Hydrogen's Role in Decarbonizing Power Generation

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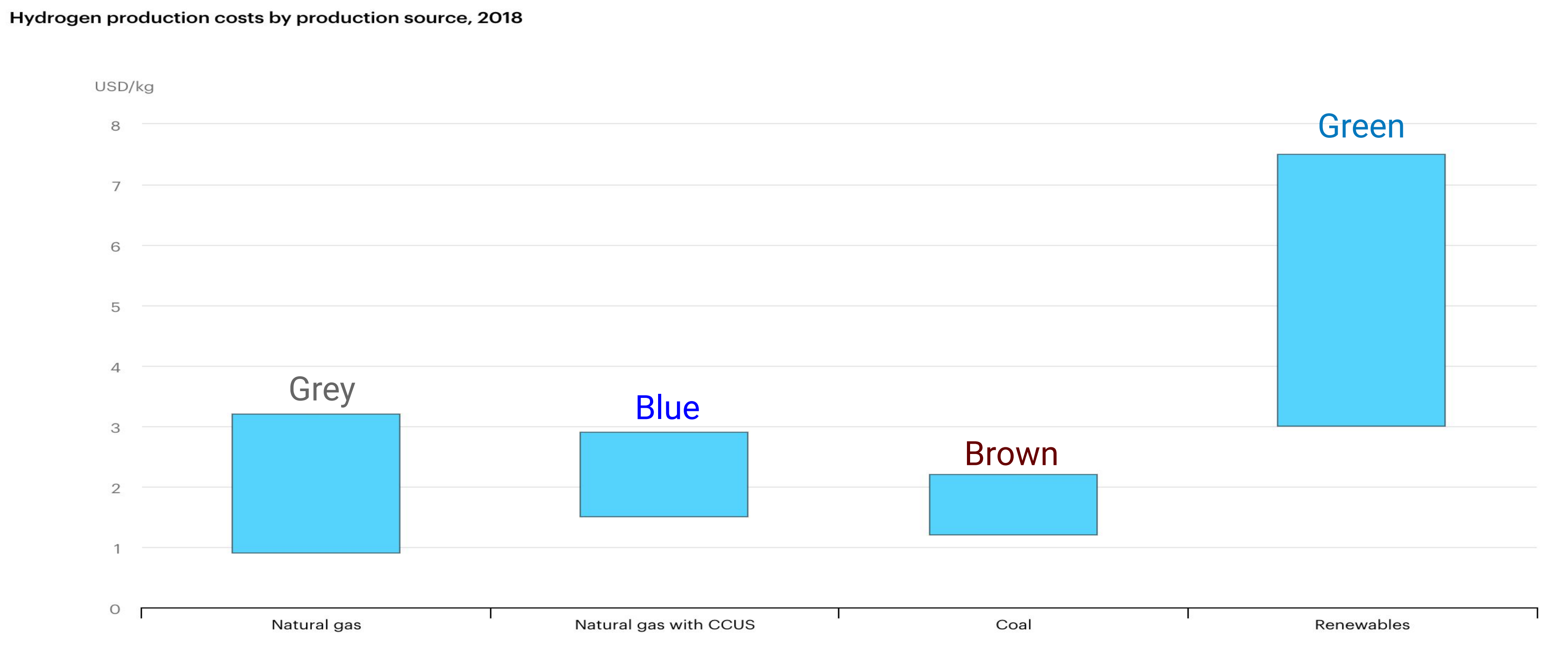
Colors of Hydrogen

This presentation will focus on Green Hydrogen.

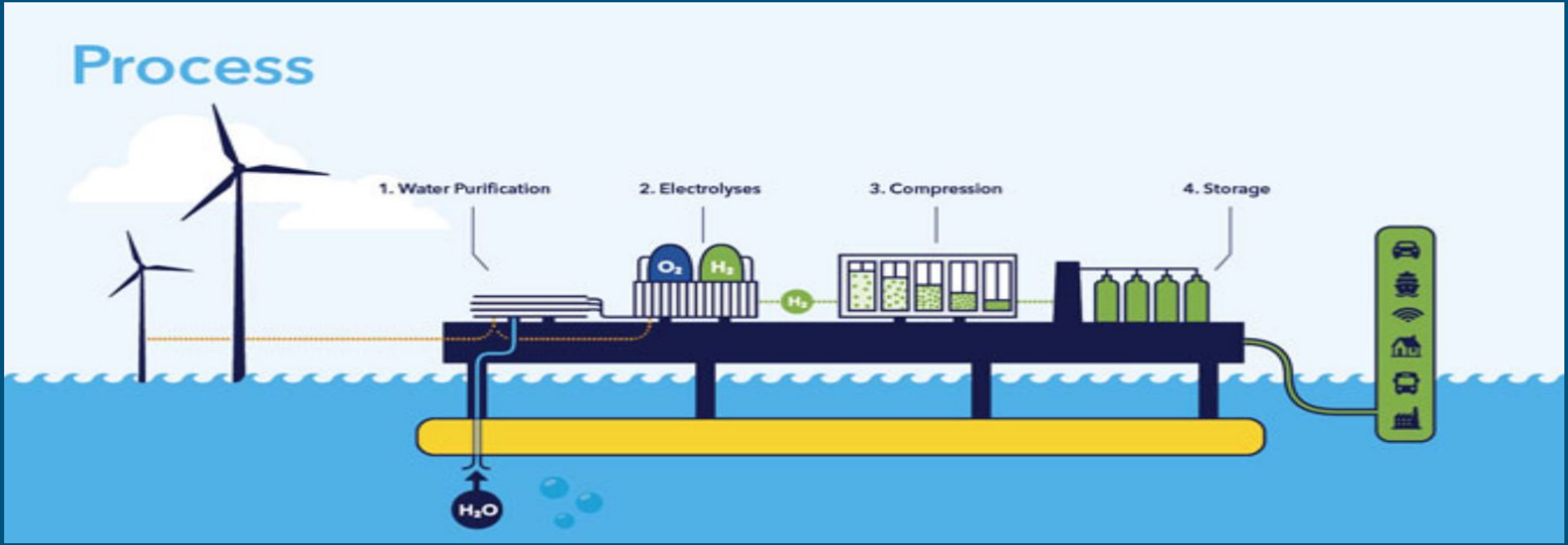
Source: Ashurst Law

Cost of Hydrogen Production By Color



Source: IEA - Future of Hydrogen

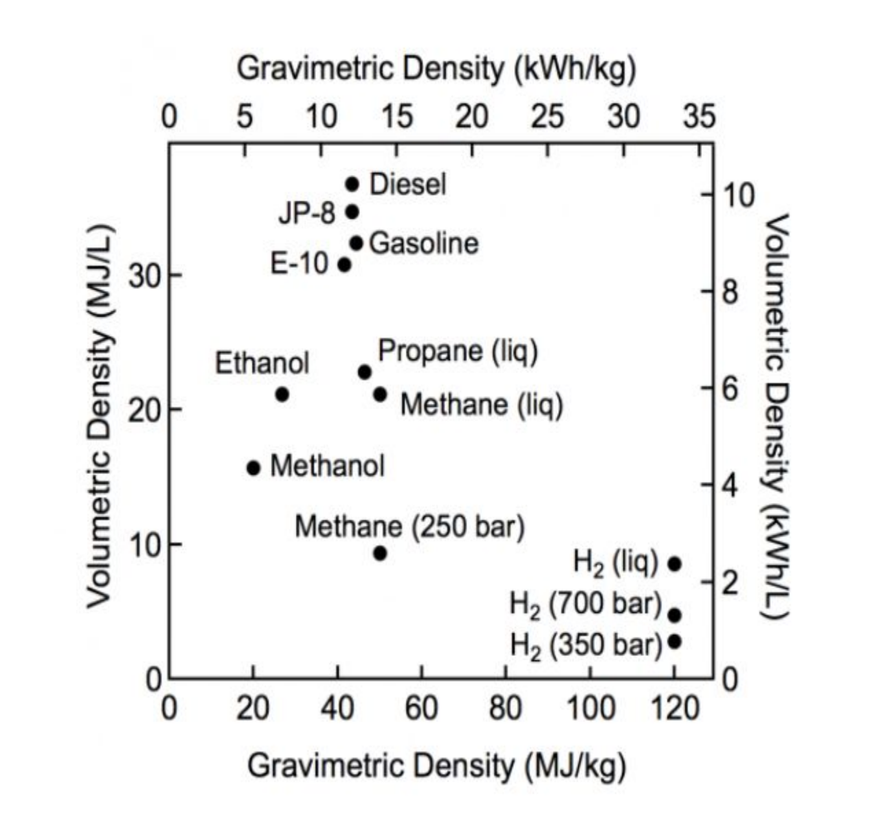
Green Hydrogen Example Process



Wind Generation →	Water Purification →	Electrolysis →	Hydrogen Compression →	Storage & Transport
Any Renewable Generation	Desalination (If necessary)	Separating H20 into Hydrogen & Oxygen	Compression for more efficient storage	Transport for consumption

Source: Windpower Engineering

Hydrogen Density

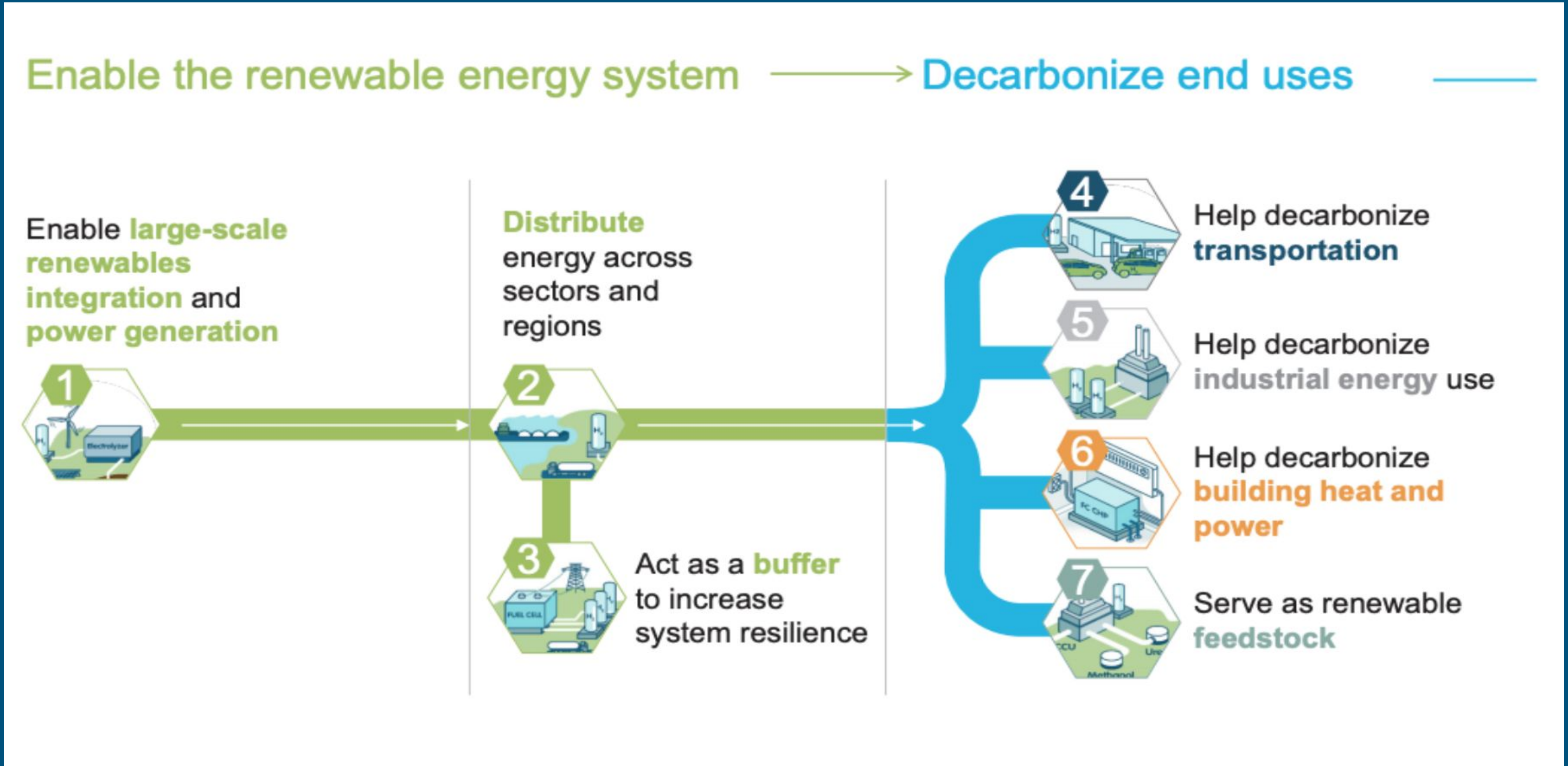


1. **Hydrogen weighs very little**
   a. High energy/weight density (Gravimetric)
2. **Hydrogen takes up a comparatively large amount of space**
   a. Low energy/volume density (Volumetric)
3. **Both have implications on the storage and transportation of Hydrogen**
   a. Costs, Space, Weight

Note: “Bar” Unit Refers to Gas Tank Pressure

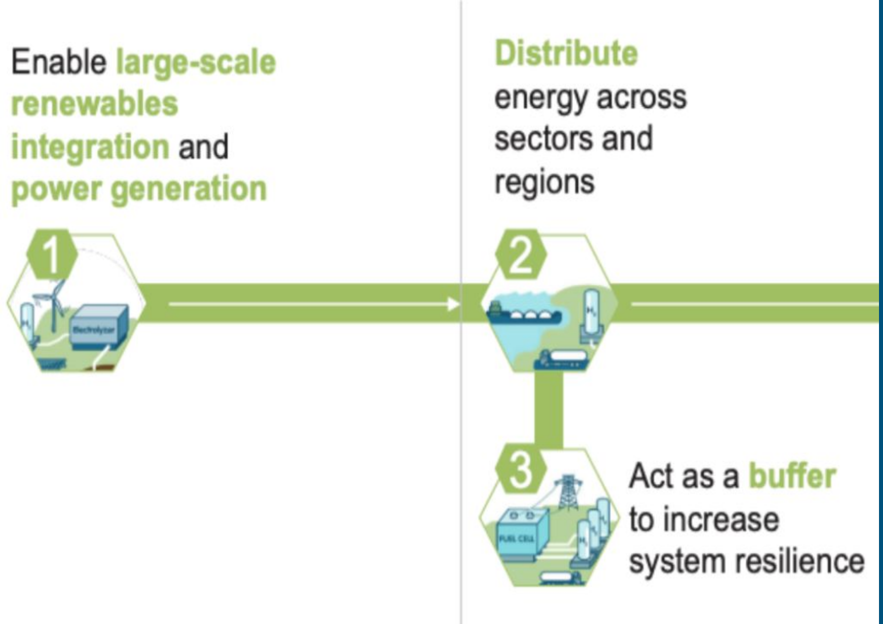
Source: Department of Energy

Green Hydrogen in the Energy Transition



Source: Hydrogen Council

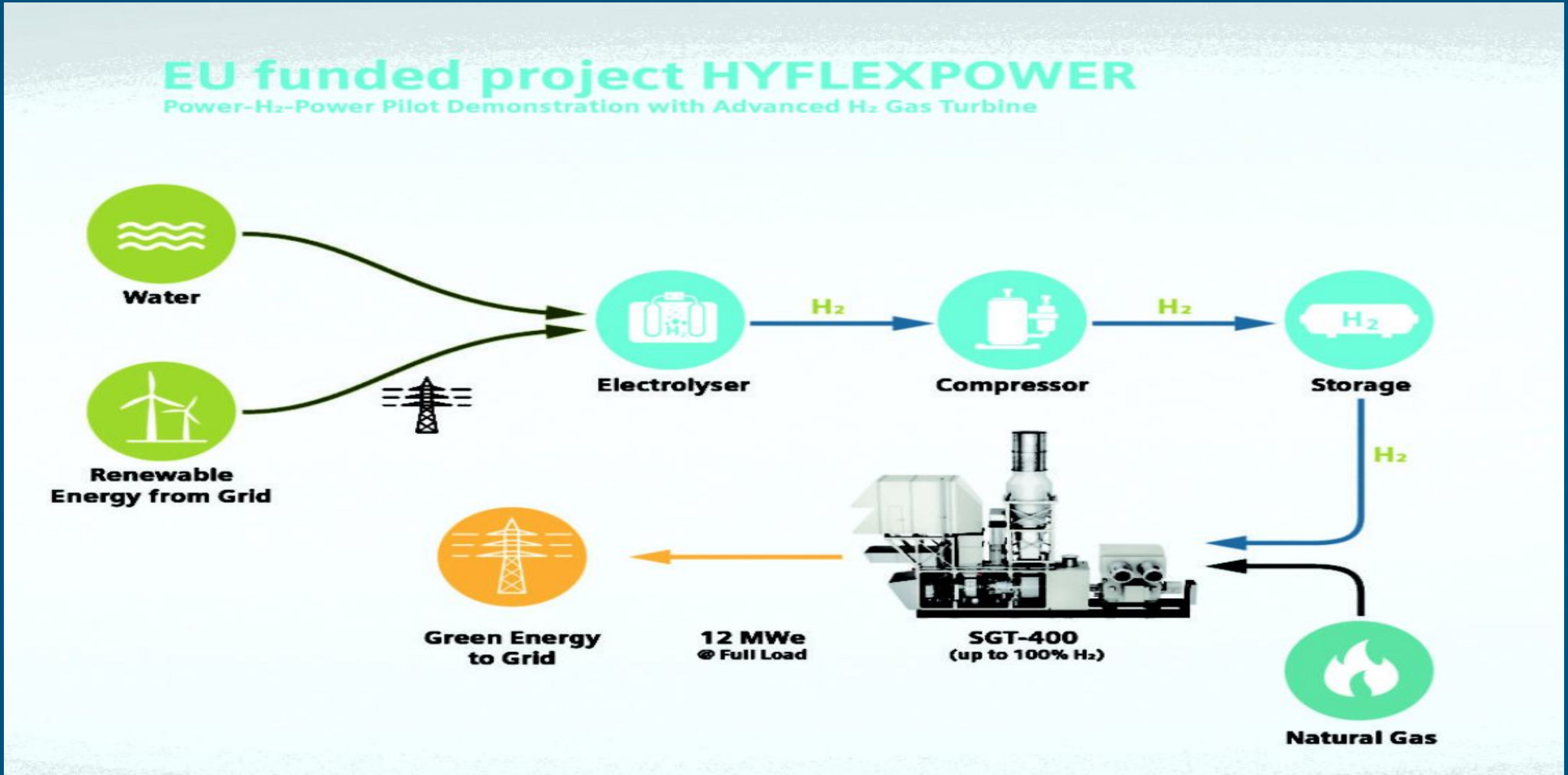
Enable the Renewable Energy System



1. **Currently, hydrogen blends can help to reduce emissions at natural gas plants**
   a. non-variable green energy production
2. **Hydrogen can be transported more easily than electricity**
   a. Transmission from high-generation to low-generation areas
3. **Using electrolysis, over-generation from solar/wind can be converted to Hydrogen to be used later**

Source: Hydrogen Council

Hydrogen in Combined Cycle Gas Turbines



EU — Siemens HYFLEXPOWER Project

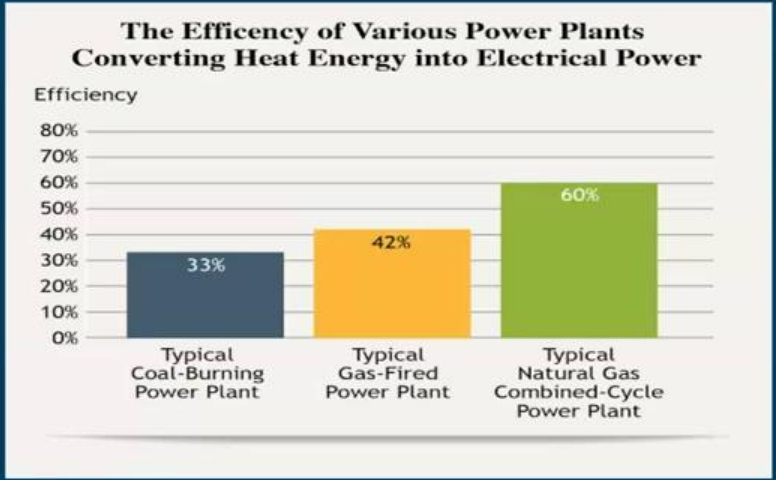
Source: Powermag

Advantages

- Reduces CO2 emissions
- Reduces energy costs up to 40%
- Higher efficiency
- Increased power reliability

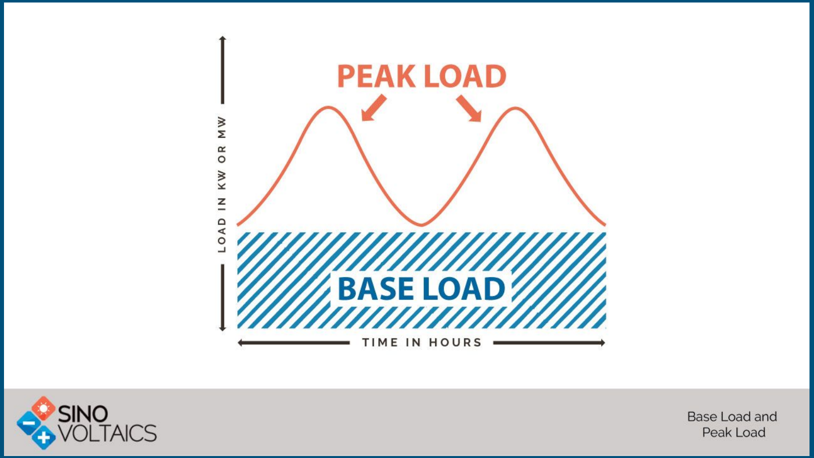
Disadvantages

- Only viable when both heat and hot water is needed
- Financially intensive (compared to regular Natural Gas plant)
- Not a true “renewable” energy source



Siemen CC Gas Plant model capable of

Baseload & Peaker Generation



Source: Sino Voltaics

Baseload

Nuclear power plant
Coal power plant
Hydroelectric

Peaker

CC Gas plant
Solar power plant
Wind turbines

H_2- Natural Gas Blend Project Development Model

- Market price of \$5.50/kg H_2
- SoCal solar (\$0.025/kWh, 28.4 % CF)
- Nel M4000 PEM Electrolyser
- Salt cavern storage with pipelines
- 5% discount rate
- 3% depreciation rate
- 36% tax rate
- 8-year life of PEM stack
- 16 year project life
- \$3/mmbtu natural gas

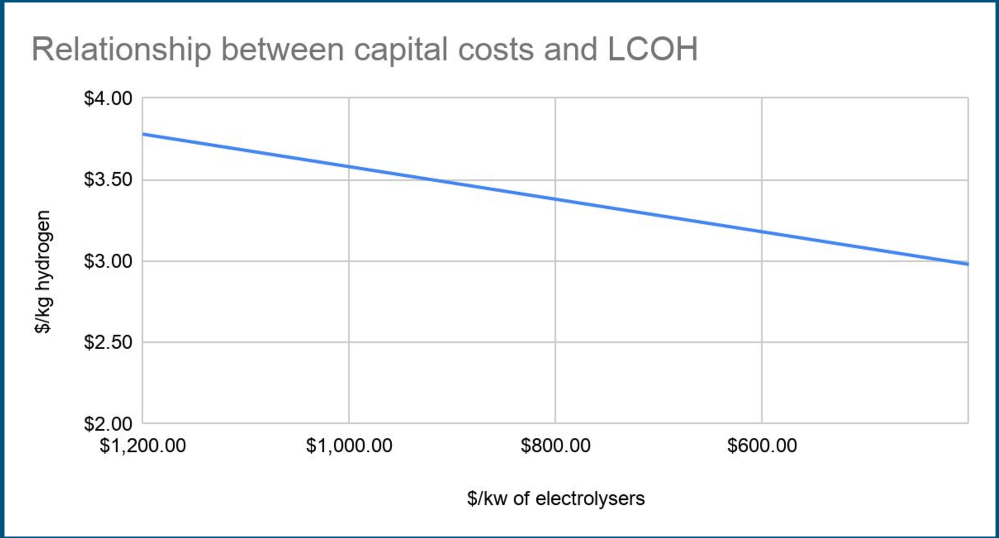
Economics of Green Hydrogen Production

LCOH- Levelized Cost of Hydrogen

Capital costs - Total upfront cost

DOE targets $400/kw by 2035

Midpoint estimate in 2020: $950/kw



Economics of Green Hydrogen Production

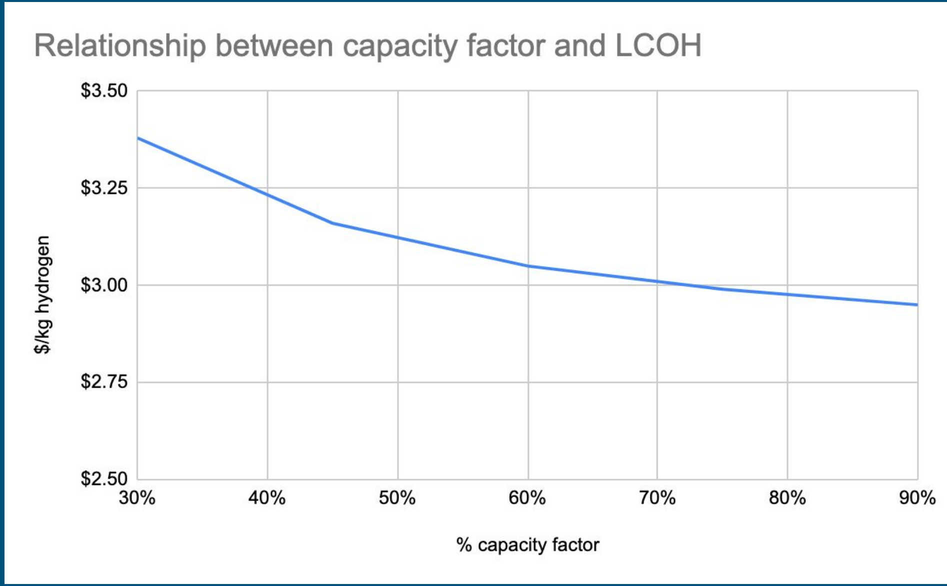
Capacity Factor - % of time in operation

%CF depends on power supply

Solar - 28.4%

Solar+Wind - ~65%

Grid + REC - 95+%



Scenario #1: Base Case

Conditions:

- 200MW solar array onsite (28.4% capacity factor) powering 220MW of electrolyzers
- No grid interconnection
- 70% natural gas, 30% hydrogen blend

Results:

- \$4.11 per kg of H_2
- \$0.0656/kWh fuel cost of power
- \$0.0331/kWh Δ fuel cost of power (relative to natural gas)

Scenario #2: Grid Interconnection

Conditions:

- 200MW solar array onsite (28.4% CF), paired with grid interconnection (85% net CF), powering 220MW of electrolyzers
- **$4/MWh REC purchase for grid electricity**
- 70% natural gas, 30% hydrogen blend

Results:

- **$3.19/ kg of H_2**
- **$0.0572/kWh fuel cost of power**
- **$0.0251/kWh Δ fuel cost of power (relative to natural gas)**

Scenario 3: Aggressive Future Case

Conditions:

- 100% renewable energy grid (95% CF) at $0.015/ kWh powering 220 MW of electrolysers
- Best-case manufacturing scenario for PEM electrolysers ($400/kW)
- $200/ton CO_2 released
- 100% hydrogen (market price of $3)

Results:

- $2.13/ kg of H_2
- $0.157/kWh fuel cost of power
- -$0.0190/kWh Δ fuel cost of power (relative to 100% natural gas)

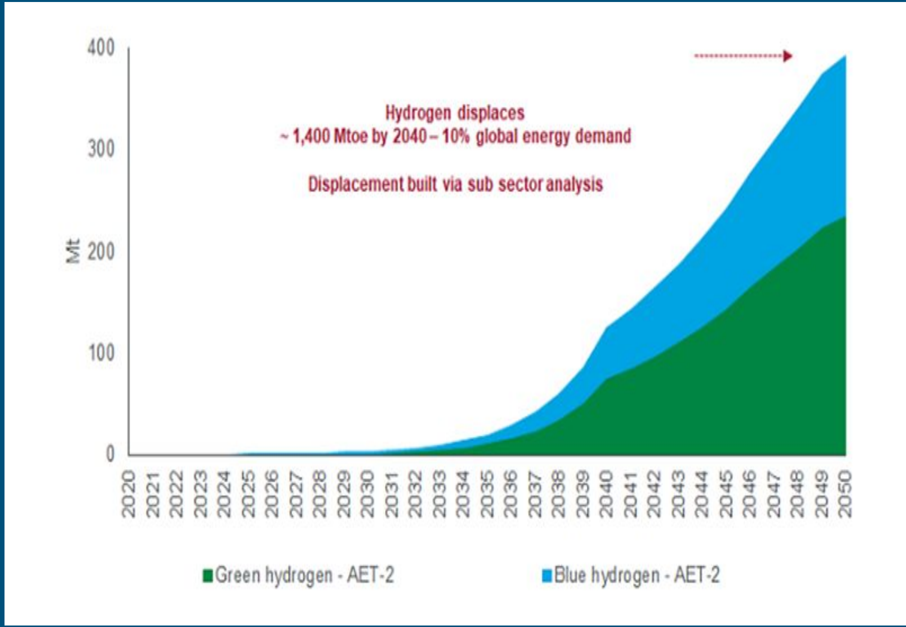
Then why do developers want to do this?

- Strict pollution restrictions inhibit permits for a CCGT due to the requirements of a rigid zero emission plan
  - Example: New York State Law

- A significant cost discrepancy exists between renewable hydrogen and fossil fuel hydrogen
  - SMR (grey) hydrogen is below $1-1.80/kg
  - Green hydrogen is $2.50-6.80/kg

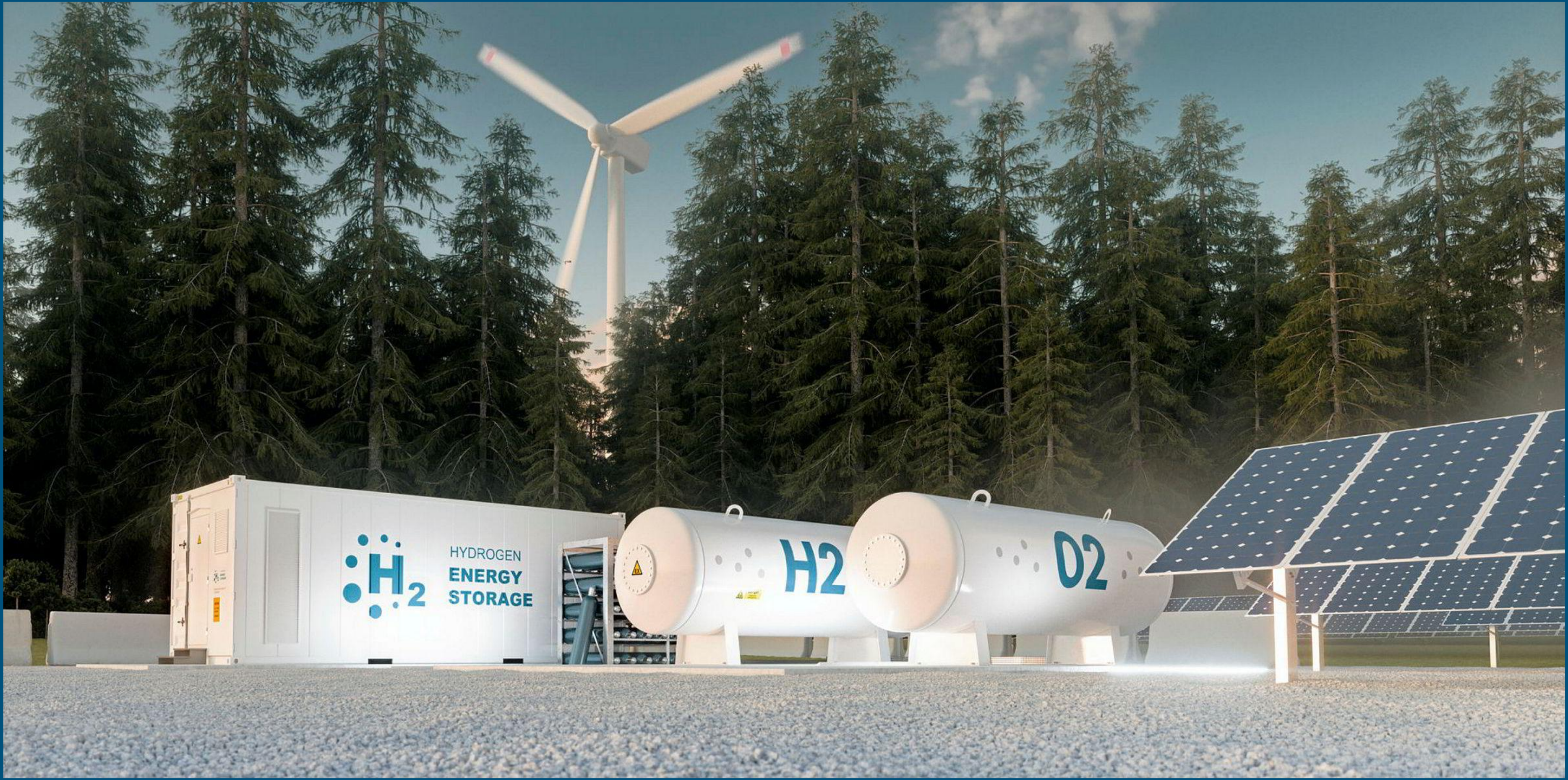
Conclusion

- As of now, the cost of producing renewable hydrogen is too high for economic viability
- However, policy incentives are a necessity to make green hydrogen competitive
    - Examples: Carbon price, zero carbon peaker, hydrogen infrastructure



Source: Forbes

Questions?


H2
HYDROGEN
ENERGY
STORAGE
H2
O2

Sources

- https://greenchemuoft.wordpress.com/2016/10/31/greenchemprinciple7
- https://hydrogencouncil.com/wp-content/uploads/2017/11/Hydrogen-scaling-up-Hydrogen-Council.pdf
- https://www.greentechmedia.com/articles/read/green-hydrogen-explained
- https://www.iea.org/reports/the-future-of-hydrogen
- http://www.fchea.org/in-transition/2019/7/22/unlocking-the-potential-of-hydrogen-energy-storage
- https://www.ashurst.com/en/news-and-insights/insights/hydrogen-a-clean-hot-topic/
- https://www.powermag.com/worlds-first-integrated-hydrogen-power-to-power-demonstration-launched/
- https://news.stanford.edu/2019/03/18/new-way-generate-hydrogen-fuel-seawater