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

Example: Hydrogen, Electrolyzers, and The Grid

• Hydrogen Electrolyzers can be used as controllable loads similar to Bitcoin Mining facilities
  • 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.

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

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

<table>
<thead>
<tr>
<th>Emissions Threshold</th>
<th>Credit Value (assumes 5x bonus)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;= 2.5 kg CO₂e/kg H₂ &amp; &lt; 4 kg CO₂e/kg H₂</td>
<td>$0.60/kg H₂</td>
</tr>
<tr>
<td>&gt;= 1.5 kg CO₂e/kg H₂ &amp; &lt; 2.5 kg CO₂e/kg H₂</td>
<td>$0.75/kg H₂</td>
</tr>
<tr>
<td>&gt;= 0.45 kg CO₂e/kg H₂ &amp; &lt; 1.5 kg CO₂e/kg H₂</td>
<td>$1.00/kg H₂</td>
</tr>
<tr>
<td>&lt; 0.45 kg CO₂e/kg H₂</td>
<td>$3.00/kg H₂</td>
</tr>
</tbody>
</table>

*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.

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 H₂ and CO₂ required for hydrogen production applications with CCS
- Industry leaders located in Texas

A Potential Hydrogen Economy in Texas

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 CO2 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.
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
MICHAEL LEWIS
Research Scientist

mclewis@cem.utexas.edu
(512) 232-5715