The Technical, Demand, and Economic Potential of H2@Scale within the United States

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Demand Potential

Demand potential of hydrogen market by 2050 is >9X.

Other applications are possible based on technology and policy growth as well as smaller applications

Application	Demand Potential (MMT/yr)	2015 Market for On-Purpose H2 (MMT/yr)
Refineries and the chemical processing industry (CPI) [a]	8	6
Metals	12	0
Ammonia	4	3
Biofuels	4	0
Synthetic fuels and chemicals	14	1
Natural gas supplementation	10	0
Seasonal energy storage for the electricity grid	15	0
Industry and Storage Subtotal	**67**	**10**
Light-duty fuel cell electric vehicles (FCEVs)	21	0
Medium- & Heavy-Duty FCEVs	11	0
Transportation Fuel Subtotal	**32**	**0**
Total	**99**	**10**

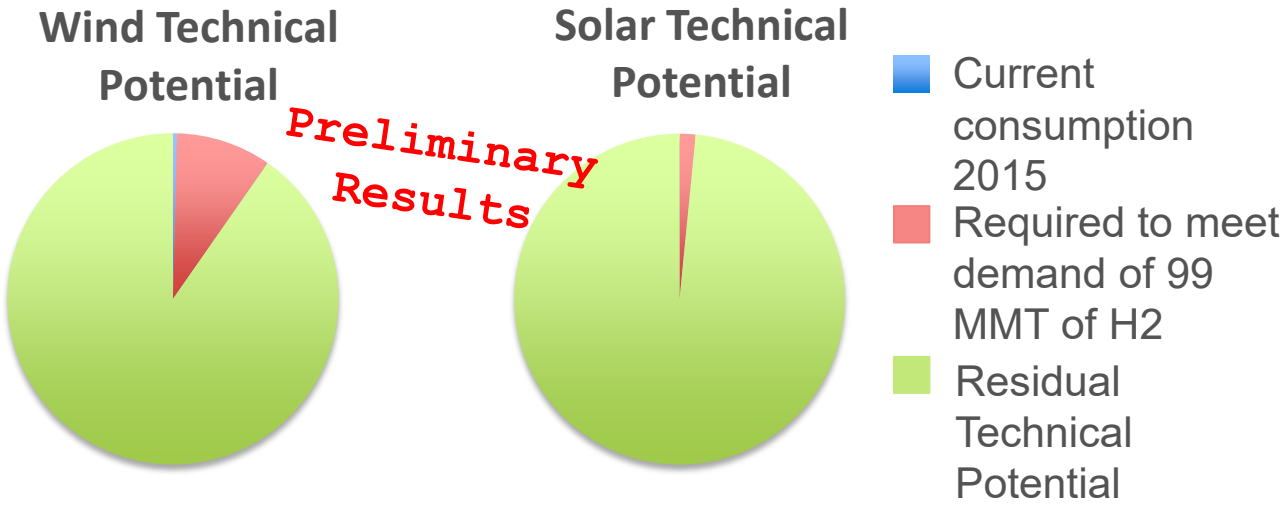
Preliminary Results

Definition: The demand potential is the estimated market size constrained by the services for which society currently uses energy, real-world geography, system performance, and by optimistic market shares but not by economic calculations.

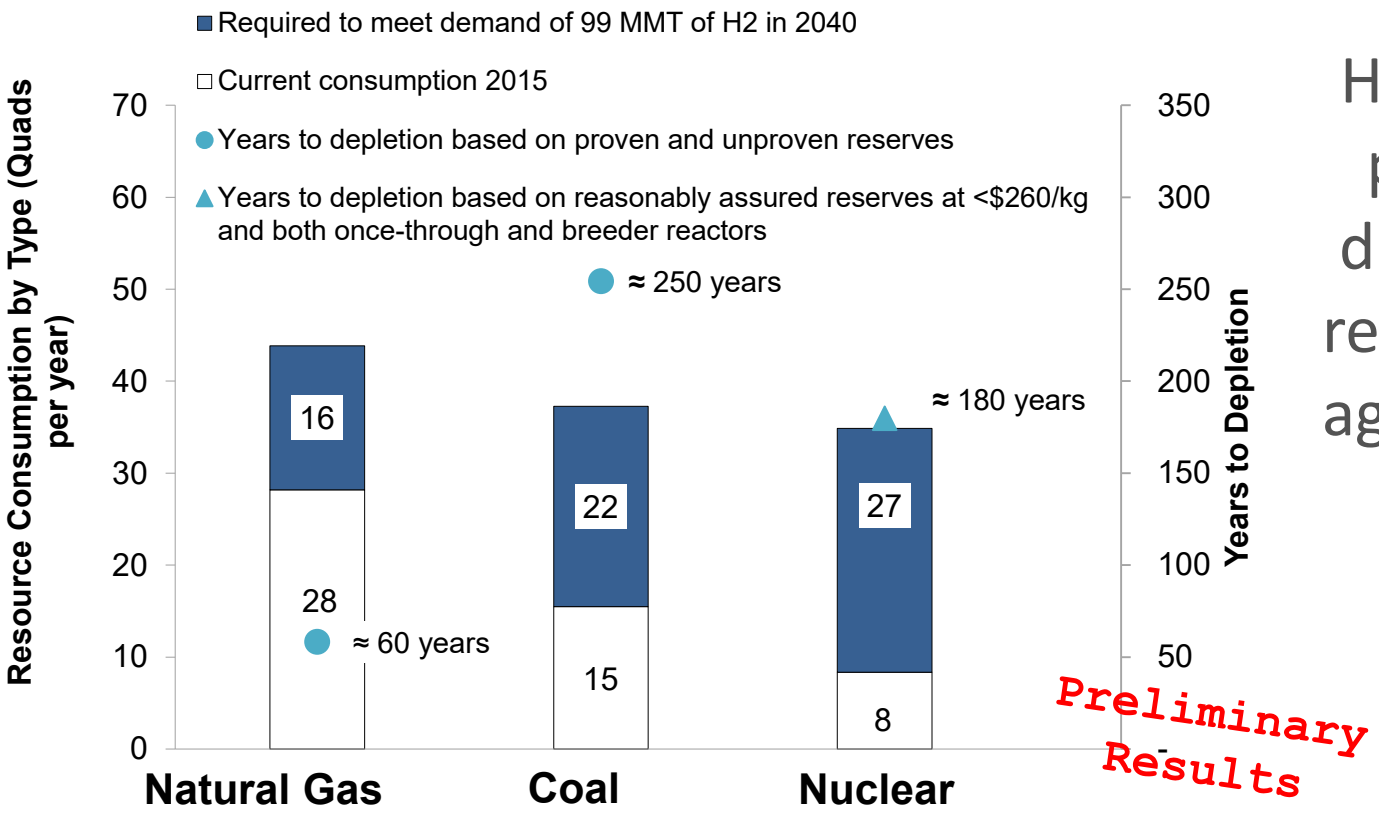
Technical Potential Supply from Renewable Resources

	EIA 2015 current consumption (quads/yr)	Required to meet demand of 99 MMT / yr (quads/yr)	Technical Potential (quads/yr)
Solid Biomass	4.7	24	19
Wind Electrolysis	0.68	16	170
Solar Electrolysis	0.17	16	1,000

Total demand including hydrogen is satisfied by ≈10% of wind, 2% of solar, and ≈150% of biomass technical potential

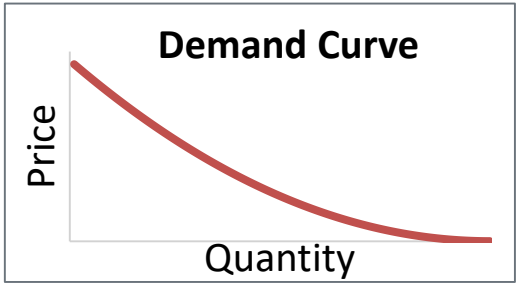


Technical Potential of Fossil and Nuclear Resources

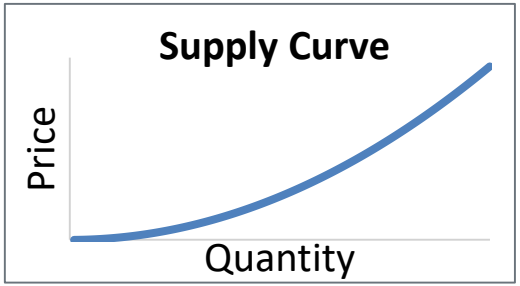


Hydrogen can be produced from diverse domestic resources to meet aggressive growth in demand

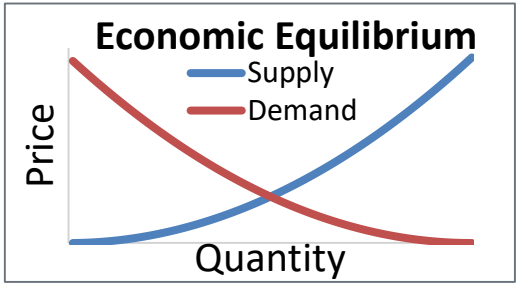
Economic Potential Methodology: Market Equilibrium



Demand Curve: how much are consumers willing and able to pay for a good?



Supply Curve: threshold prices showing how much are producers willing and able to produce at each?



Economic Equilibrium: Quantity where demand price is equal to the supply price**.**

- No excess supply or demand.
- Market pushes price and quantity to equilibrium.

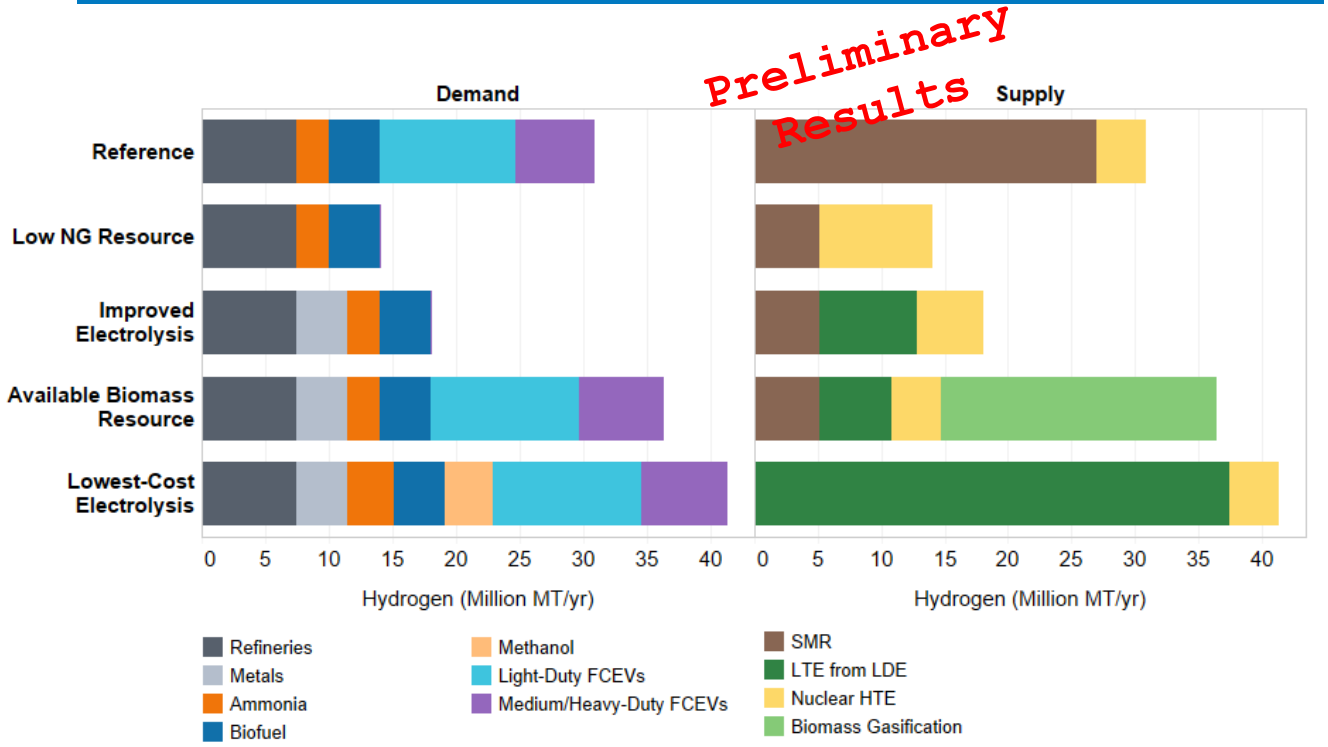
Methodology described in Schwartz, Robert A. *Micro Markets A Market Structure Approach to Microeconomic Analysis*. Wiley Finance. Chichester: Wiley, 2010.

Economic Potential: Five National Scenarios

Scenario Name	Reference	Low NG Resource	Improved Electrolysis	Available Biomass Resource	Lowest-Cost Electrolysis
Natural gas price assumption	Reference	Higher			
Low-Temperature Electrolysis (LTE) capital costs Low-cost, Dispatch-constrained Electricity purchase assumption	Current Trajectory		Improvements		Aggressive Assumptions
Biomass	Not available			Available	Not Available
Metals demand	Competitive Market		Premium Available		

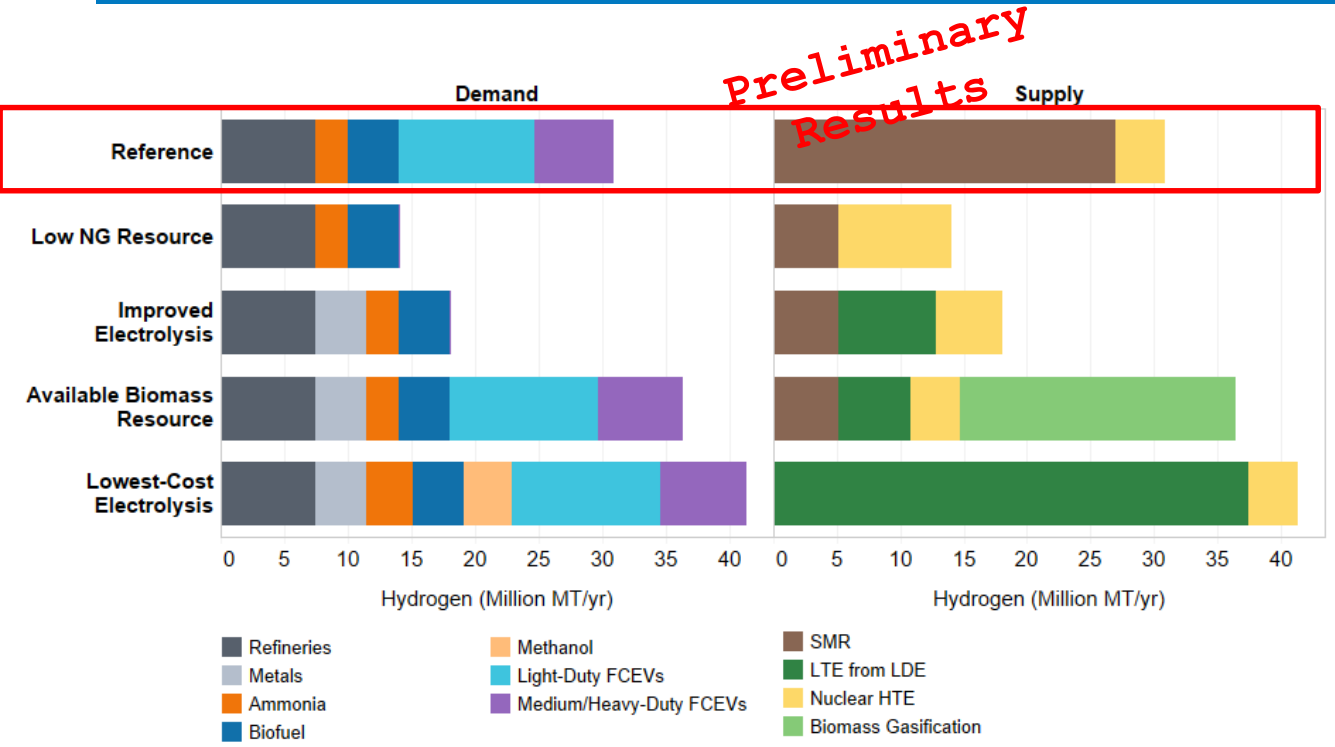
Key differences in scenarios: 1) natural gas price assumption, 2) electrolyzer cost assumption, 3) electrolyzers' access to grid service markets, 4) increased threshold price in metals industry, & 5) competition for biomass resource

Economic Potential Results



The economic potential of hydrogen demand in the U.S. is 1.4-4X current annual consumption.

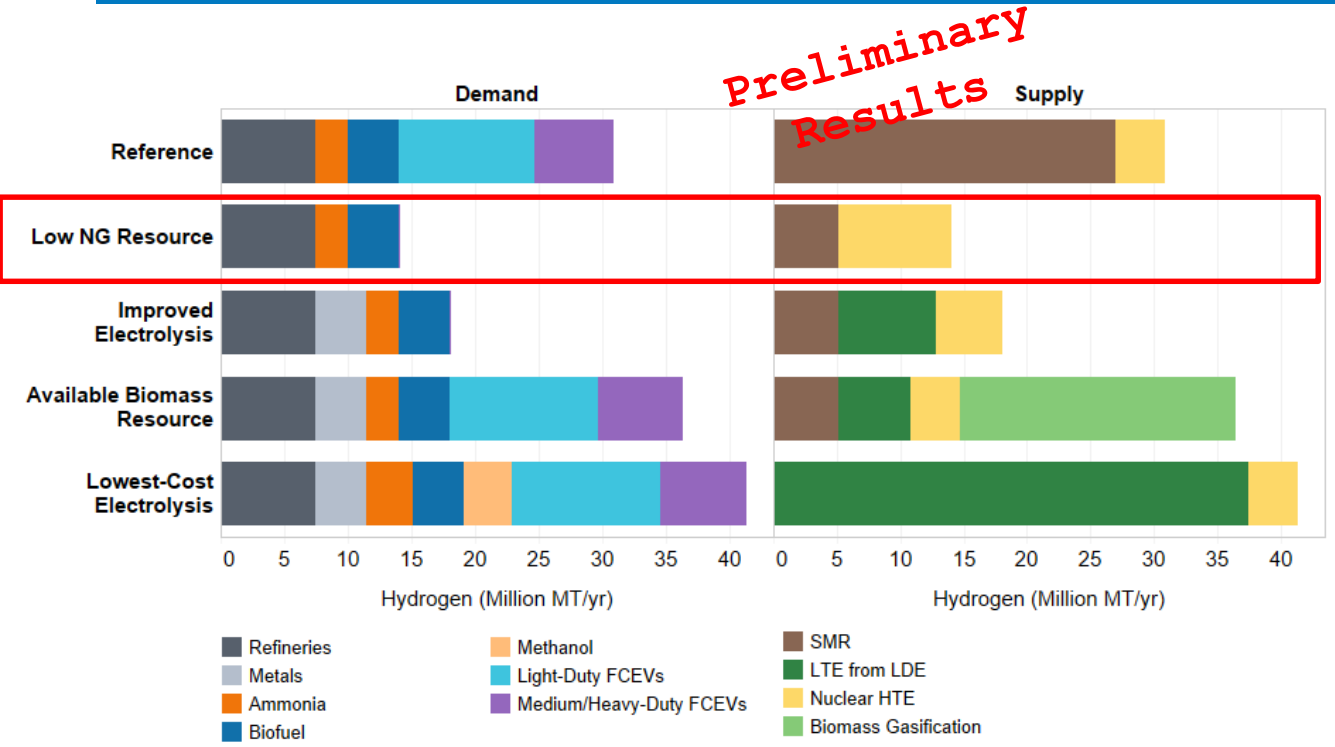
Reference Scenario



- Lowest natural gas prices; thus, higher penetrations of FCEVs
- About 10% of U.S. nuclear generation to H_2
- Refineries and ammonia demands based on growing markets
- Biofuels demand limited to Renewable Fuels Standard

FCEV: Fuel Cell Electric Vehicle

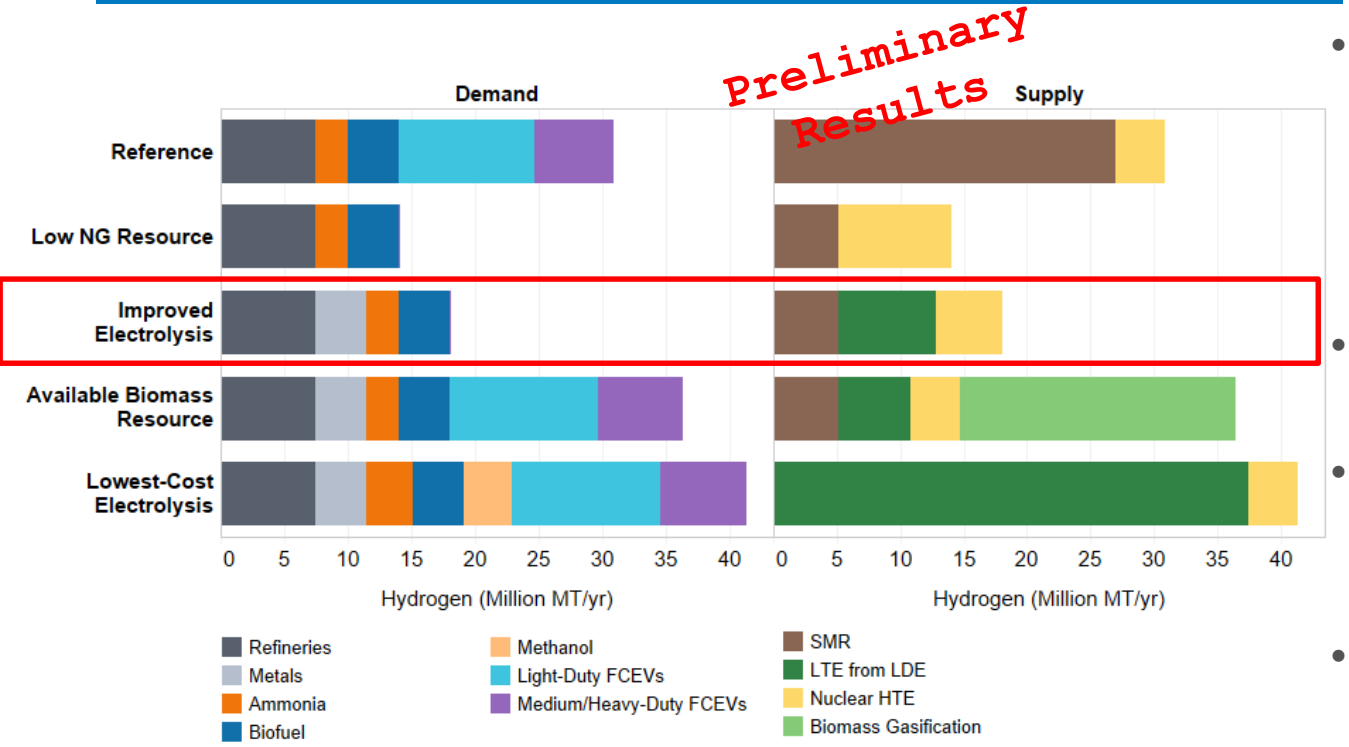
Low Natural Gas Resource Scenario



- Higher natural gas prices than reference scenario
- Thus, negligible growth in hydrogen demand
- Only economic demands: refining, ammonia, biofuels

FCEV: Fuel Cell Electric Vehicle

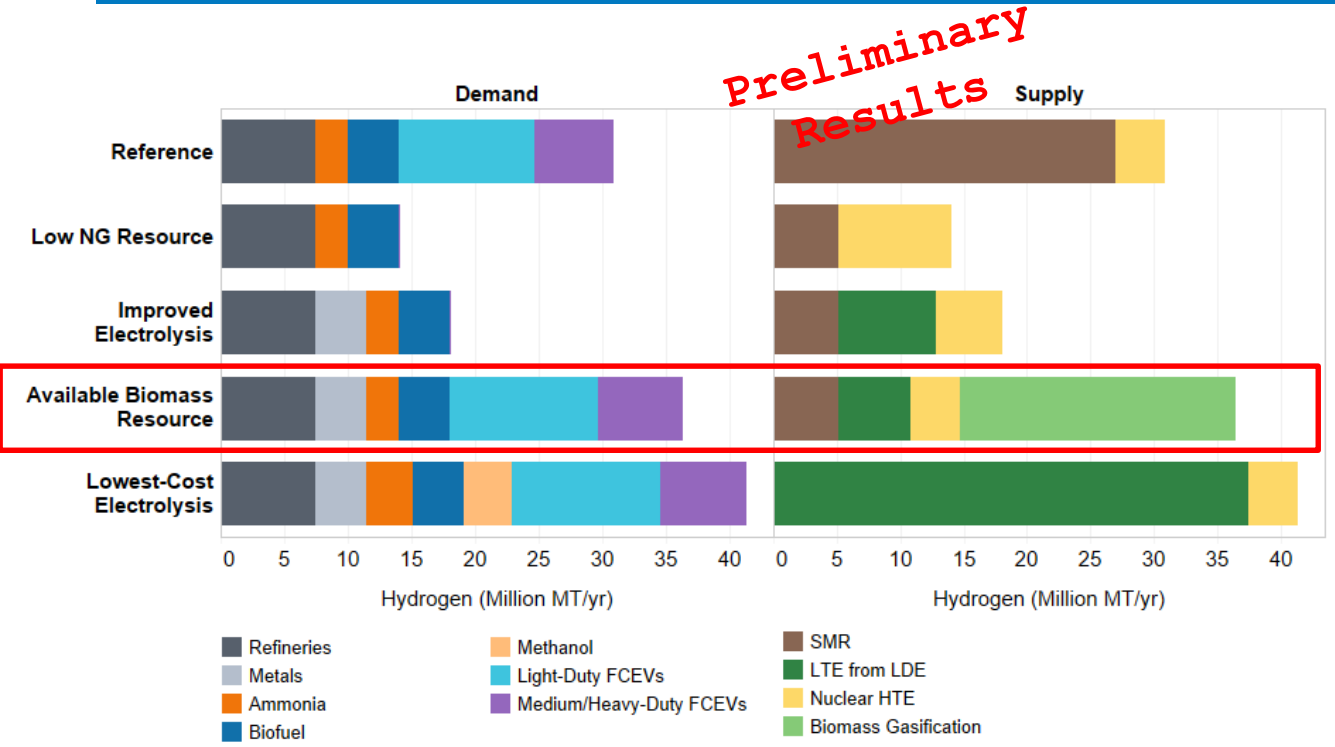
Improved Electrolysis Scenario



- Low-Temperature electrolyzer (LTE) purchase cost reduced to $200/kW & reduced electricity price adder
- Supply growth due to electrolytic hydrogen
- Increased willingness to pay for H2 for metals refining
- Leads to demand for growing domestic metals refining industry

FCEV: Fuel Cell Electric Vehicle

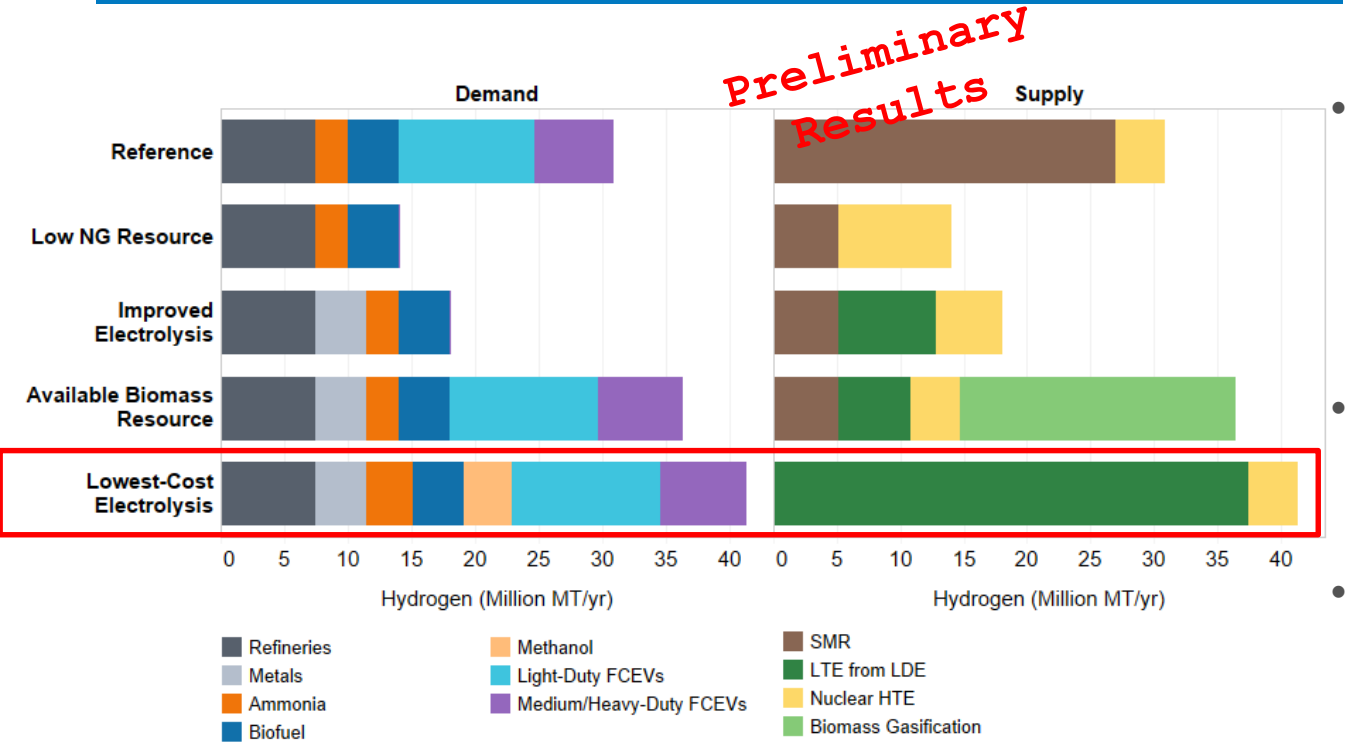
Available Biomass Resource Scenario



- Only scenario with biomass available for hydrogen production
- Lowest cost biomass resource assumed available
- Lower cost hydrogen allows demand growth

FCEV: Fuel Cell Electric Vehicle

Lowest-Cost Electrolysis Scenario



- Low-Temperature electrolyzer (LTE) purchase cost reduced to $100/kW & no electricity price adder
- Electrolytic hydrogen less costly than steam methane reforming
- Larger ammonia and chemicals opportunities than other scenarios

FCEV: Fuel Cell Electric Vehicle

Key Conclusions

- **The potential demand of hydrogen demand in the U.S. is >9X current annual consumption.**
- **The economic potential of hydrogen demand in the U.S. is 1.4-4X current annual consumption**.
  - Range across 5 scenarios developed using a variety of economic and R&D success assumptions
- Up to 20% of current **nuclear power plants could improve their profitability** by producing hydrogen.

For More Details

- Power-to-Gas Technical Session
  - Thursday at 1:30 in room 103 A/B
- Two presentations
  - H2@Scale: Economic Potential of Hydrogen as an Energy Intermediate
  - Electrolysis' Potential Value for Supporting the Electrical Grid

Thank You

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Additional information on H2@Scale can be found at:

https://www.hydrogen.energy.gov/pdfs/review18/h2000_pivovar_2018_o.pdf
https://www.hydrogen.energy.gov/pdfs/review19/sa171_ruth_2019_o.pdf
http://energy.gov/eere/fuelcells/downloads/h2-scale-potential-opportunity-webinar

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