Advanced Power and Energy Program



Realizing the Potential of Clean Hydrogen

Jeffrey Reed February 14, 2024





- Hydrogen is a highly energetic molecule that can be used as a fuel or feedstock in many applications
- Hydrogen is widely used today for refining, fertilizer production, and as a chemical feedstock – current global consumption ~90 million metric tonnes
- Currently produced through reformation of natural gas and has a carbon footprint on the order of 12 – 13 kg-CO2e per kg of hydrogen
- The U.S. Department of Energy defines "Clean Hydrogen" as hydrogen having a carbon intensity (CI) below 4 kg-CO2e per kg of hydrogen (well-to-gate)
- Ultra-low carbon hydrogen has CI below 0.45 kg-CO2e per kg of hydrogen

Why is Clean Hydrogen Important?

- 1. Potential for true zero GHG and toxic air emissions
- 2. The high energy density and transportability of hydrogen make is suitable for applications for which the use of renewable electricity and battery storage are not feasible

Mobility Applications	Power, Gas and Industry
1. Light and Medium Duty Vehicles	12. Stationary Power / Microgrids
2. Line-haul and Drayage Trucking	13. Pipeline Gas for Buildings / Blending
3. Transit	14. Data Centers
4. Passenger Rail	15. Ammonia
5. Freight Rail	16. Refining
6. Forklifts	17. Steel
7. Construction and Mining Equipment	18. E-Fuels (e.g., methanol, SNG)
8. Cargo Handling	19. Other Industrial Heat and Process H2
9. Harbor Craft	 Metals Food and Beverage Cement Pulp and Paper (incl recycled)
10. Ocean Going Vessels	 Industrial Boilers Glass Mfg. Soybean Oil Processing Corn Milling
11. Aviation	 Plastics Mfg.

2/12



Source: UCI CEI

Source: Data from Princeton Net Zero America study 2020

UC Where Do Things Stand with Clean Hydrogen Deployment?

- More than 20 national and international decarbonization strategies feature hydrogen use to serve 15% to 25% of energy demand
- The sector is at the early commercial deployment stage in the US, EU, China, Japan, Korea, and Australia
- In the United States, the DoE has awarded on the order of \$1B to each of 7 regional hydrogen hubs
- California was awarded up to \$1.2B for the Advanced Renewable and Clean Hydrogen Energy Systems (ARCHES) renewable hydrogen hub (headquartered at UCI Beall Applied Innovation)
- The UCI Clean Energy Institute is a global leader in clean hydrogen research







Hydrogen Research at the UCI Clean Energy Institute

Production



- Power-to-Gas on Campus Microgrid
- Power-to-Gas Design -- Five Points
- GridH2 Optimal Use of Excess Renewables

Transport and Storage



System impacts (leakage and

Gas grid H2 carrying capacity Optimal pathways for deep

decarbonization of the gas system

embrittlement)

٠



- Electrochemistry
- Hydrogen tolerance of burners
- Emissions/AQ impacts
- 6/12 Performance validation

4.93 3.95 2.96

1.97

0.99

0.00 -0.99 -1.97

-2.96 -3.95

End Use

© UCI Clean Energy Institute 2024

UC Is Clean Hydrogen Ready to Scale or "Developmental"?

- All technologies necessary for scale up of a global clean hydrogen sector are fully mature, proven, and in commercial use (with the possible exception of repurposed natural gas facilities)
- Cost reduction is the largest technical challenge but no "breakthroughs" are required to reach target cost levels production scale is the key



Year of Initial Operation

UC What are the Barriers to Scaling the Sector?

- Inaccurate information emanating from proponents of alternative technologies
 - Hydrogen technology is unproven and unsafe
 - Hydrogen will lead to increased NOx emissions
 - Hydrogen is a global warming gas
 - The promotion of "clean hydrogen" is a ploy to prolong the use of natural gas
 - Sound bits versus nuanced technical arguments
- Political opposition by the current administration threatened cancelation of the blue-state hubs
- The same siting and permitting bottlenecks plaguing the clean energy sector overall
- Backlash from spotty performance by the hydrogen refueling sector in California

UC Natural Gas Combustor NOx Emissions w/Hydrogen



© UCI Clean Energy Institute 2024

UC Gas Turbine Applications: NOx Emissions w/Hydrogen



UC Hydrogen Global Warming Impact

- Hydrogen emitted to the atmosphere participates in reactions that have a global warming impact
- (As do oxygen and nitrogen)
- Degree of impact depends on how much hydrogen is emitted across the supply chain
- 100-year GWP estimated to be on the order of 10 kg-CO2_e / kg-H₂
- Even at 10% venting + leakage, substituting renewable hydrogen for diesel or natural gas reduces global warming impact by over 90%



UC What's Needed to Realize the Potential of Clean Hydrogen?

- More effective messaging
- Sustained policy support including rational incentives (like EVs and solar) IRA Tax Credits key
- Avoidance of early stumbles in execution no Solyndra's





Thank You



#RH2@APEP RENEWABLE HYDROGEN

UCI ADVANCED POWER AND ENERGY PROGRAM

jgreed@uci.edu

© UCI Clean Energy Institute 2024