



Opportunities to Enable Electrolytic H₂ Projects for Ammonia in the US

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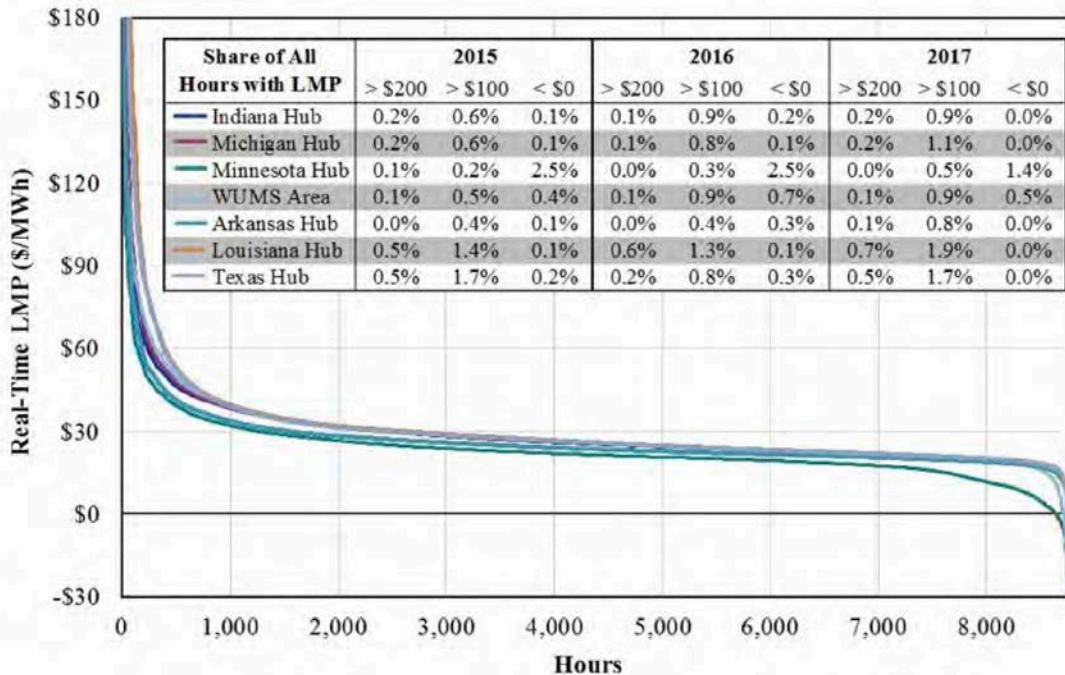
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Electricity Prices Vary Across the Year

Figure A2: Real-Time Energy Price-Duration Curve
2017

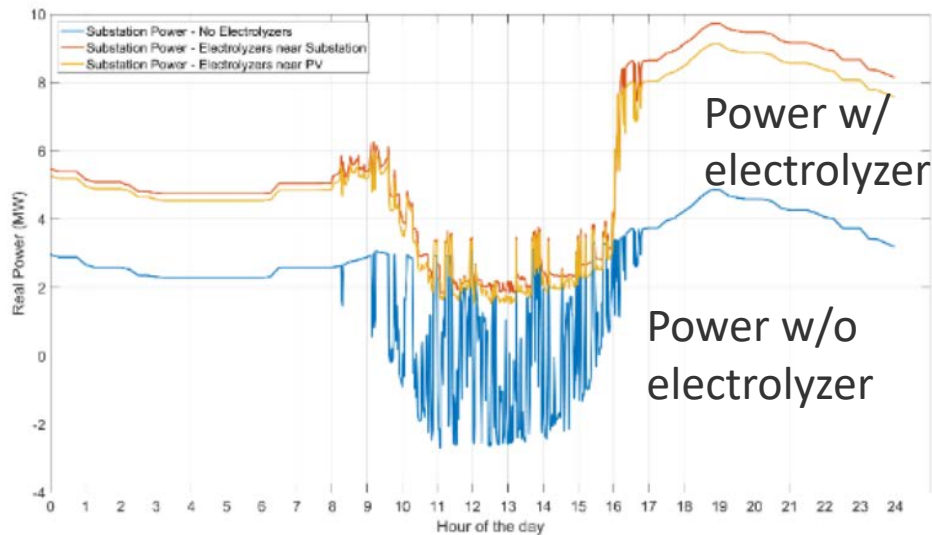


LMP: Locational marginal price

- Hours with energy at very low and very high prices are increasing
- Other revenue streams (e.g., capacity, services) are becoming more critical
- Wind and solar power purchase agreements (PPAs) are key opportunities

Potential Ability for Electrolyzers to Balance the Grid

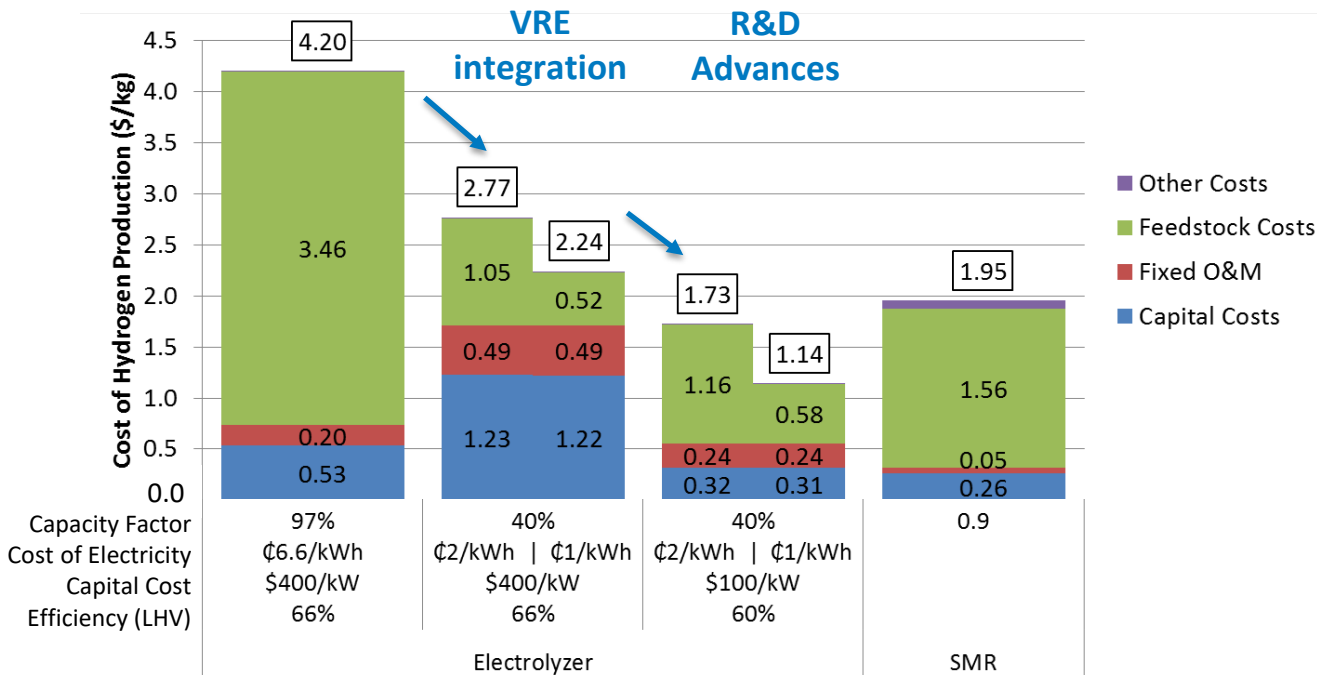
- Flexible electrolytic hydrogen production can
 - Utilize electricity during periods of oversupply on the grid
 - Reduce power spikes
- By providing services, the electrolyzers' net electricity prices could be lower than market purchase prices



https://www.hydrogen.energy.gov/pdfs/review19/ta015_hovsapien_2019_o.pdf

Potential Opportunity: Low Temperature Electrolysis

Potential Levelized Costs of H₂ Production



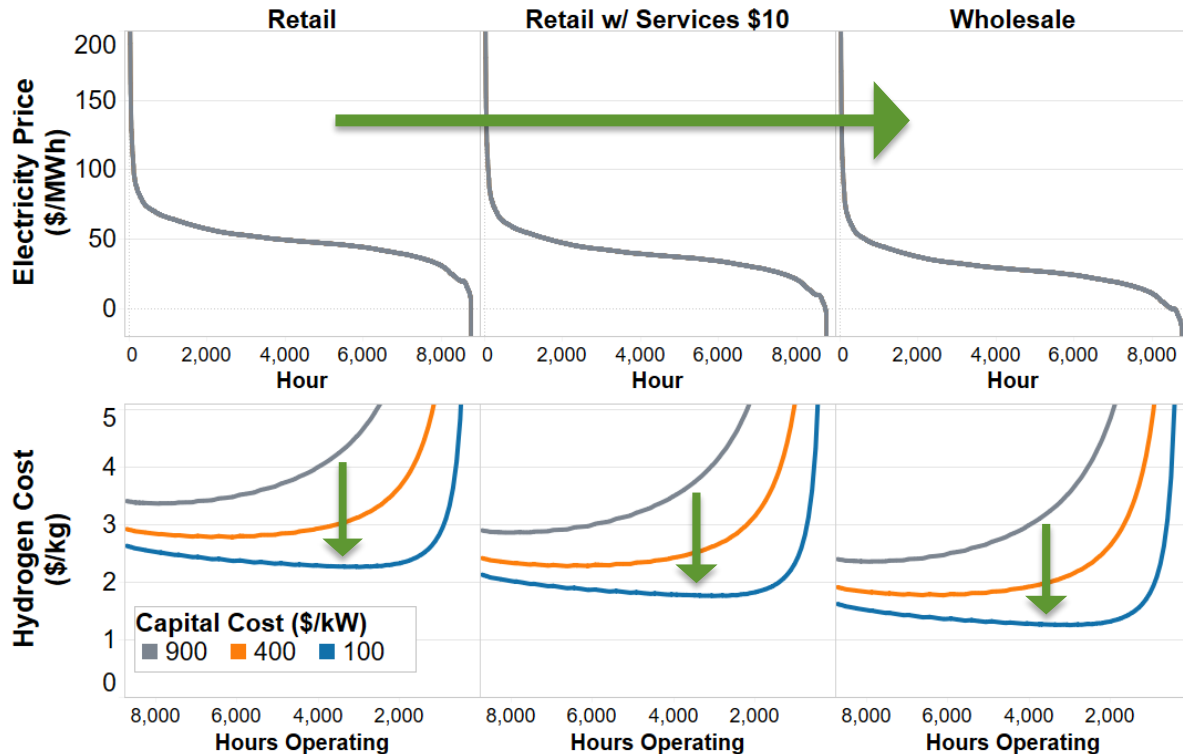
Electrolytic H₂ has the potential to be cost competitive.

Availability of low-cost electricity can help enable low-cost H₂ production, even at low capacity factors.

VRE: Variable renewable energy
SMR: Steam methane reforming

Achieving Hydrogen Cost Reductions

Example 2017 Electricity Prices from Palo Verde, AZ



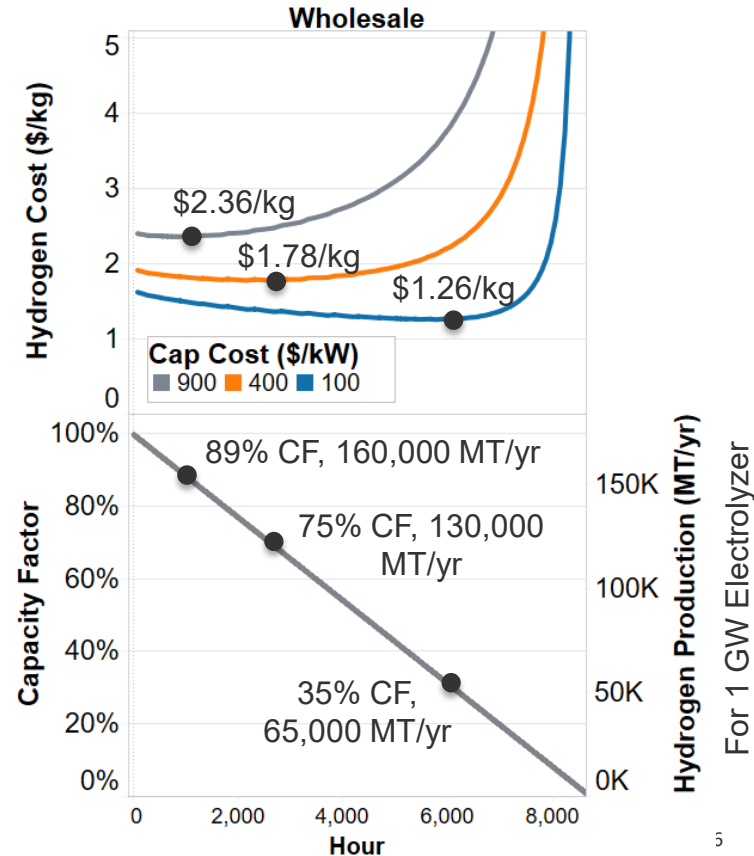
Electrolytic hydrogen production costs can be reduced

- **Favorable electricity pricing structures** (reducing non-energy adders, regional prices)
- **Low cost electrolyzers** (manufacturing scale, stack costs, power electronics)

Impact on Ammonia Production

Given a 1 GW electrolyzer:

- **Peak hydrogen production** of 20,000 kg/hr
- **“Cost-optimal” hydrogen production** varies with electricity prices and electrolyzer capital costs
 - **Annual production** ranges from 65-160K MT/yr (370-900K MT/yr ammonia)
 - **Electrolyzer capacity factors** range from 35-89%
- Hydrogen production costs approach those of SMR, **further analysis needed for impact on ammonia production costs**



Discussion: How can we enable and utilize low-cost hydrogen?

- **Electrolyzer technology**—Increased manufacturing scale, advances in R&D
- **Regional considerations**—Favorable electricity pricing and/or market structures
- **Impact on ammonia production**—Process design considerations, storage requirements
- **Regulatory drivers**—Demand pull or supply push?
- **What else should we consider?**

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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