NREL
Transforming ENERGY

Electrolysis' Potential Value for Supporting the Electrical Grid

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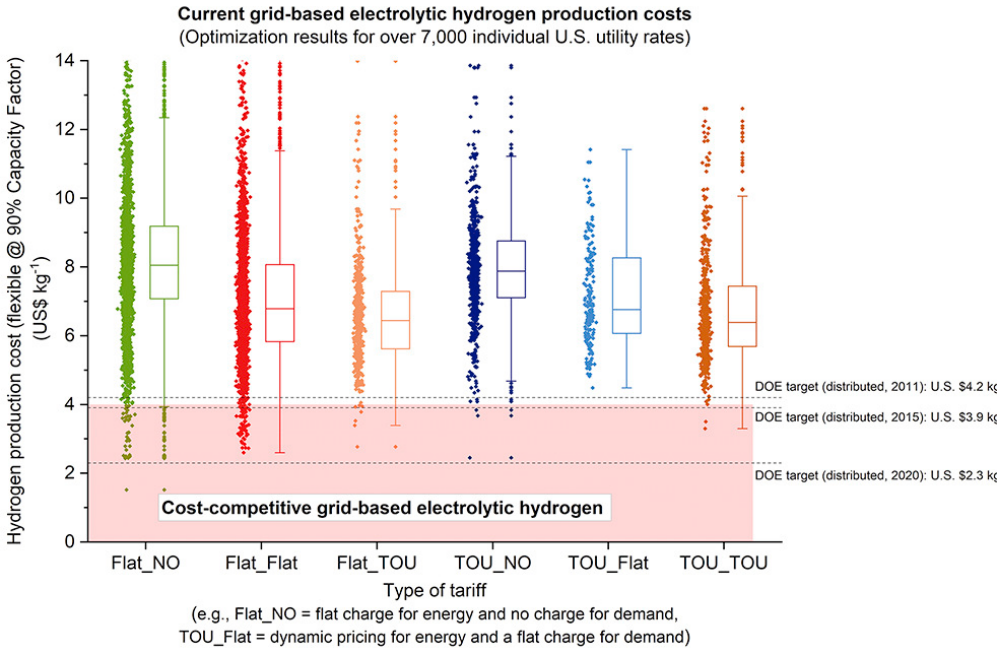
Current Opportunities for Electrolytic Hydrogen

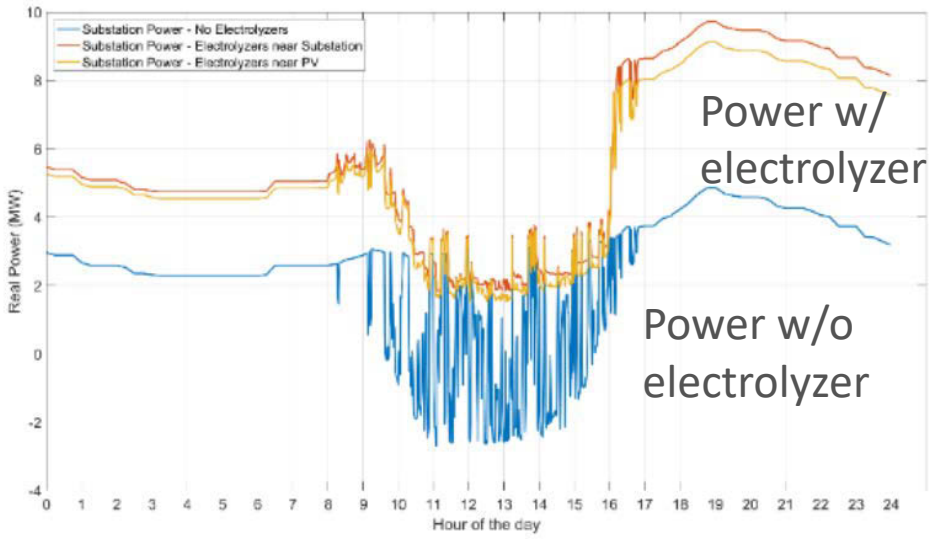
- Some locations already have tariffs that are sufficient for electrolyzers today[1]
- Other locations may inherently have lower electricity prices, however prices may be more *volatile*



[1]Guerra, Omar J., Joshua Eichman, Jennifer Kurtz, and Bri-Mathias Hodge. 2019. "Cost Competitiveness of Electrolytic Hydrogen." *Joule*, July. https://doi.org/10.1016/j.joule.2019.07.006.

Potential Ability for Electrolyzers to Balance the Grid

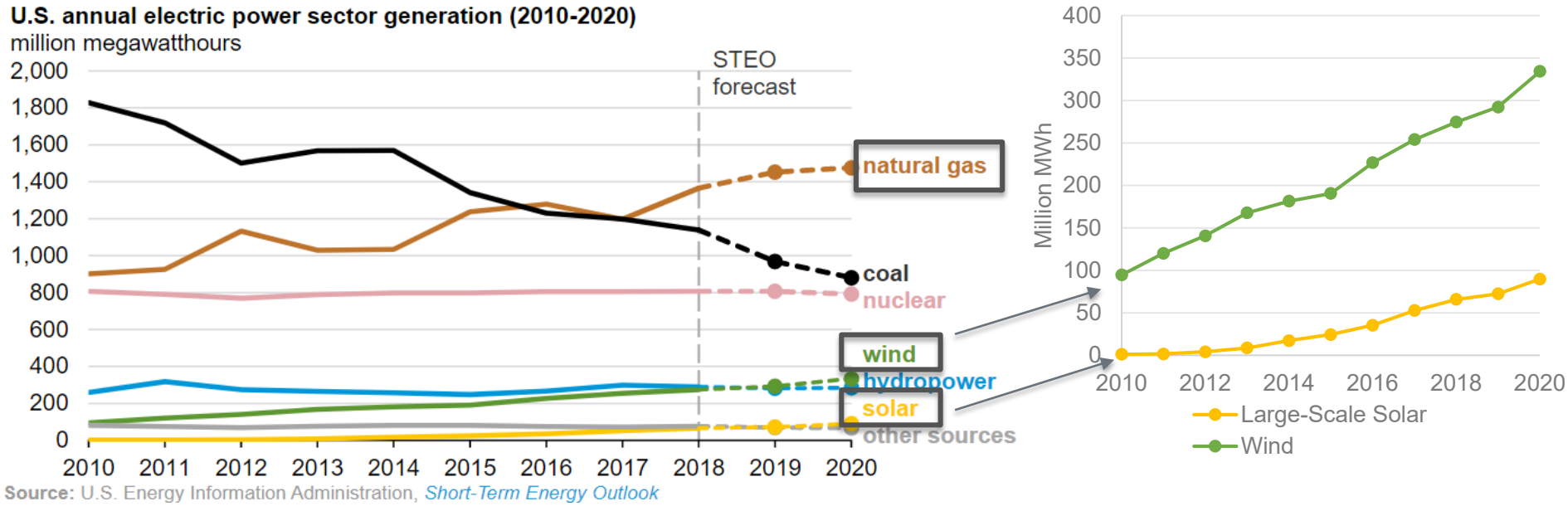
- Flexible electrolytic hydrogen production can
  - Utilize electricity during periods of oversupply on the grid
  - Reduce power spikes
- By providing services, the electrolyzers' net electricity prices could be lower than market purchase prices



https://www.hydrogen.energy.gov/pdfs/review19/ta015_hovsapian_2019_o.pdf

The Electricity Mix is Changing

Projected growth in renewable and gas-fired generation



Source: U.S. Energy Information Administration, *Short-Term Energy Outlook*

Electricity Prices Vary Across the Year

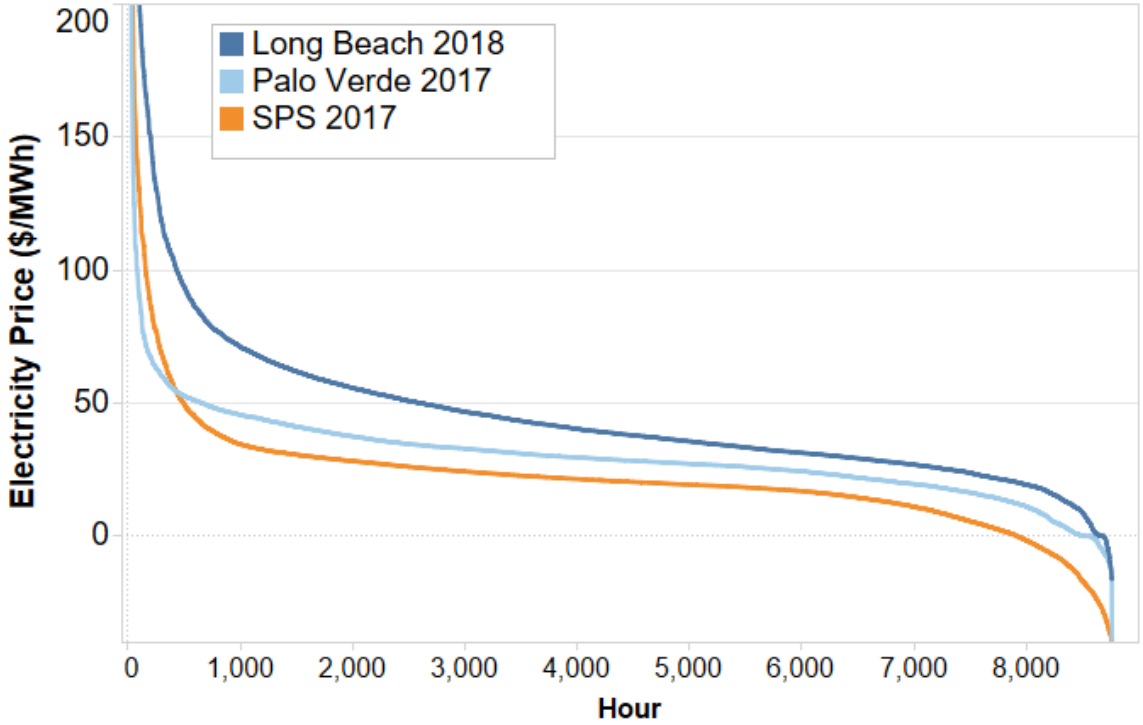
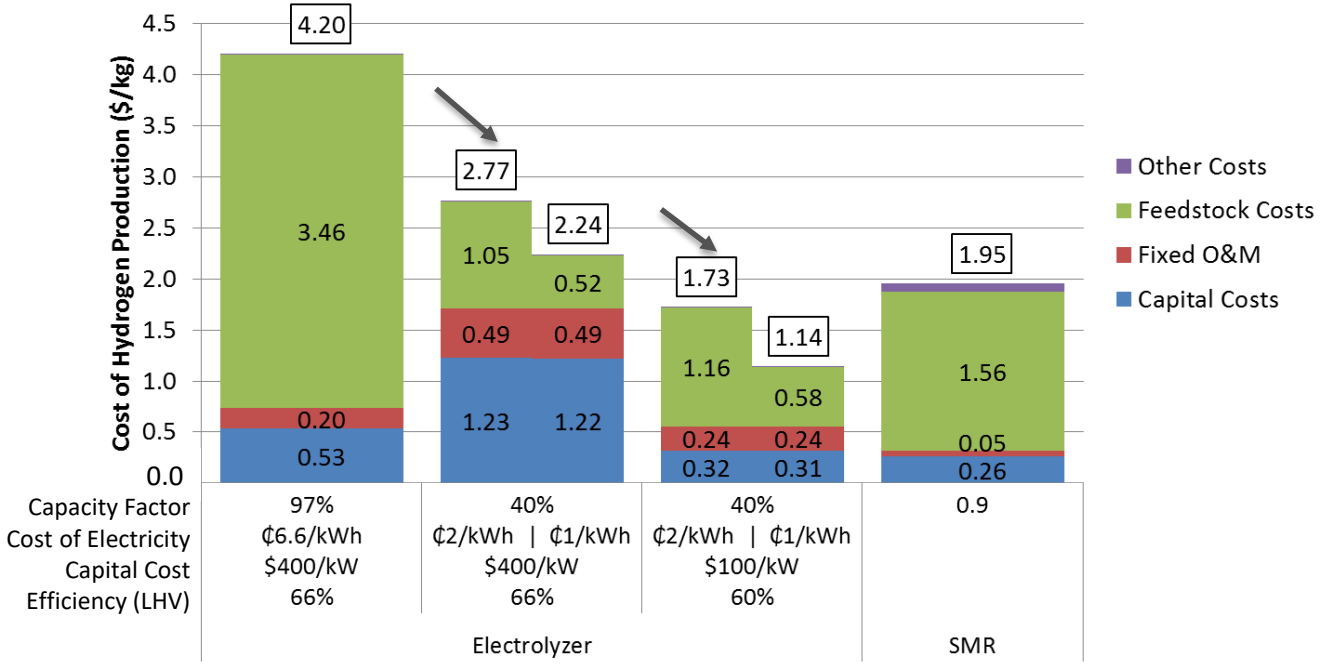


Figure created using data from publicly available CA-ISO and SPP datasets

- 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 Opportunity: Low Temperature Electrolysis

Potential Levelized Costs of H_2 Production

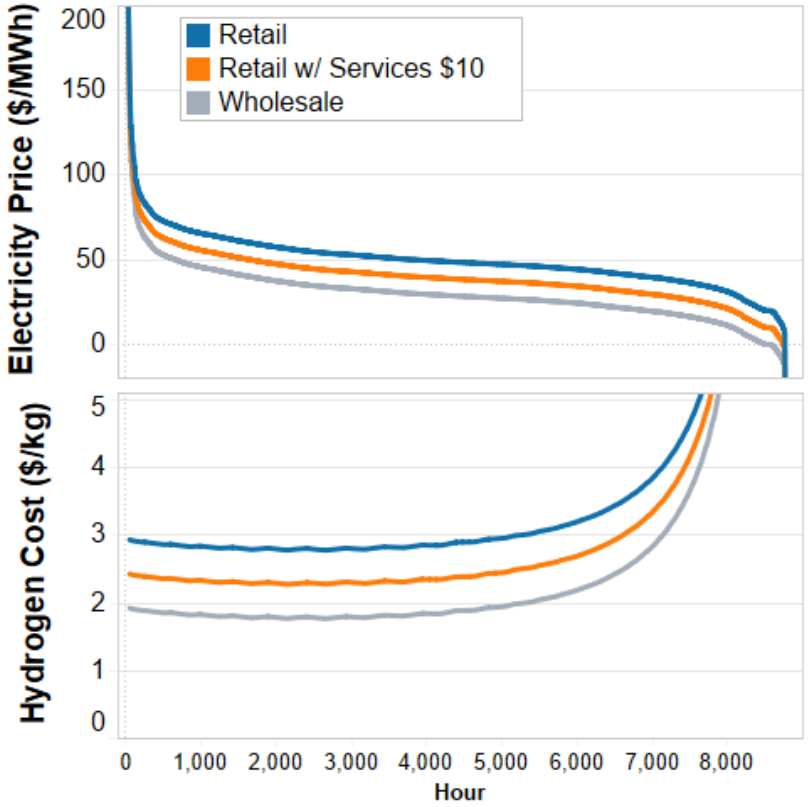


Source: Bryan Pivovar & Josh Eichman

Electrolytic H_2 has the potential to be cost competitive.

Availability of low-cost electricity can help enable low-cost H_2 production, even at low capacity factors.

Opportunity for Electrolytic Hydrogen Generation



Palo Verde 2017

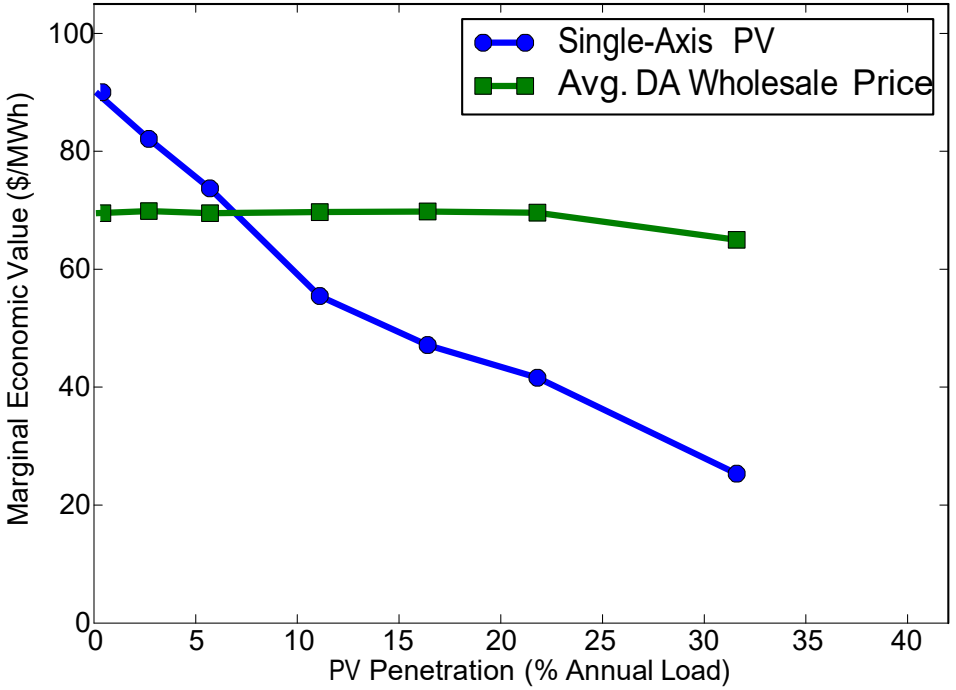
- Electrolytic hydrogen could be cost-competitive if flexible, low-temperature electrolyzers can be purchased at $400/kW and markets are available

$400/kW electrolyzer purchase cost. Operating during lowest cost hours of the year

Investment in Variable Renewable Generation may Decrease Due to Price Suppression

Economic value of VRE generation decreases with increasing penetration

Decreased value potentially limits penetration of VRE generation

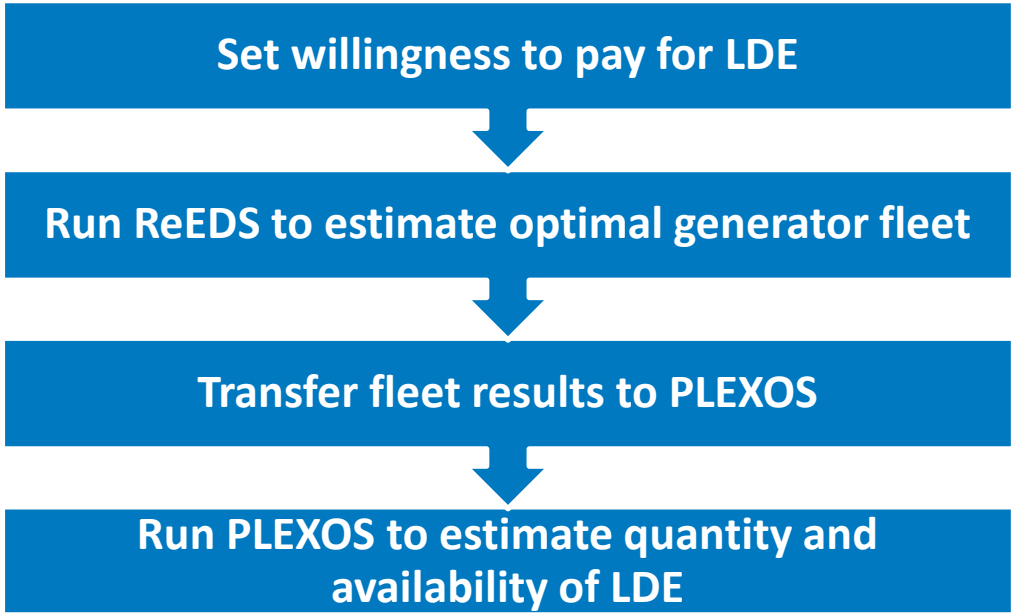


Changes in the Economic Value of Variable Generation at High Penetration Levels: A Pilot Case Study of California Andrew Mills and Ryan Wiser, June 2012, http://eetd.lbl.gov/EA/EMP

A Dispatchable Load Could Utilize Low-Cost, Dispatch-Constrained Electricity (LDE)

A controllable, dispatchable load could remove the cap on penetration of variable renewable generation

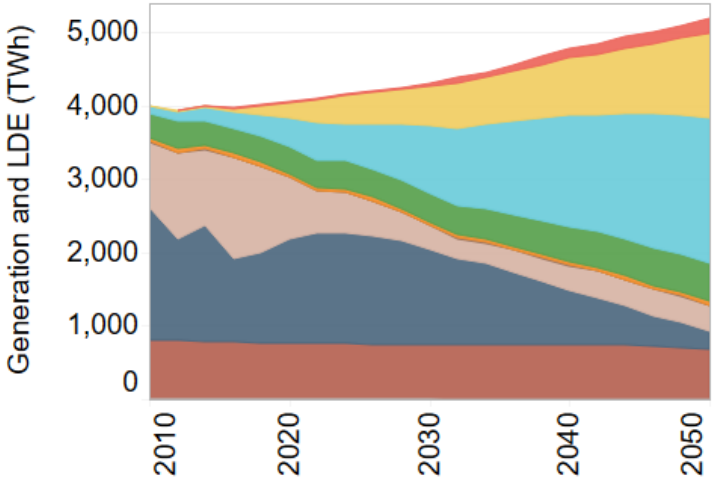
We developed a method to estimate LDE availability providing a flexible load will pay for it.



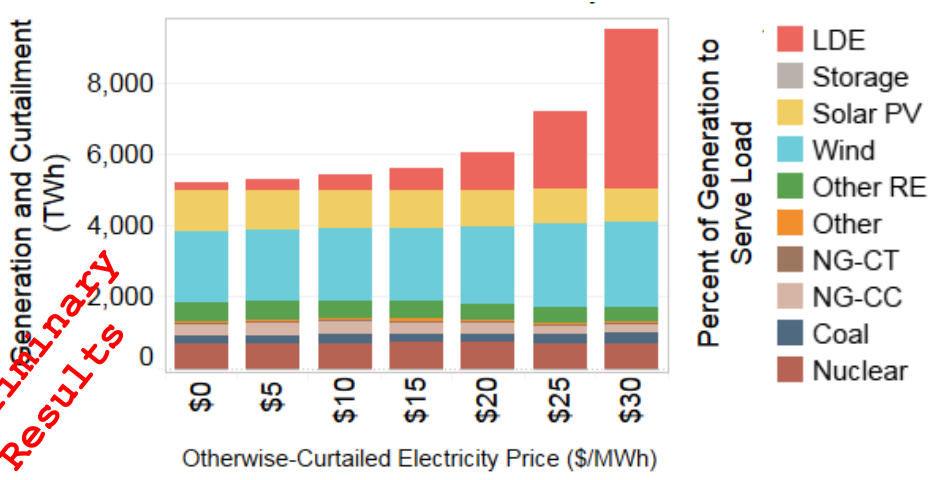
LDE Generation

Used ReEDS to estimate generator fleet and generation mix at multiple LDE values

Buildout with $0/MWh LDE

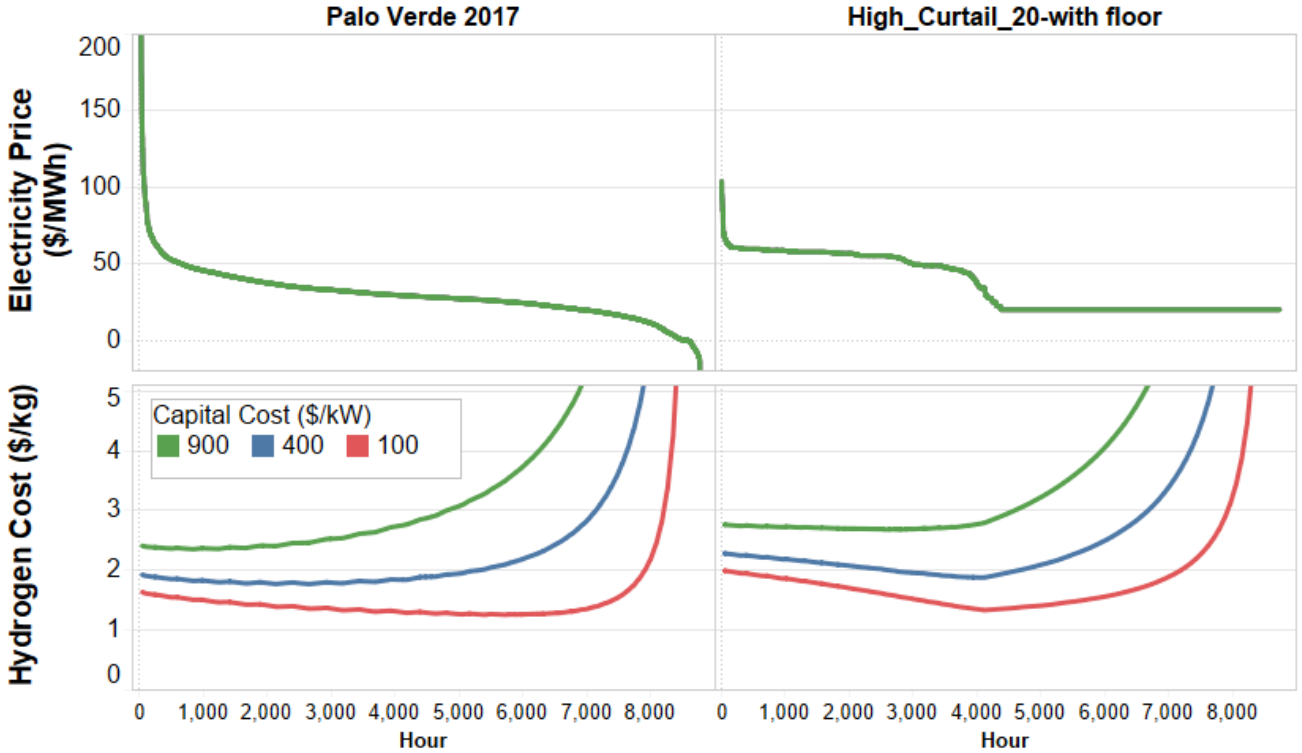


2050 Results at Various LDE Values



High Curtailment Scenario

Future Opportunities for LDE Utilization at Palo Verde



Under parameters that lead to high variable renewable generation and with a $20/MWh price floor,

- Additional LDE is available
- Electrolytic hydrogen can be cost competitive at Palo Verde

A Dispatchable Load Could Utilize Low-Cost, Dispatch-Constrained Electricity (LDE)

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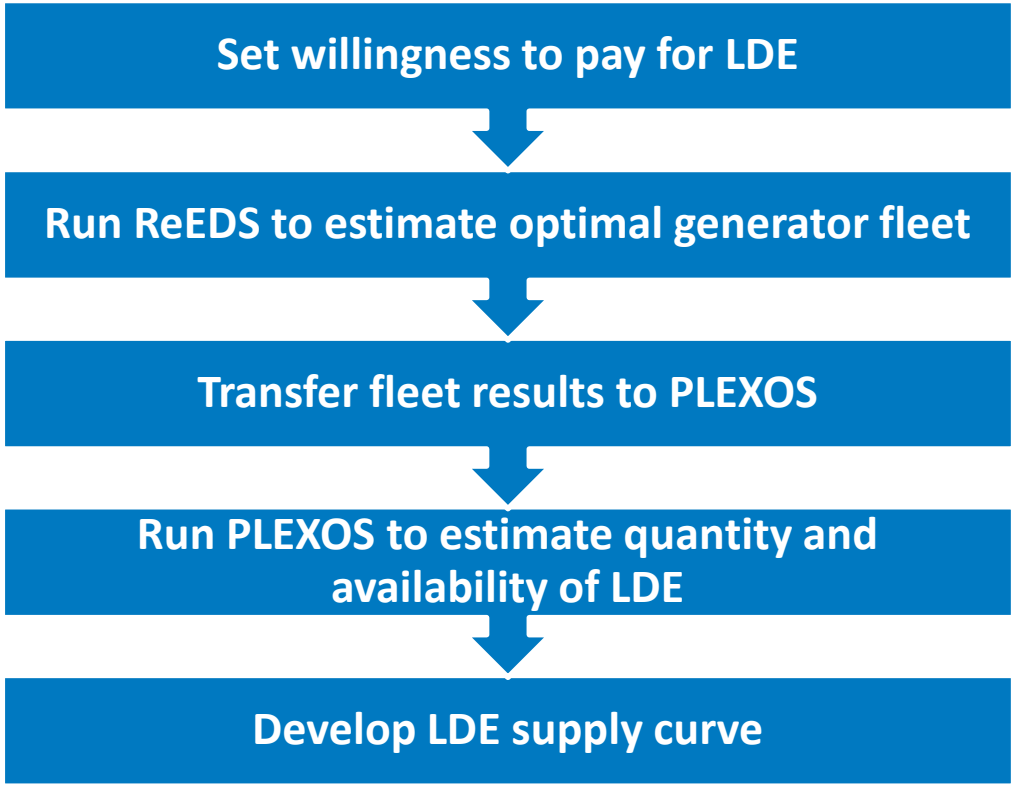
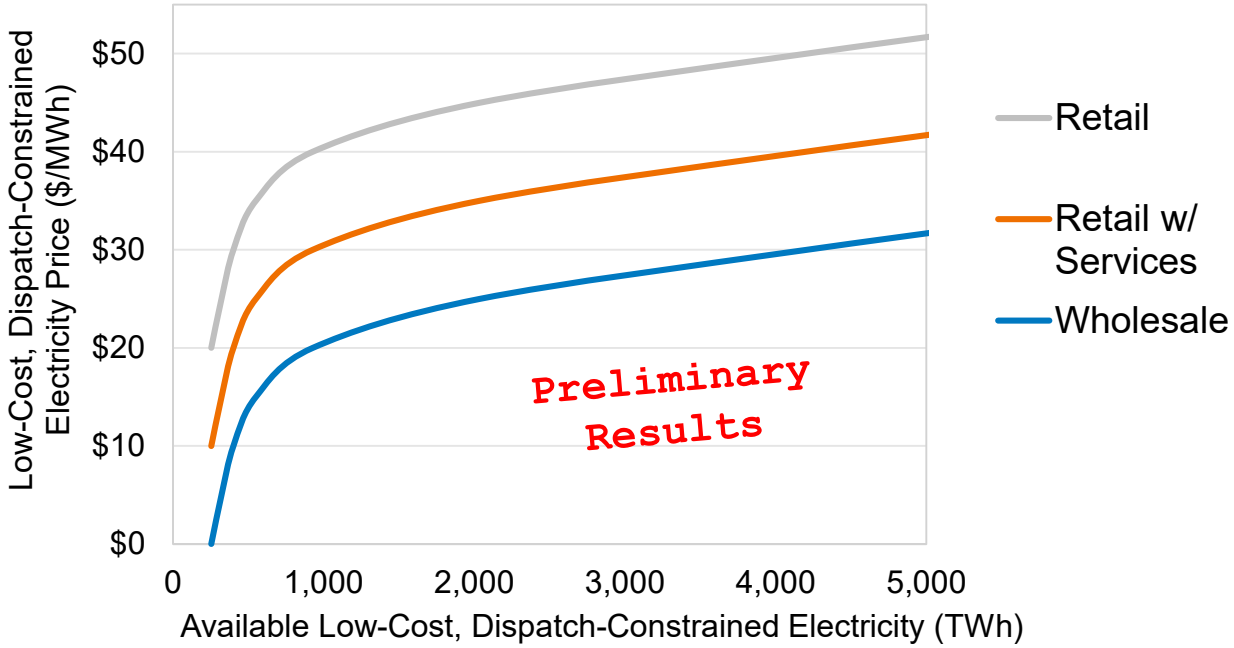


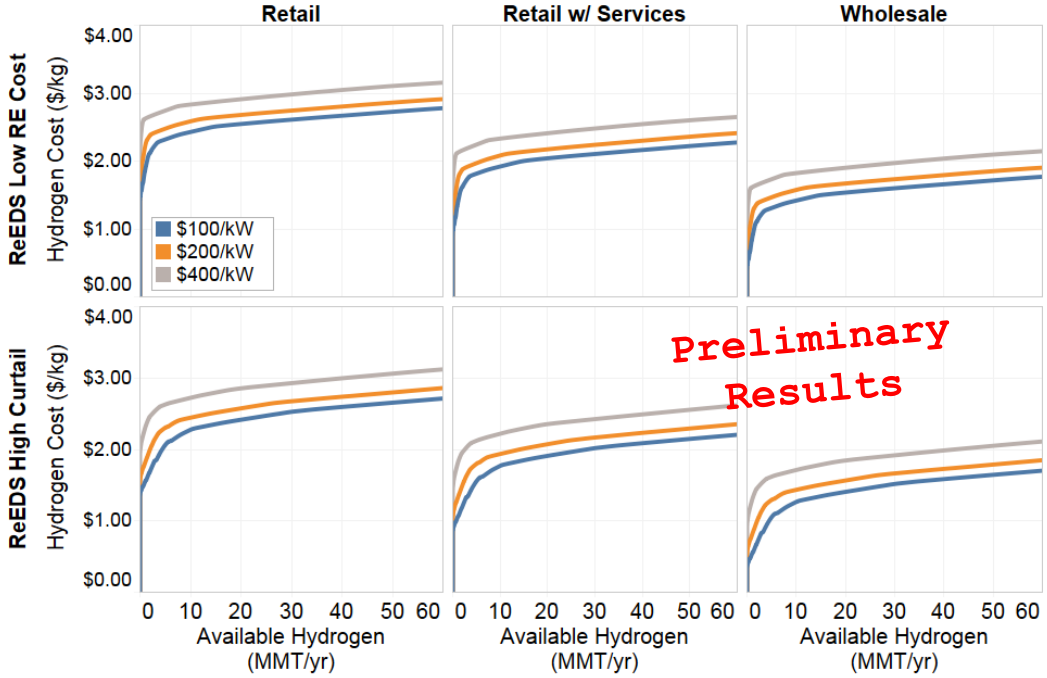
LDE Supply Curves

Used PLEXOS Unit Commitment Model to create supply / availability curves for LDE



Used LDE Supply Curves in H2@Scale Economic Potential Analysis

Developed supply curves for LTE-generated hydrogen based on each price / availability factor combination



Low Temperature Electrolysis of Low-Cost, Dispatch-Constrained Electricity:

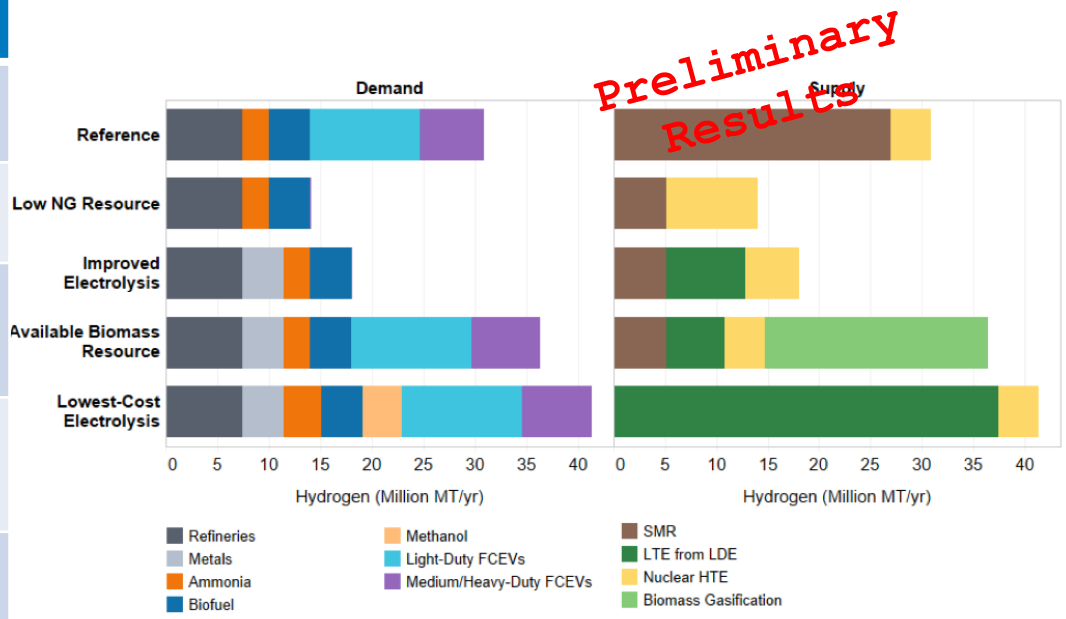
- **Calculated hydrogen levelized costs** using H2A Future Central Hydrogen Production from PEM Electrolysis model at each price / availability factor combination
- Added **$20/MWh for transaction fees** for "Retail" prices and **$10/MWh for "Retail w/ Services"**
- Assume storage and delivery costs ~$0.40/$kg_{H2}$ (cost for pipeline transport of 200,000 MT/yr 250 miles with geologic storage)

Economic Potential Analysis Results

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

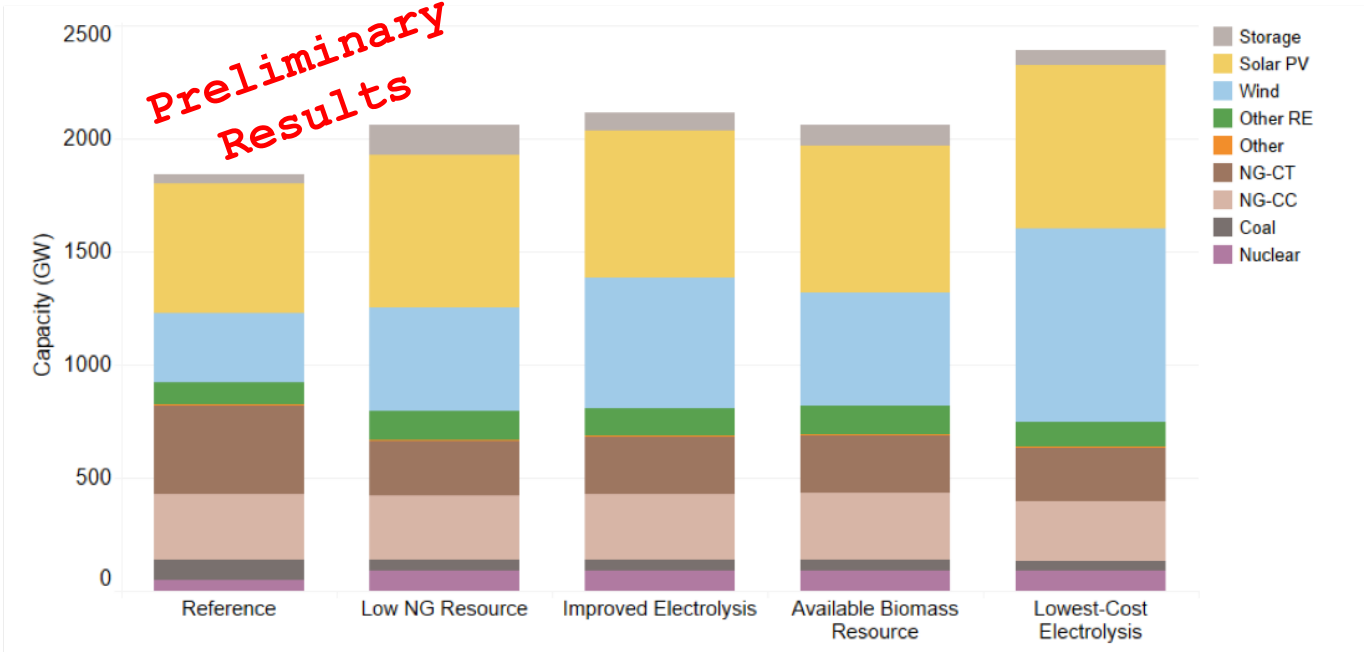
Scenario	Insights
Reference	Low-cost natural gas drives growth in H_2 markets with some nuclear participation*
Low NG Resources	Higher cost natural gas results in minimal growth in H_2 applications
Improved Electrolysis	Drivers for metals applications increase market. Some LTE penetration at $200/kW capital cost with grid value.
Available Biomass Resources	If the biomass is not used for higher value purposes, it could be a key resource
Lowest-Cost Electrolysis	$100/kW electrolyzers with high grid value can enable additional H2 applications

*~20% of U.S. nuclear generation is used for hydrogen production



Potential Impact on Wind and Solar PV Markets

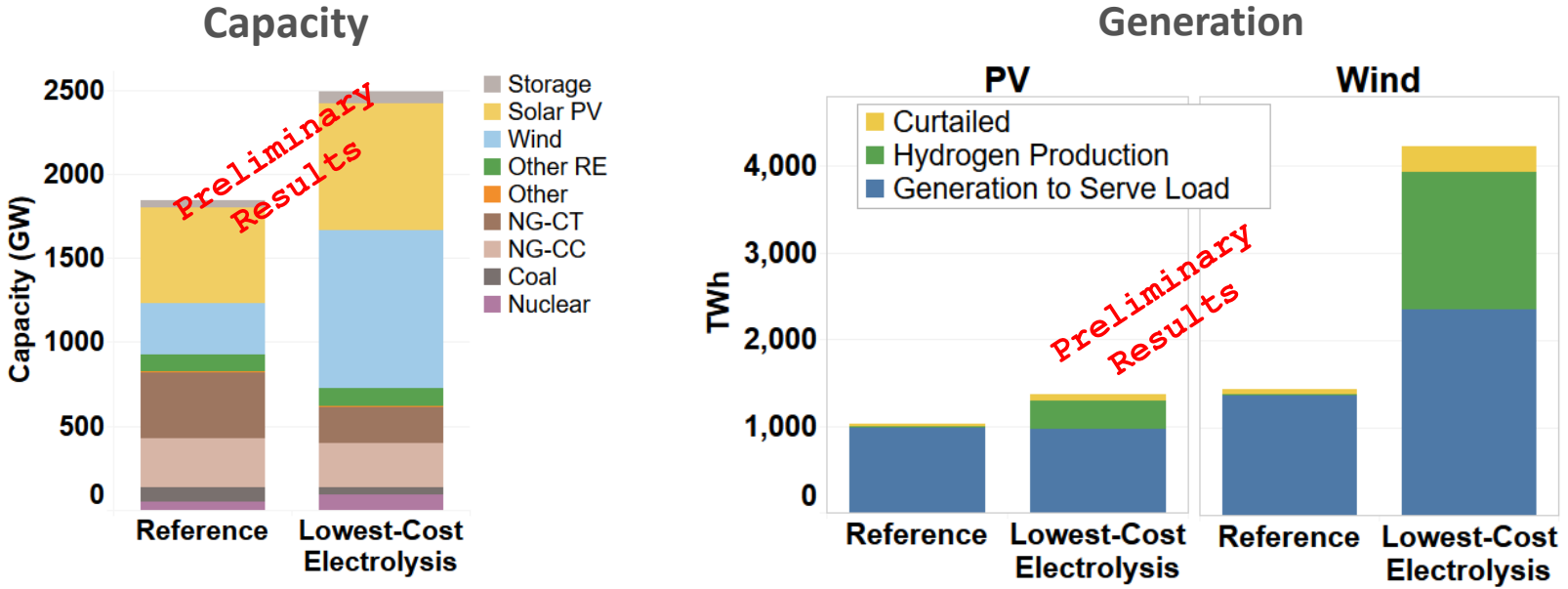
H2@Scale has the potential to increase the total market size of wind and solar PV capacity



Cost of Electrolyzer:	$400/kW	$400/kW	$200/kW	$200/kW	$100/kW

Potential Impact of H2@Scale on Wind and Solar PV Markets

Hydrogen is a potential dispatchable load that can increase economic demand for variable electricity



- **Estimates are based on national scenarios with minimal resolution into regional constraints.**
- **Lowest-Cost Electrolysis assumes aggressive electrolyzer costs ($100/kW)**

Conclusions & Uncertainties

- Electrolysis has the potential to enable higher penetrations of variable renewable generation on the grid
  - Fluctuations balancing
  - Dispatchable load that can utilize LDE

But

- Will mechanisms exist to enable the use of LDE by electrolyzers?
  - Access to wholesale markets
  - Compensation for providing grid services

Thank You

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www.nrel.gov
NREL/PR-6A20-75373

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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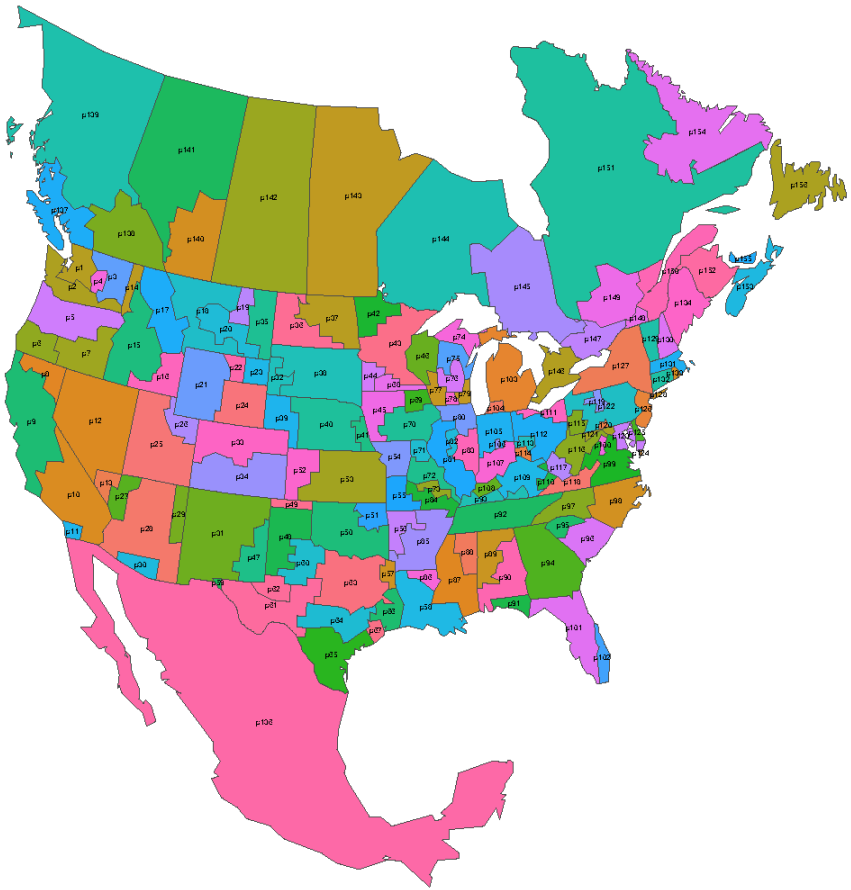
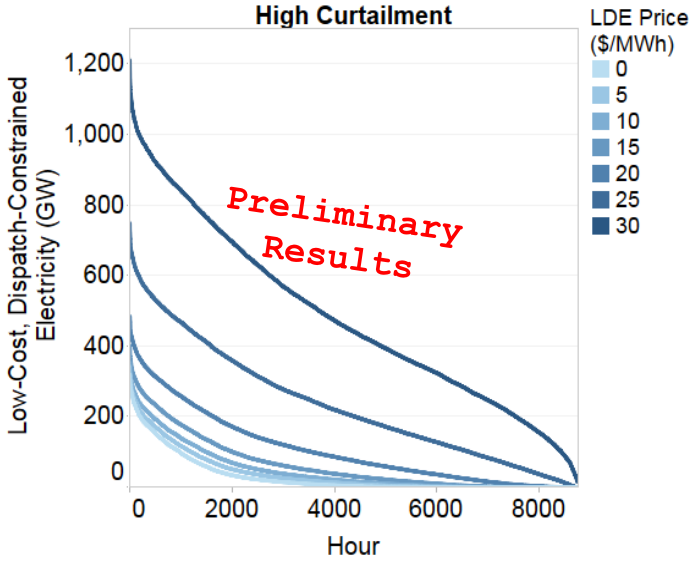
Supplemental Slides



Quantification of LDE Cost and Availability

Novel analysis using capacity expansion (ReEDS) and production cost models (PLEXOS) to estimate the potentials quantity of LDE, including spatial and temporal characteristics



- **High levels of potential LDE, but availability varies over time and geography**
- **Demand for LDE may help increase market sizes of VRE generators**