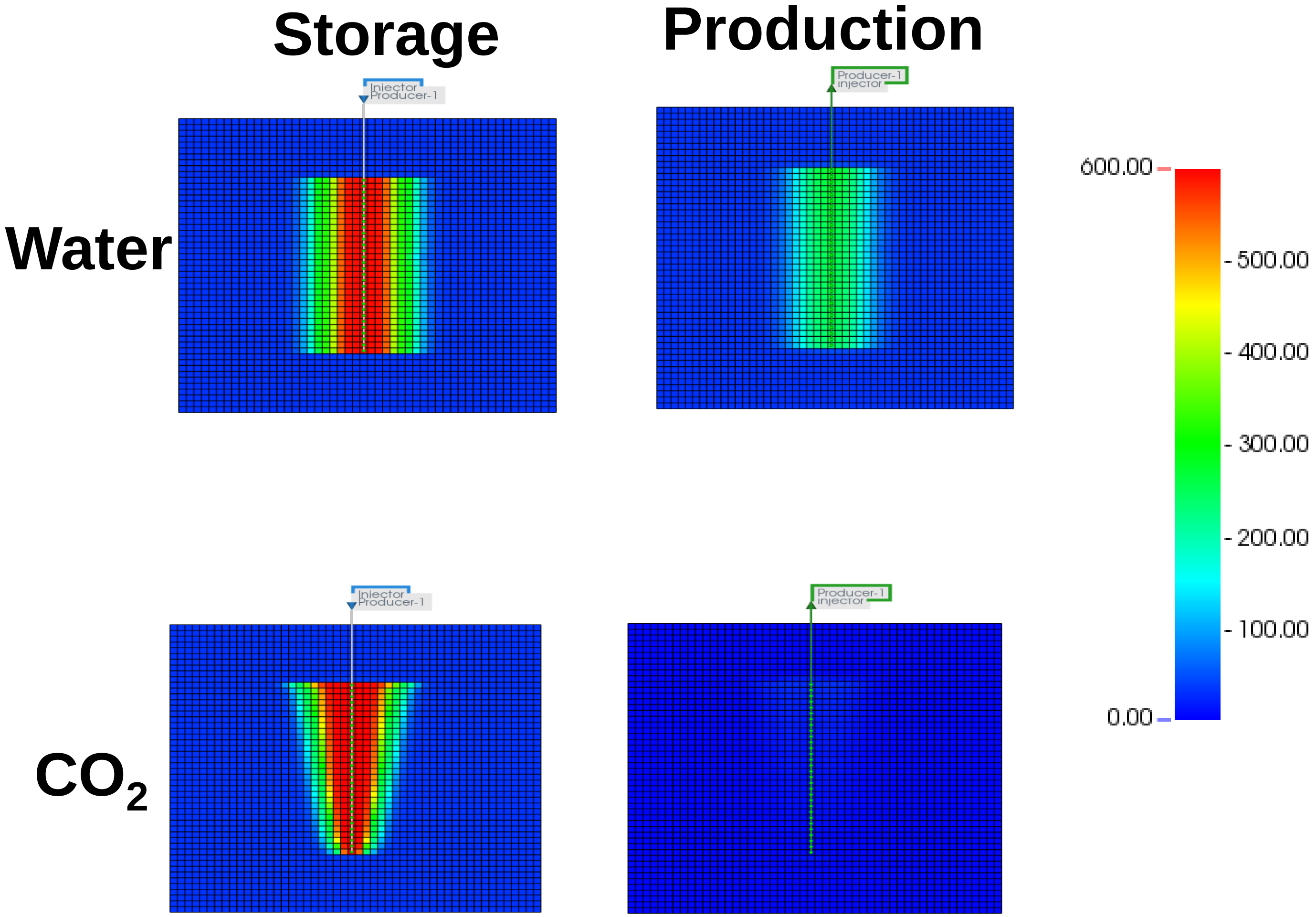
Thermal storage in subsurface



Geo-CSP

6) Geothermal Storage for CSP





The efficiency of geothermal heat storage and heat extraction can reach more than 90%, and the efficiency of heat storage and heat extraction using CO2 is even higher than water, and heat extraction can achieve the storage of 1,500 tons of CO2 per year.

4. Conclusions and Suggestions

① **The renewable energy includes geologic hydrogen, geothermal and natural solar, wind, tide, and green hydrogen, electrochemical energy, etc. Each renewable energy has its own advantage and disadvantage, coupled utilization is the best option.**

② **Multiple renewable energy resources can be converted to other energies for easy storage.**

③ **Current energy storages via electrochemical method, physical storage, material-based, etc have limited capacities, subsurface has vast capability for energy storage.**

④ **Hydrogen, thermal fluids heated by renewable power, compressed air, etc can be stored in the subsurface for long term storage and utilization, which provides an innovative solution for surplus renewable energy and energy sustainability.**

UN GEONOW 2024
首届联合国地信周

THANK YOU

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