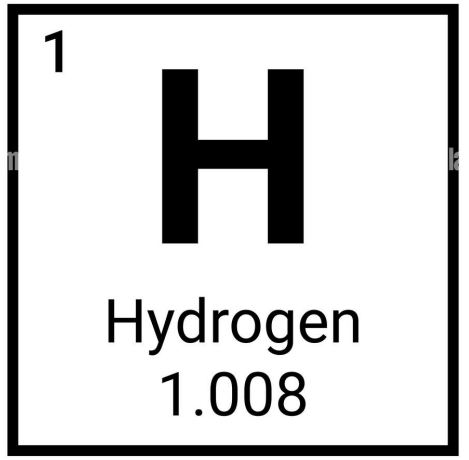
The University of Texas at Austin
Cockrell School of Engineering

The University of Texas at Austin
Center for Electromechanics
Cockrell School of Engineering

HYDROGEN – A VERSATILE CLEAN ENERGY CARRIER

Clean Hydrogen Day Celebration at UT Austin
Thursday October 5, 2023
Mike Lewis

Hydrogen 1.01

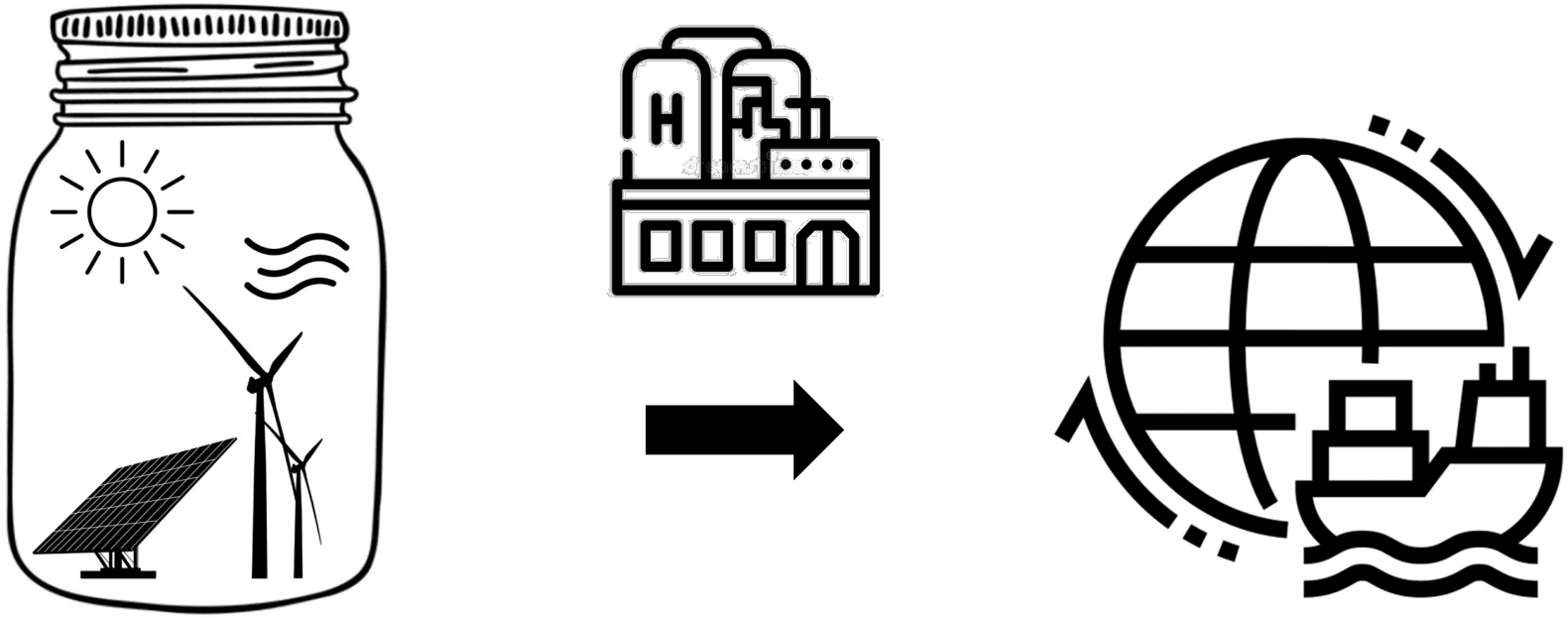


- Most abundant element in the universe
- Present in common substances (water, sugar, methane)
- Very high energy by weight (3X more than gasoline)
- A versatile clean energy carrier with a wide rage of applications

Challenges

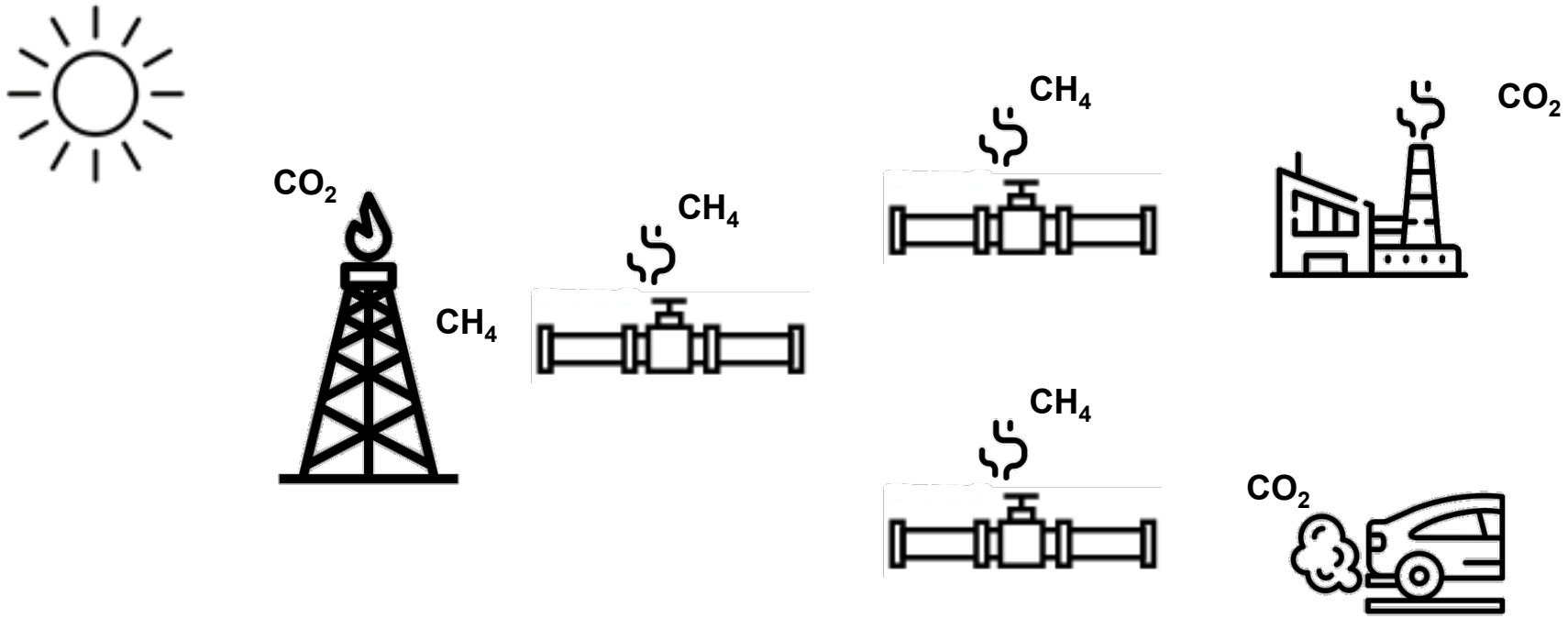
- Rarely found naturally, typically make from water or hydrocarbon sources
- Production, storage, and transport are all energy intensive due to poor gravimetric density
- How we will use and produce hydrogen is not without controversy
  - Today costs are relatively high and infrastructure is limited
  - Hydrogen emissions can prolong GHG in the atmosphere

Hydrogen is a versatile clean energy carrier



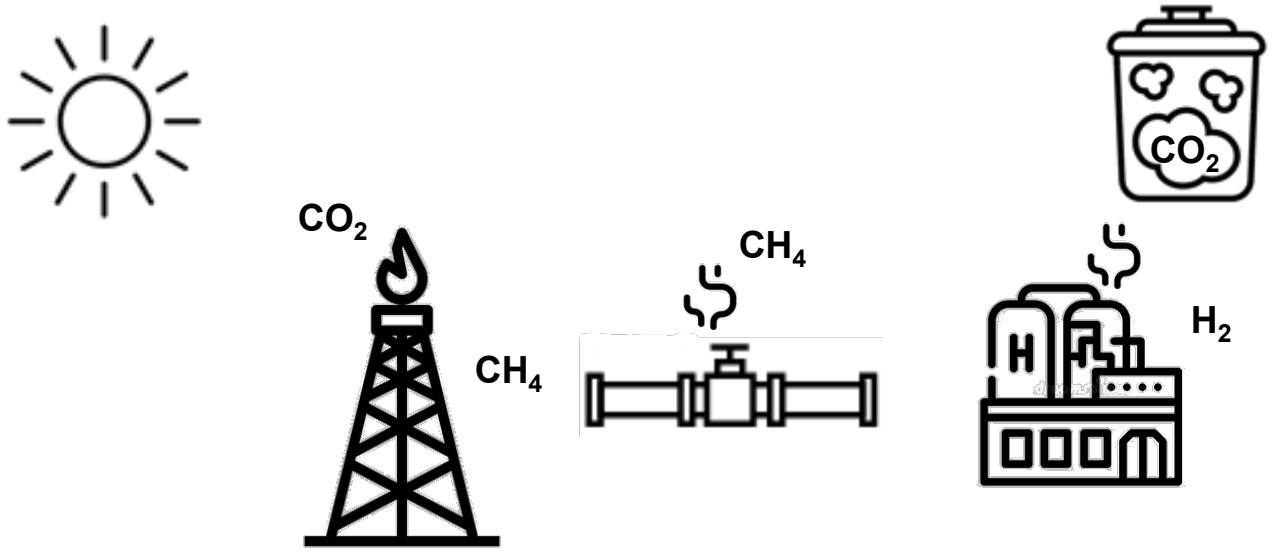
Hydrogen can allow us to capture wind and solar power and move it around the world?

Hydrogen is a versatile clean energy carrier



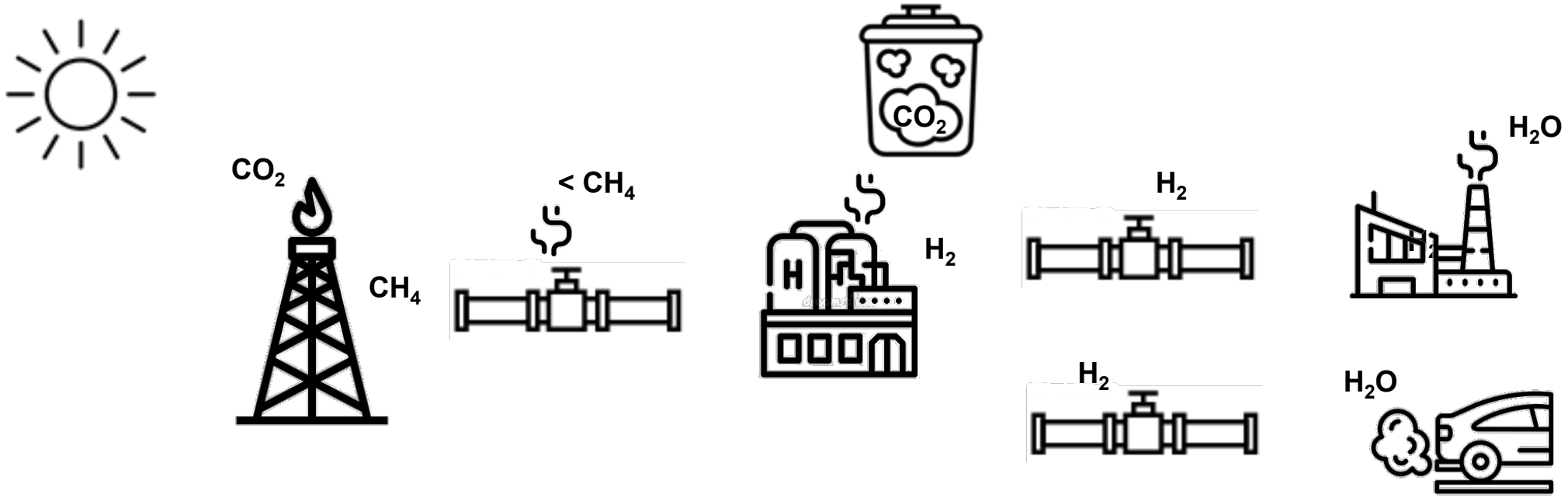
The Sun and Earth worked long and hard to provide the fossil fuels we use today.
How can we use this valuable energy resource while managing the carbon responsibly?

Hydrogen is a versatile clean energy carrier



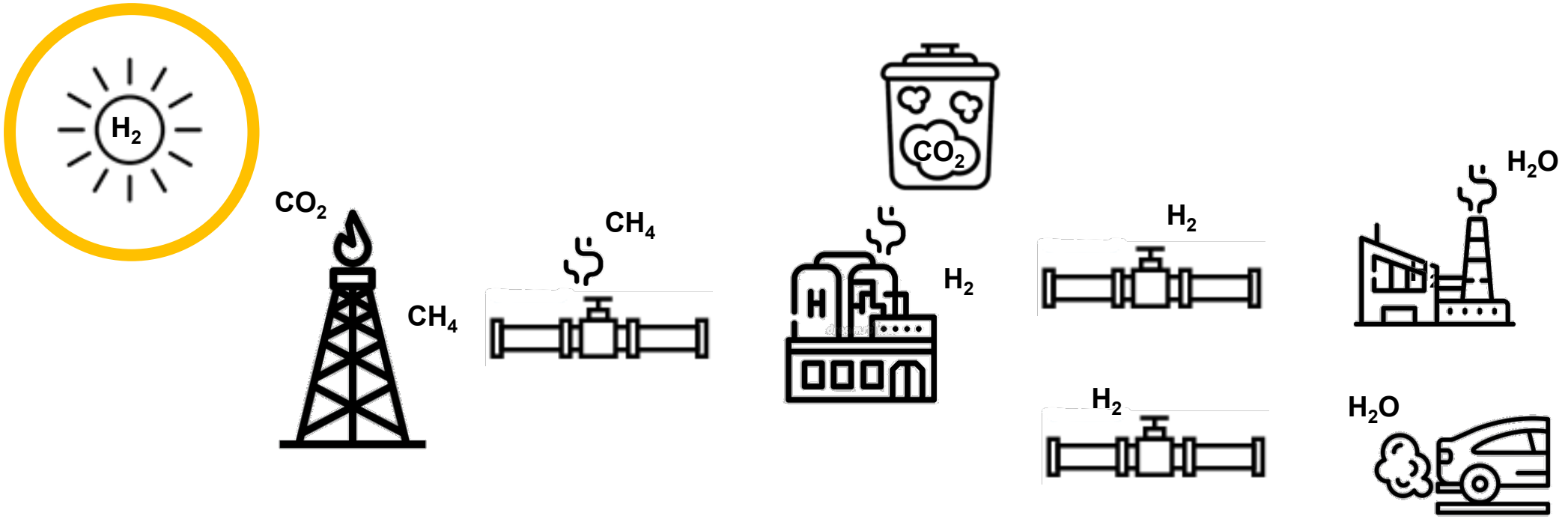
It is possible to capture the carbon from every tailpipe or smokestack in the world. Hydrogen gives us an opportunity to do so responsibly in central locations.

Hydrogen is a versatile clean energy carrier



Clean hydrogen can then be transported and used in numerous applications, thereby reducing emissions at many tailpipes and smokestacks around the world.

Hydrogen is a versatile clean energy carrier



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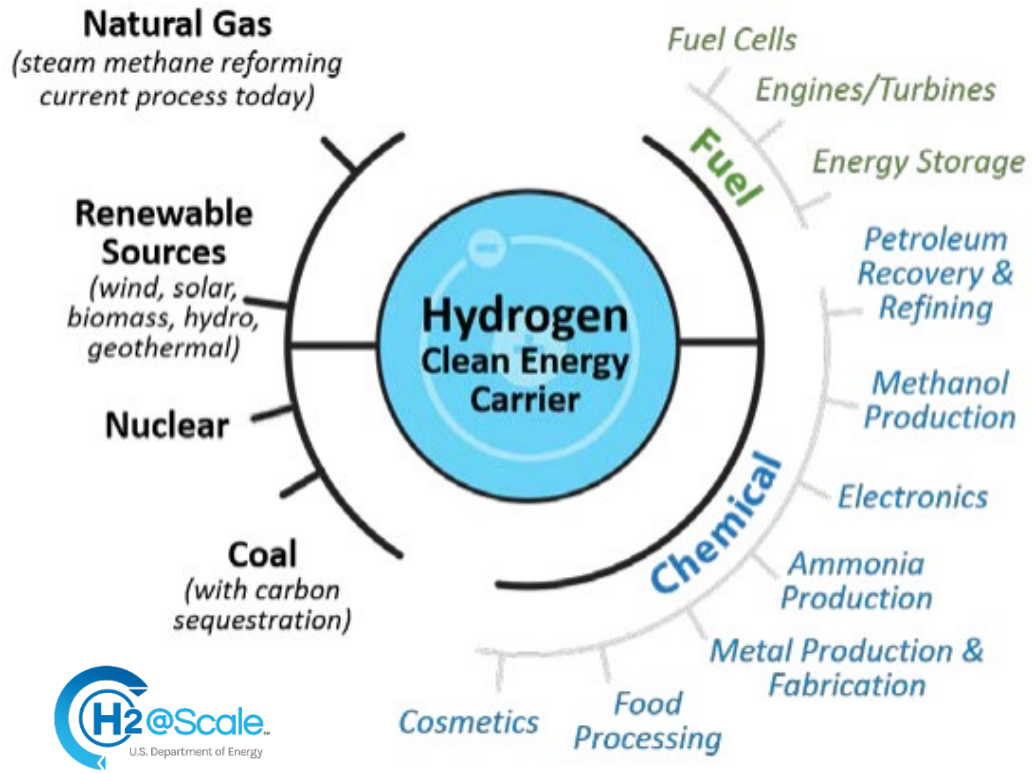
Hydrogen's Role in Decarbonization

Hydrogen can enable U.S. energy security, resiliency, and economic prosperity, and is part of an "all of the above" energy strategy for these reasons:

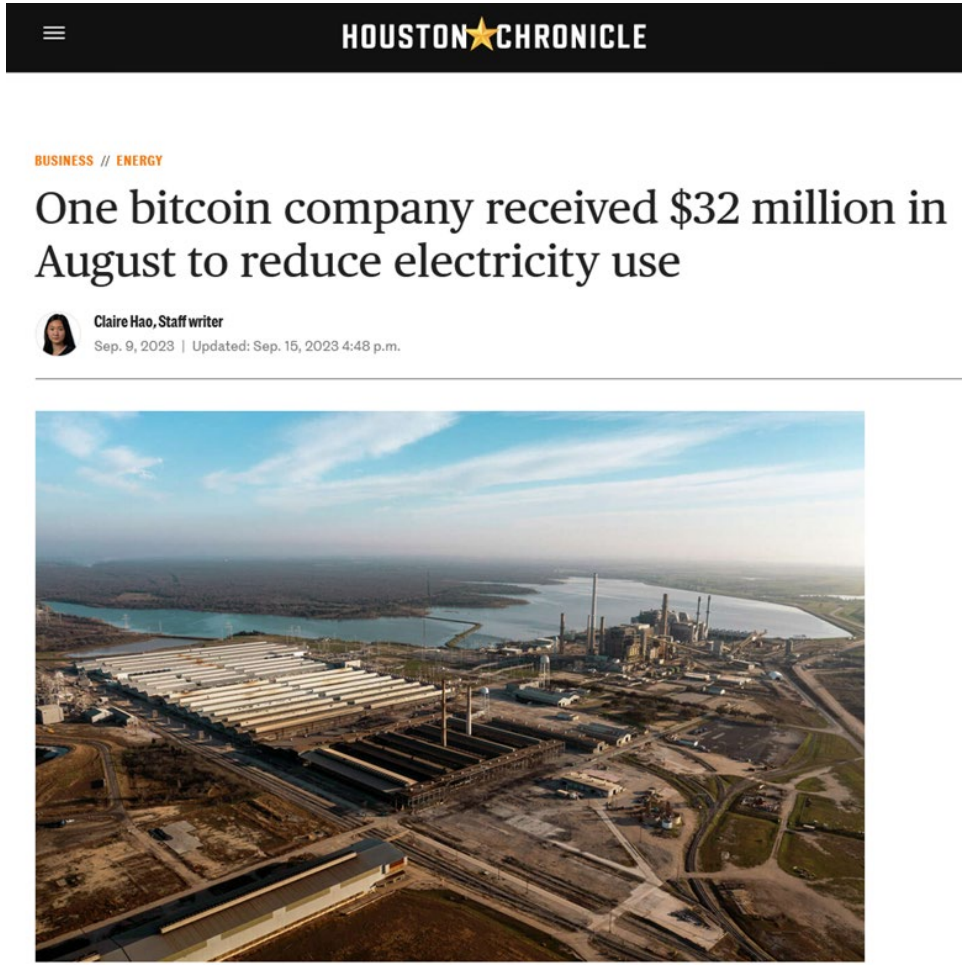
1) Hydrogen can be produced from diverse domestic resources for use in multiple sectors, or for export.
2) Hydrogen is a critical feedstock for the entire chemicals industry, including liquid fuels.
3) Hydrogen and fuel cells can enable zero or near zero emissions in transportation, stationary or remote power, and portable power applications.
4) Hydrogen can be used as a "responsive load" on the grid to enable grid stability and gigawatt-hour energy storage, and increase utilization of power generators, including nuclear, coal, natural gas, and renewables.
5) Hydrogen can enable innovations in domestic industries, such as transportation (e.g., in vehicles, aviation, and marine applications) and iron making.



Source: https://www.energy.gov/sites/default/files/2020/07/f76/hfto-h2-at-scale-handout-2020.pdf

Example : Hydrogen, Electrolyzers, and The Grid

- Hydrogen Electrolyzers can be used as controllable loads similar to Bitcoin Mining faciltiies
  - During periods of high demand (or low supply), ERCOT pays Bitcoin facilities to reduce their load.
  - Electrolysis facilities could use the same mechanism to potentially reduce the cost of hydrogen.
- Hydrogen storage can make renewable energy dispatchable 24/7/365, even in time of peak demand
  - Underground hydrogen commercial today to support petrochemical energy stores more energy than all grid scale batteries in Texas.



HOUSTON CHRONICLE

BUSINESS // ENERGY

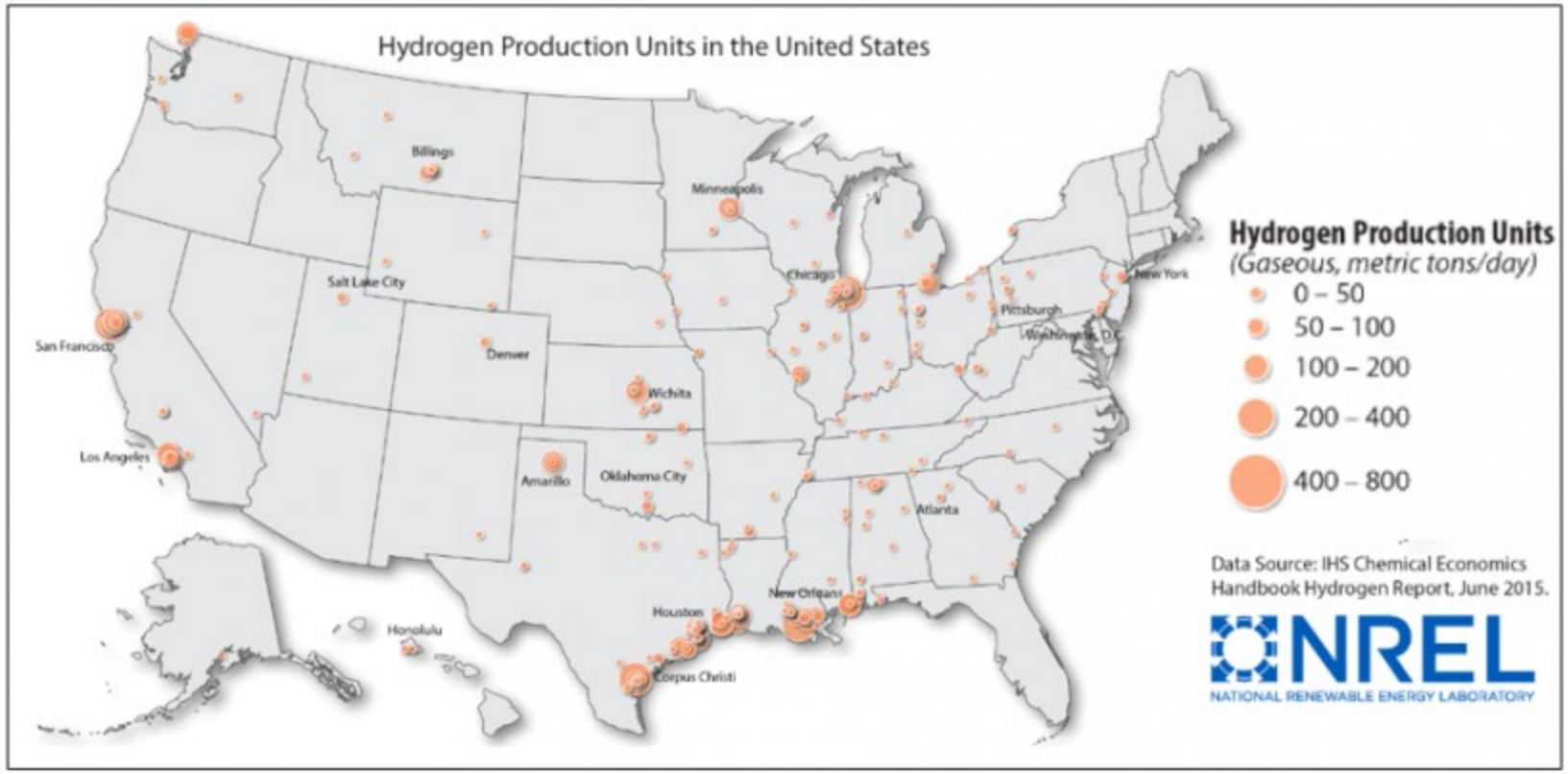
One bitcoin company received $32 million in August to reduce electricity use

Claire Hao, Staff writer

Sep. 9, 2023 | Updated: Sep. 15, 2023 4:48 p.m.

https://www.houstonchronicle.com/business/energy/article/ercot-bitcoin-crypto-riot-platforms-payment-18352991.php

Hydrogen in the U.S. Today



U.S. annual hydrogen production

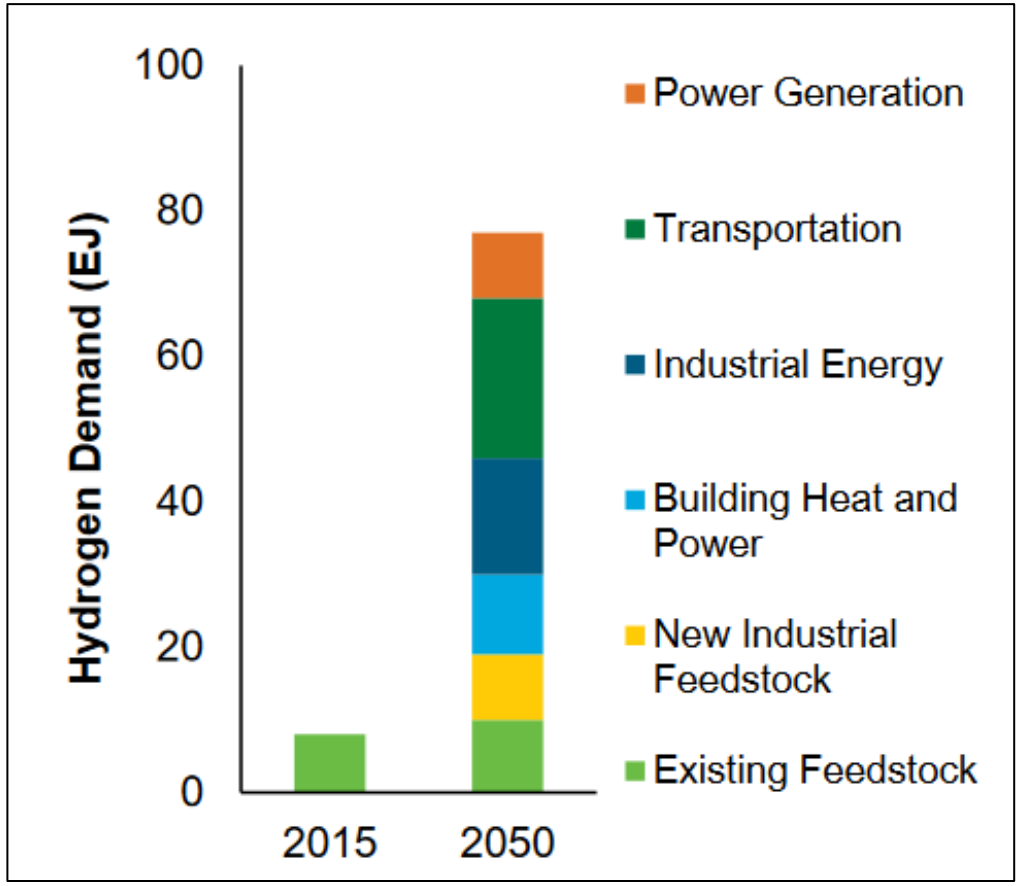
10 million metric tons

Largest Users in the U.S.

Petroleum Processing	68%	Fertilizer Production	21%

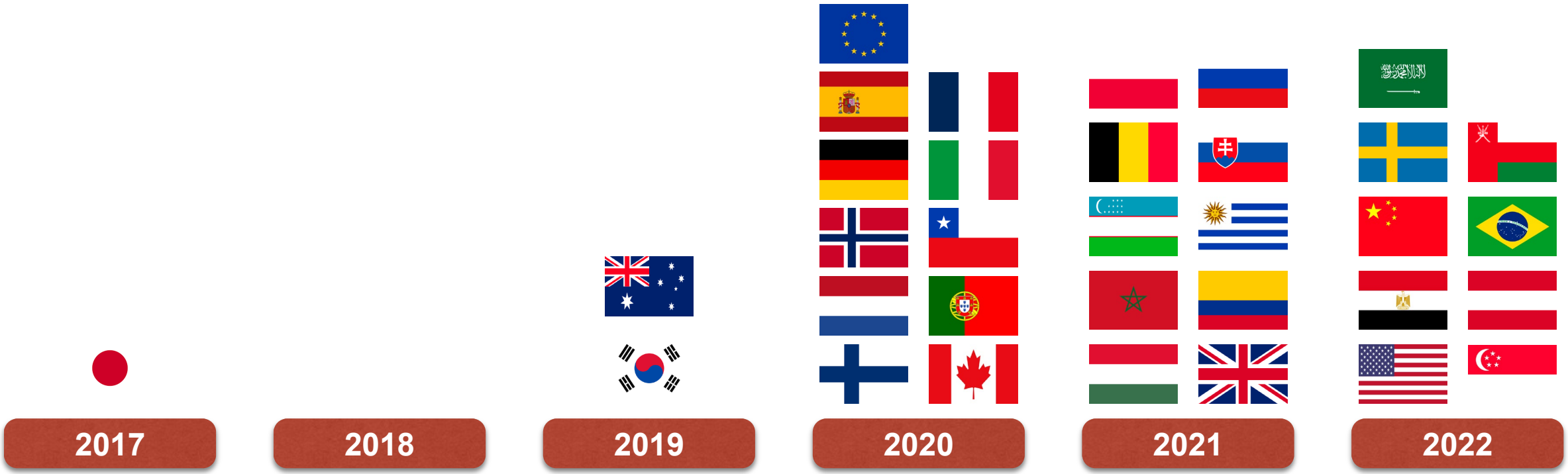
Why Now is an Exciting Time for Hydrogen

- New hydrogen markets are emerging
- International momentum is building to develop a hydrogen energy economy
- Department of Energy programs and goals
- U.S. Policy supporting hydrogen infrastructure and production



Source: "Hydrogen Scaling Up." Hydrogen Council. November 2017. http://hydrogencouncil.com/wp-content/uploads/2017/11/Hydrogen-scaling-up-Hydrogen-Council.pdf

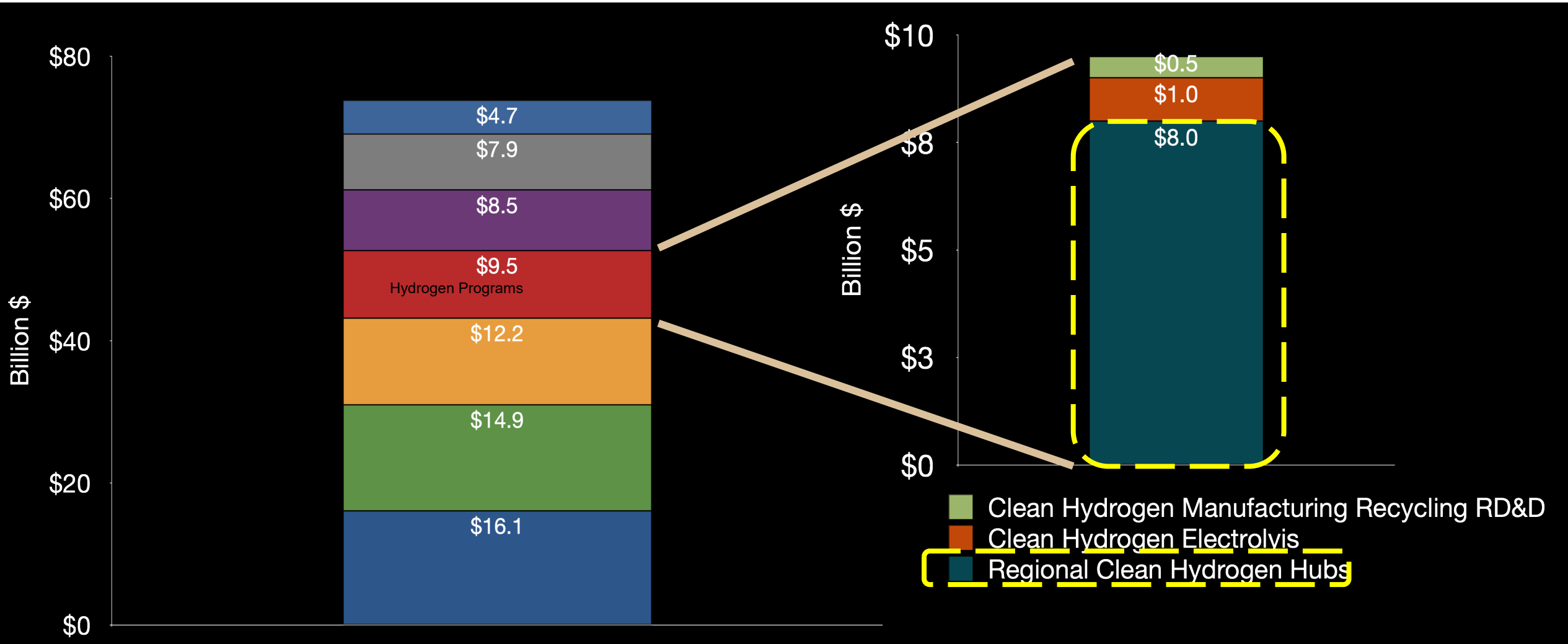
National Hydrogen Strategies



DOE low-carbon hydrogen cost targets

- Launched in June 2021, the *Hydrogen Earthshot* sets a target to reduce the cost of clean hydrogen to $1/kg by 2032
- 80% cost reduction compared to current average cost of producing hydrogen from renewable energy ($5/kg)
- Modeled after the successful SunShot Initiative that drove cost declines in solar energy
- Other Energy Earthshot initiatives include: Long Duration Storage Shot, Carbon Negative Shot, Enhanced Geothermal Shot, Floating Offshore Wind Shot, and Industrial Heat Shot

Infrastructure Investment and Jobs Act included $9.5 billion for hydrogen programs



Regional Clean Hydrogen Hub Program

Production

At least one from…

- Renewable energy
- Nuclear energy
- Fossil fuels

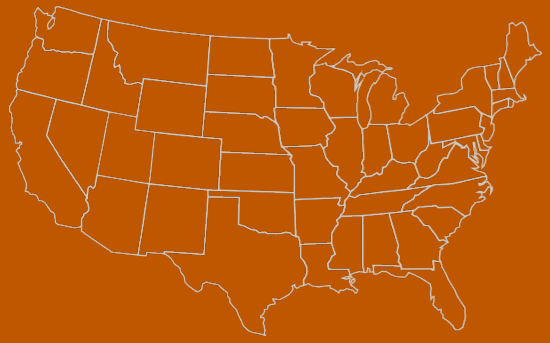
End Use

At least one in…

- Residential and commercial heating
- Electric power generation
- Transportation
- Industrial sector

Geography

Each in different regions of the US



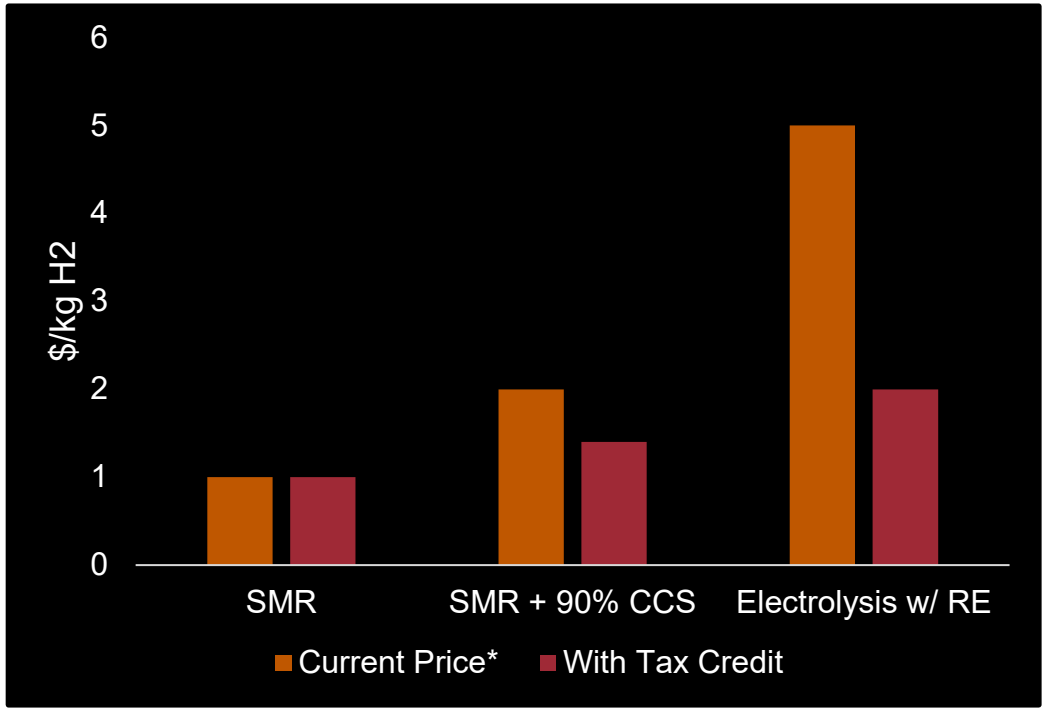
At least two in…

- Natural gas producing regions

The new clean hydrogen production tax credit included in the *IRA* could make clean hydrogen competitive

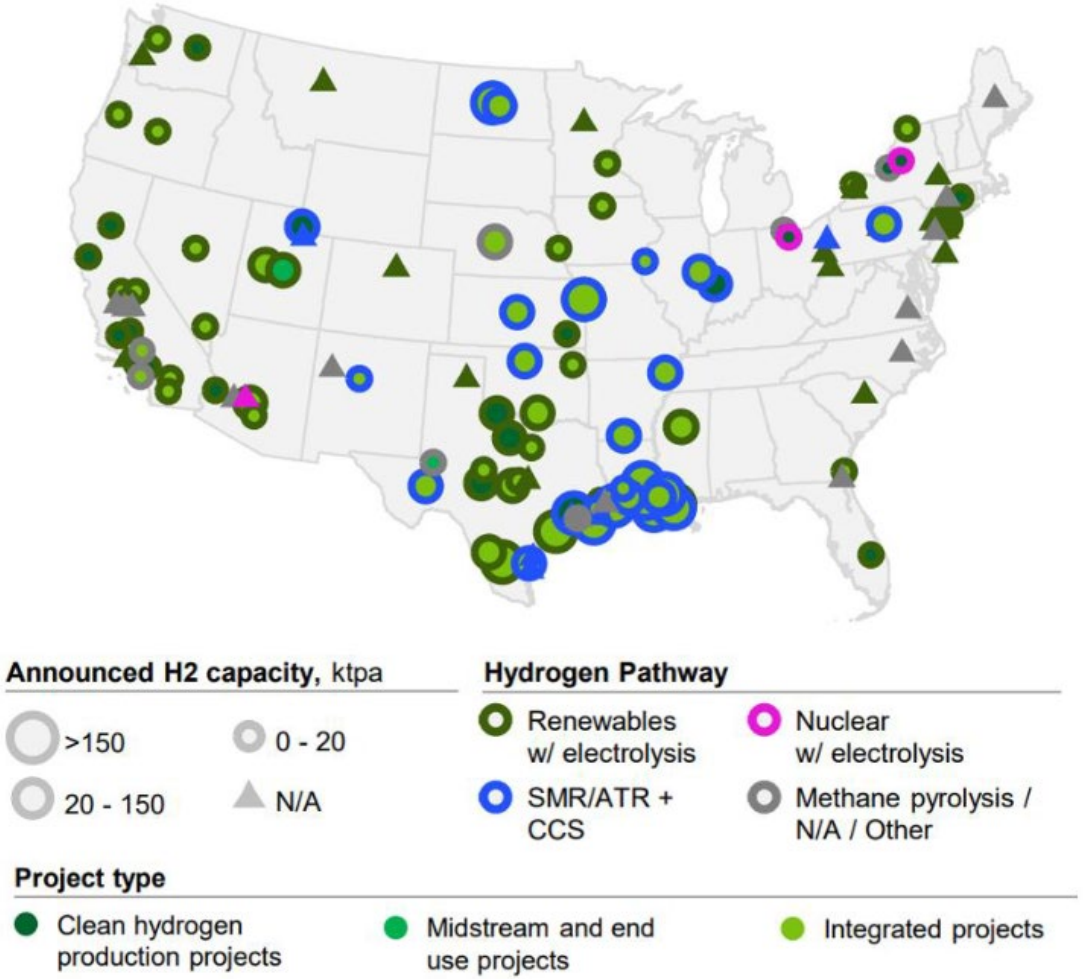
Clean hydrogen PTC has a tiered credit value structure based on production emissions

Emissions Threshold	Credit Value (assumes 5x bonus)
>= 2.5 kg CO_{2e}/kgH_2 & < 4 kg CO_{2e}/kg H_2	\$0.60/kg H_2
>= 1.5 kg CO_{2e}/kgH_2 & < 2.5 kg CO_{2e}/kg H_2	\$0.75/kg H_2
>= 0.45 kg CO_{2e}/kgH_2 & < 1.5 kg CO_{2e}/kg H_2	\$1.00/kg H_2
< 0.45 kg CO_{2e}/kg H_2	\$3.00/kg H_2



*Approximate prices of current production methods to demonstrate impact of tax credit

Publicly announced clean hydrogen production



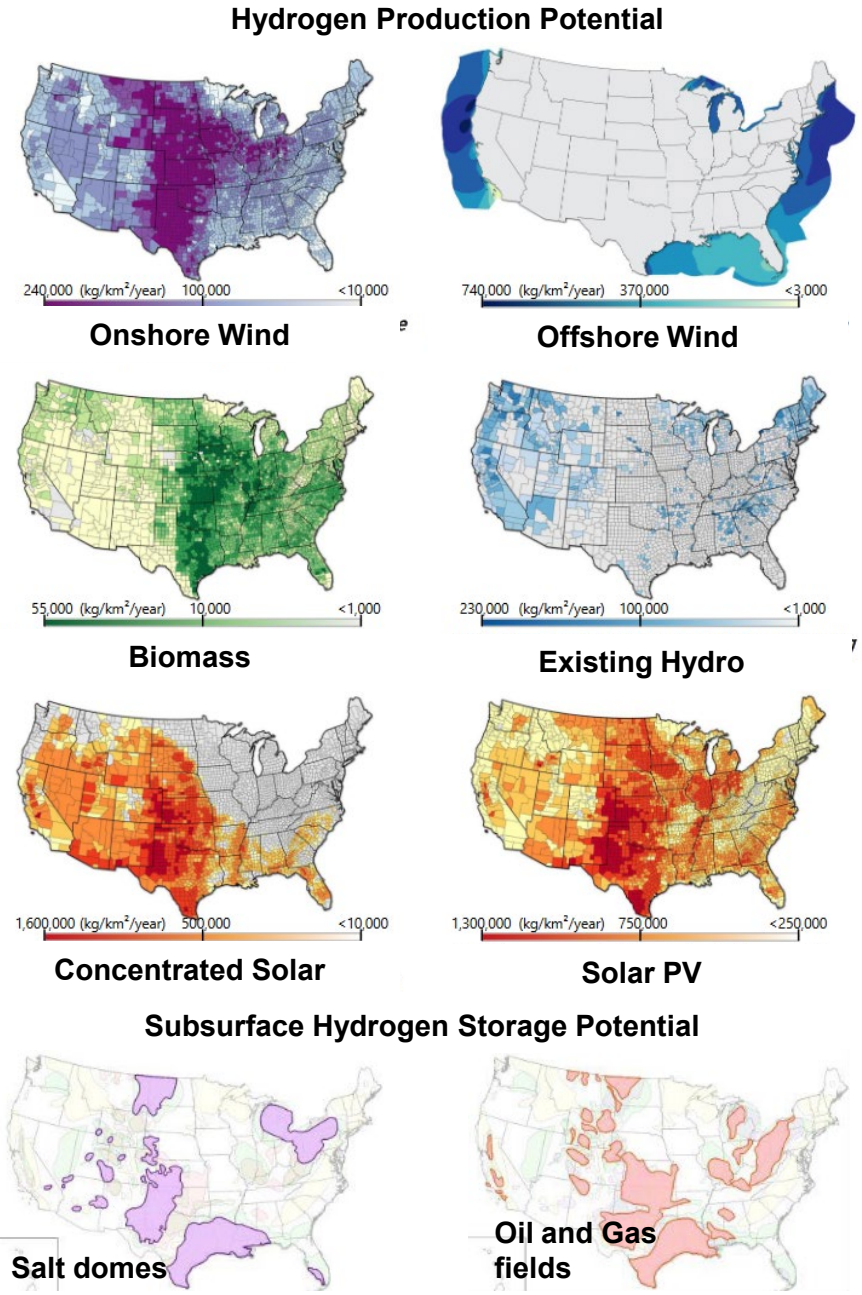
As of EOY 2022, with total production potential of 12 MMT/year.

https://www.hydrogen.energy.gov/docs/hydrogenprogramlibraries/pdfs/us-national-clean-hydrogen-strategy-roadmap.pdf

Why Hydrogen in Texas?

- Ample resources for hydrogen production
  - Both natural gas and renewable energy
- Currently produce about 1/3 of total US hydrogen production in Texas
  - 3 MMT of 10 MMT consumed annually in US
- Existing hydrogen demand in refining oil and producing petrochemicals and ammonia
- Serviced by 1600 miles of existing hydrogen pipelines
- Geology well suited for storage of H_2 and CO_2 required for hydrogen production applications with CCS
- Industry leaders located in Texas

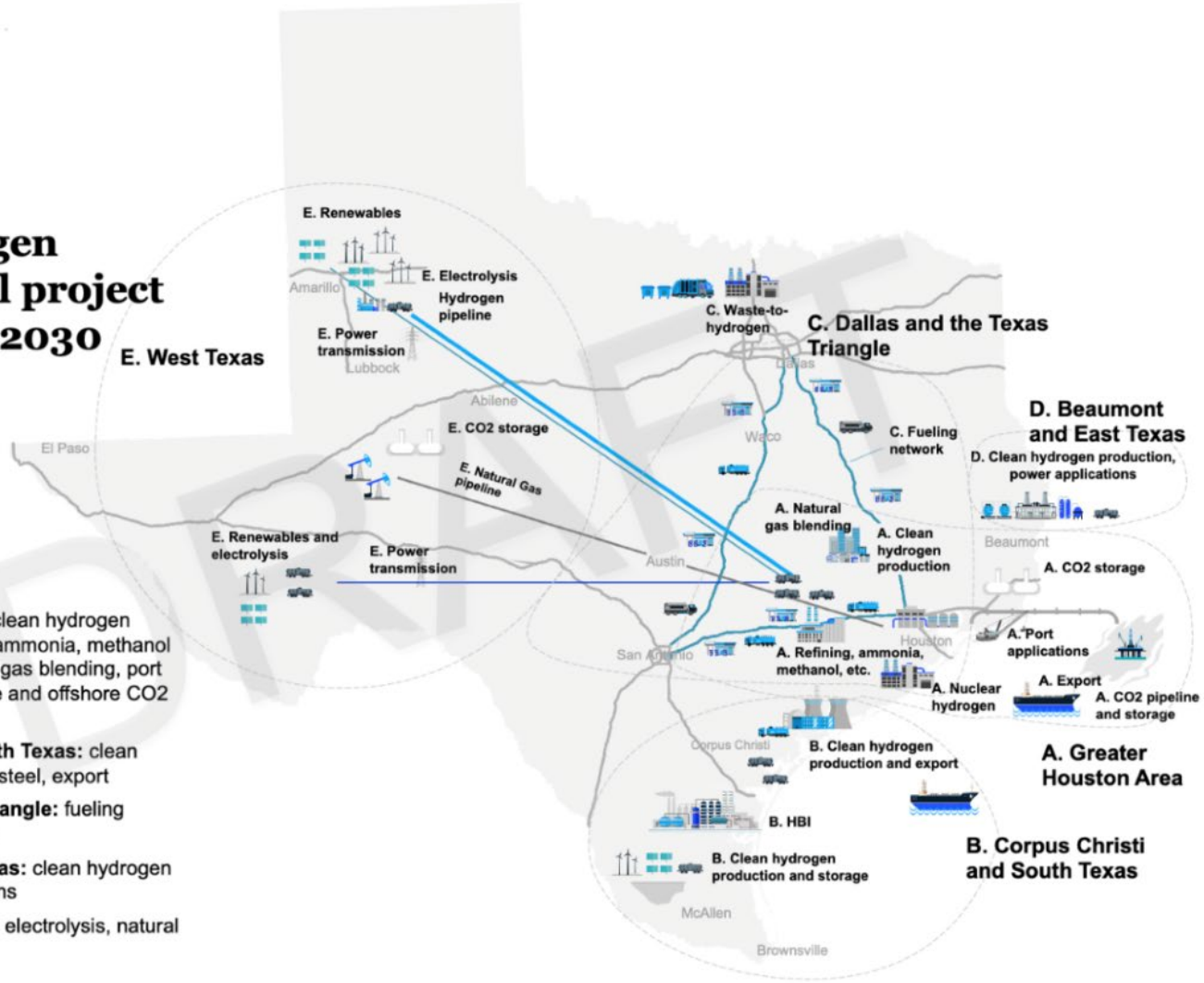
https://www.hydrogen.energy.gov/docs/hydrogenprogramlibraries/pdfs/us-national-clean-hydrogen-strategy-roadmap.pdf



A Potential Hydrogen Economy in Texas

Texas hydrogen hub potential project examples by 2030

Illustrative



Emerging clusters

A. Greater Houston Area: clean hydrogen production serving refining, ammonia, methanol and other industries, natural gas blending, port applications, export, onshore and offshore CO2 storage

B. Corpus Christi and South Texas: clean hydrogen production, iron & steel, export

C. Dallas and the Texas Triangle: fueling network, waste-to-hydrogen

D. Beaumont and East Texas: clean hydrogen production, power applications

E. West Texas: renewables, electrolysis, natural gas, CO2 storage

Potential opportunity by 2050

21MT of clean hydrogen production in Texas, including 11MT local demand, 10MT export

220MT global CO_2 abatement potential from 21MT of hydrogen, i.e., 4x Houston's 2019 emissions

30-60% projects located in communities most impacted by environmental justice

180k potential direct, indirect, and induced jobs to be created in the hydrogen economy

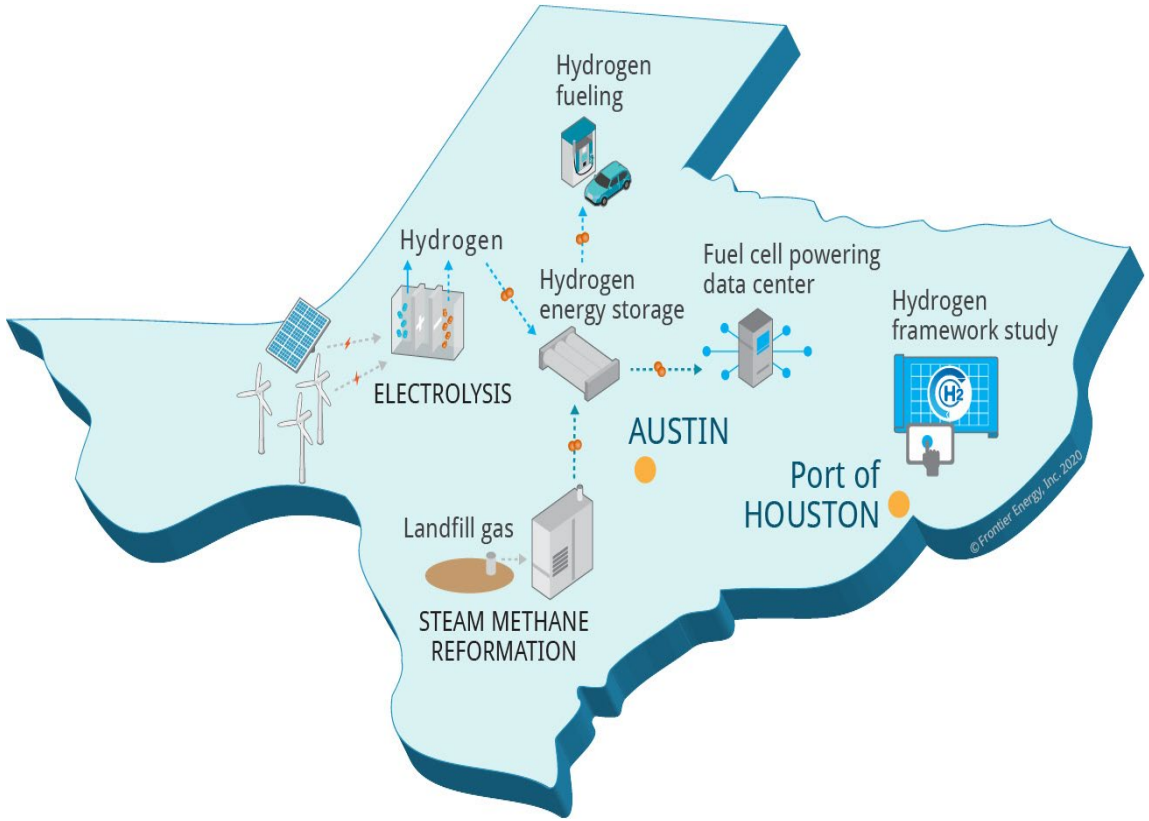
$100b potential addition to Texas' GDP, i.e., 6% of Texas' 2019 GDP

Study led by Center for Houston Future

Demonstration and Framework for H2@Scale in Texas

Two Research Tracks

- Demonstrate multiple RH2 generation options, co-located with vehicle fueling and a large base load consumer to enable cost-effective H2 energy solutions
- Develop framework for actionable H2@Scale pilot plans in Texas, Port of Houston and Gulf Coast region, including energy storage



Sponsored by the Department of Energy – EERE with cost share from project partners

FRONTIER energy | TEXAS The University of Texas at Austin | gti GAS TECHNOLOGY INSTITUTE

Demonstration activities at UT

~100% renewable H_2 generation

- 75 kg/day using renewable natural gas in two steam methane reformers
- 40 kg/day using renewable energy to power two electrolyzers

Hydrogen storage

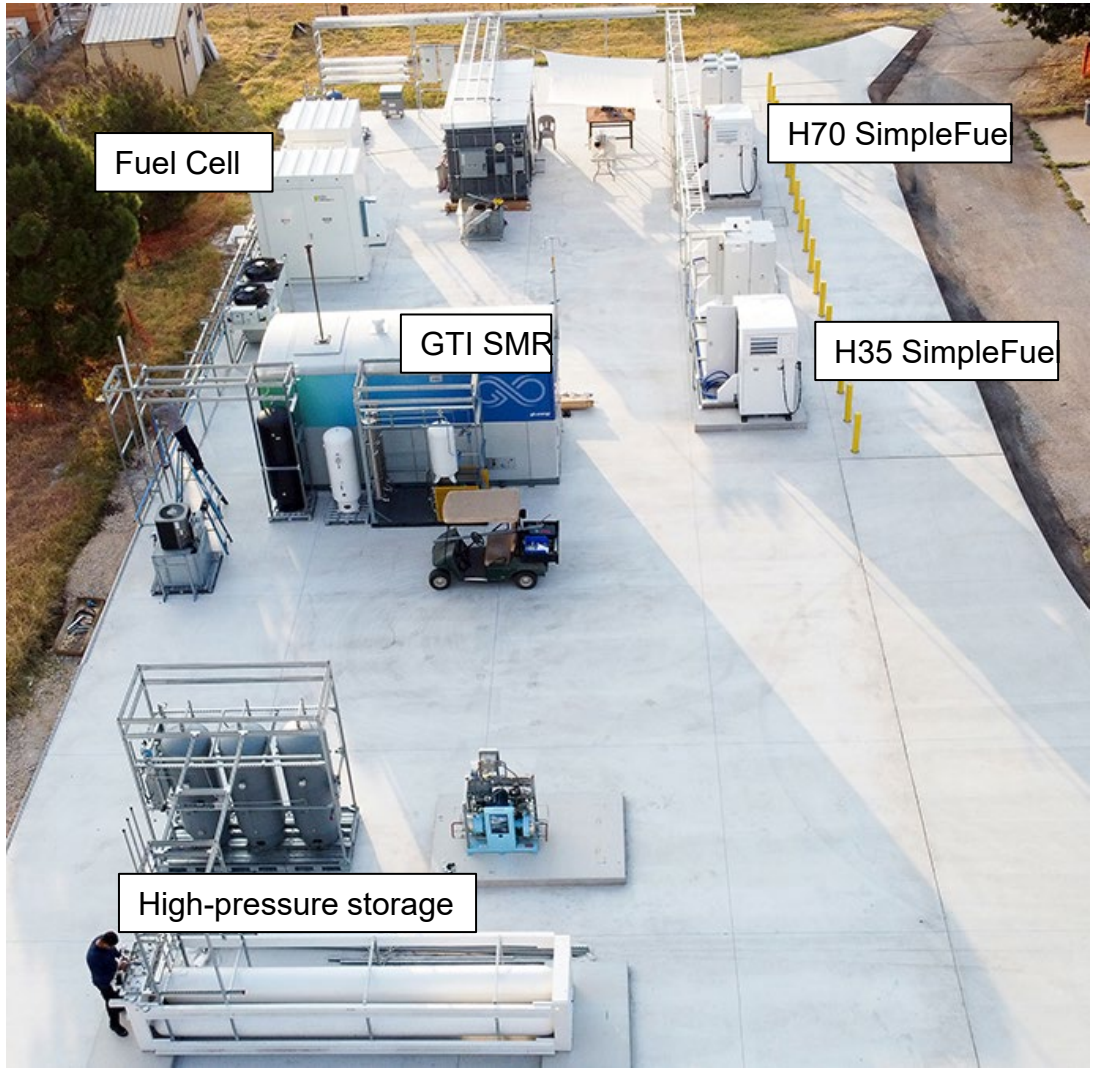
- 45 kg in ASME Type I pressure vessels at approximately 5000 psi

Large scale, industry H_2 user

- 100kW fuel cell powering Texas Advanced Computing Center

Vehicle refueling

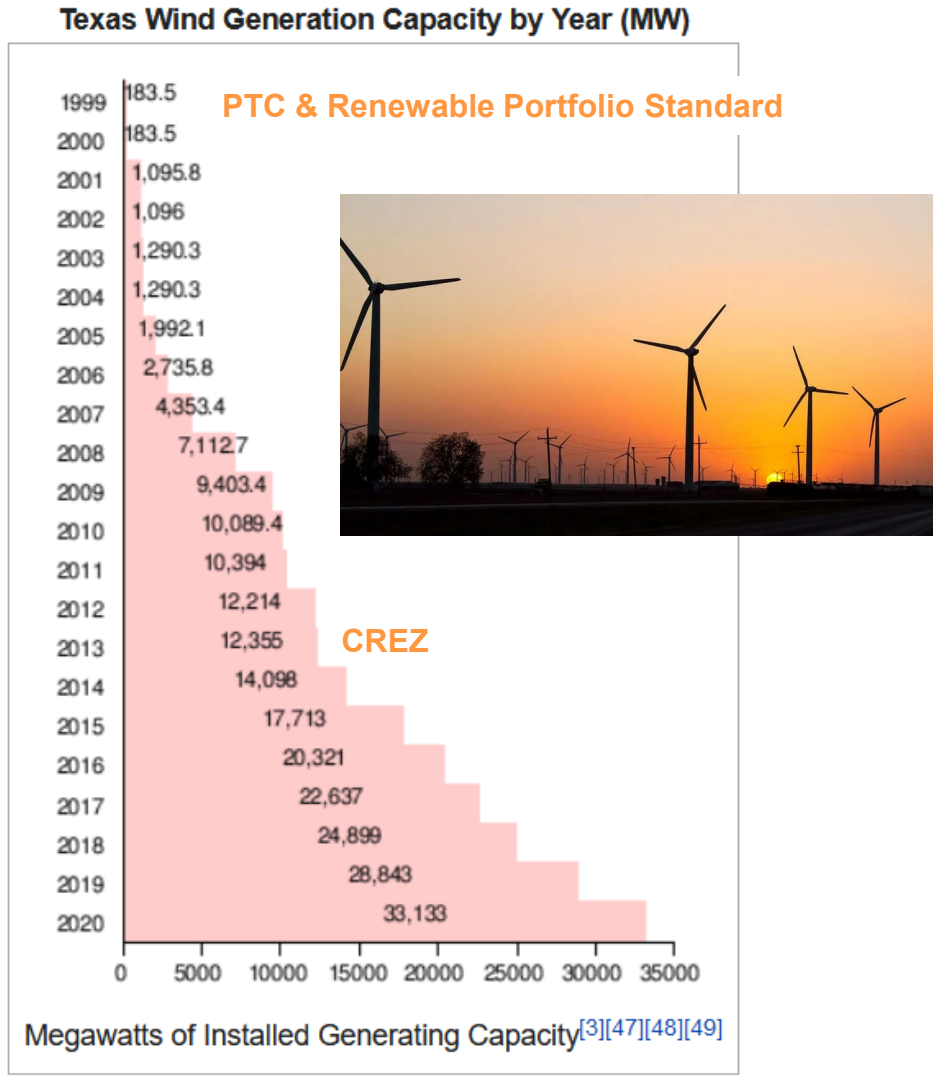
- Two fuel dispensers for gaseous hydrogen at 350 bar and 700 bar



There is a model for Hydrogen in Texas…

Wind Power development in Texas

- PTC enabled the business opportunity
- Renewable Portfolio Standard spurred growth
- CREZ later expanded electric transmission corridors
- Provided value for land owners and jobs for local communities
- Infrastructure Incentives and Hydrogen Production Tax Credit policies could enable similar growth for hydrogen



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