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Economic Analysis of Integrated Solar Power, Hydrogen Production, and Electricity Markets

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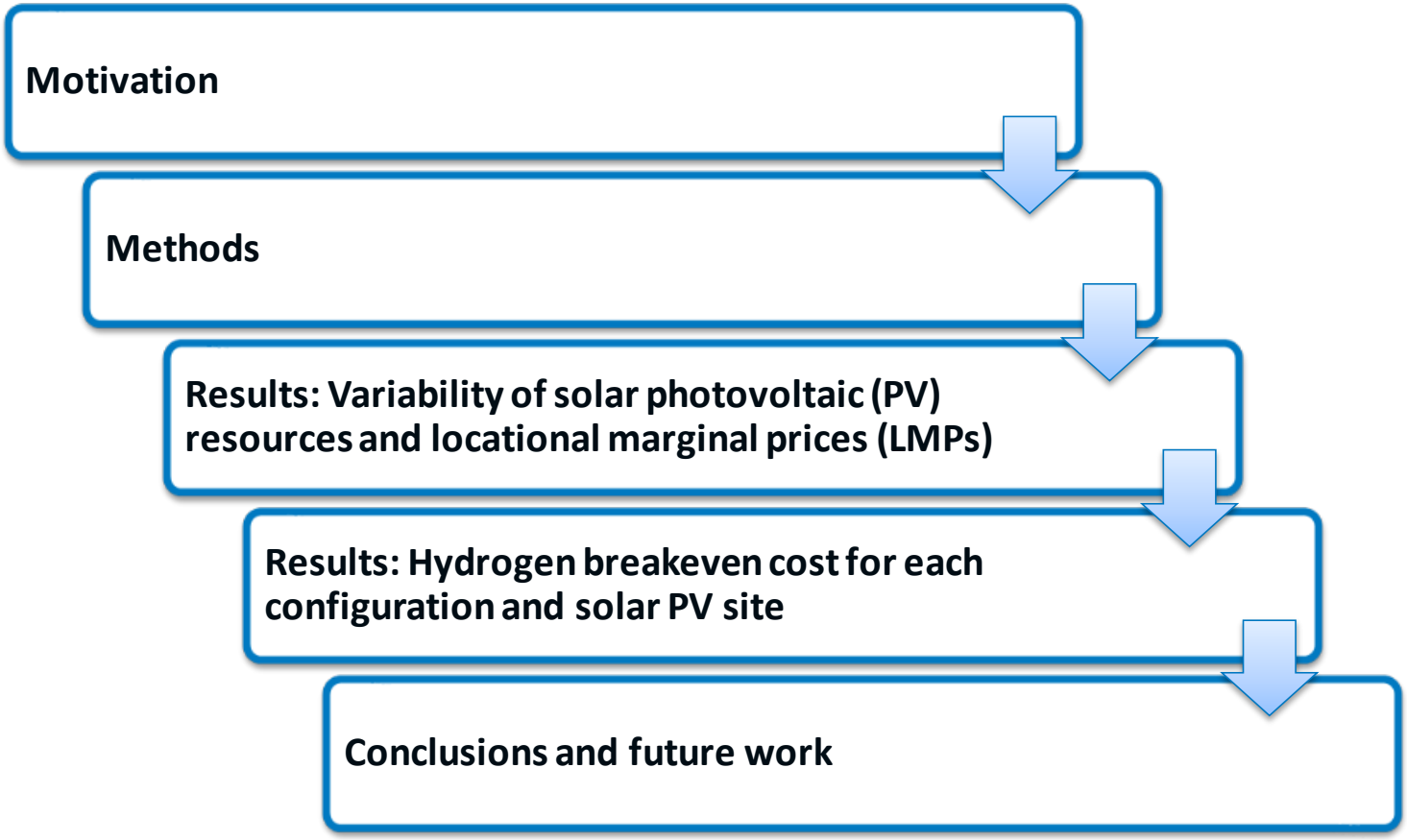
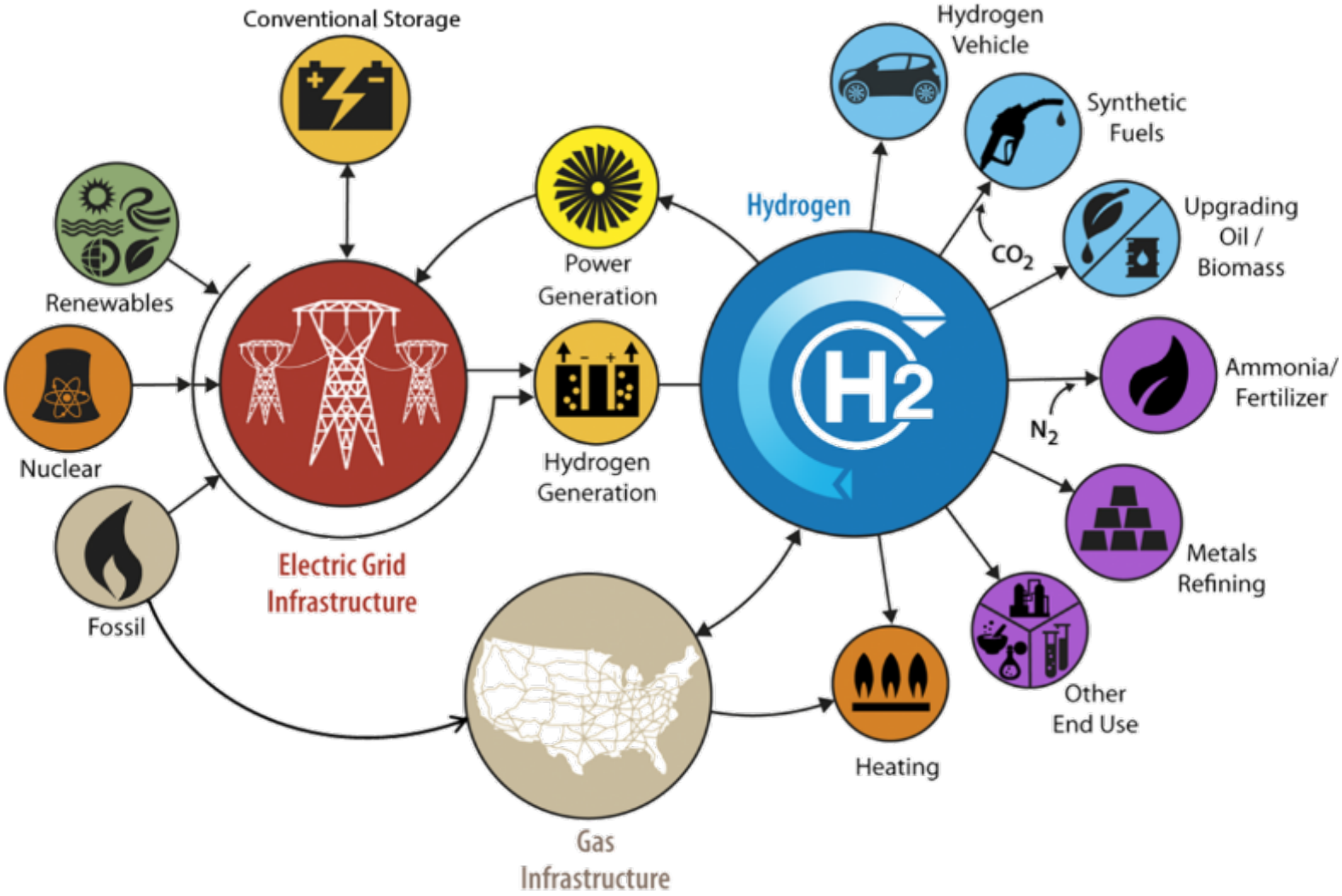
2019 AIChE Annual Meeting
Orlando, Florida
November 11, 2019

NREL/PR-5D00-75443

Outline

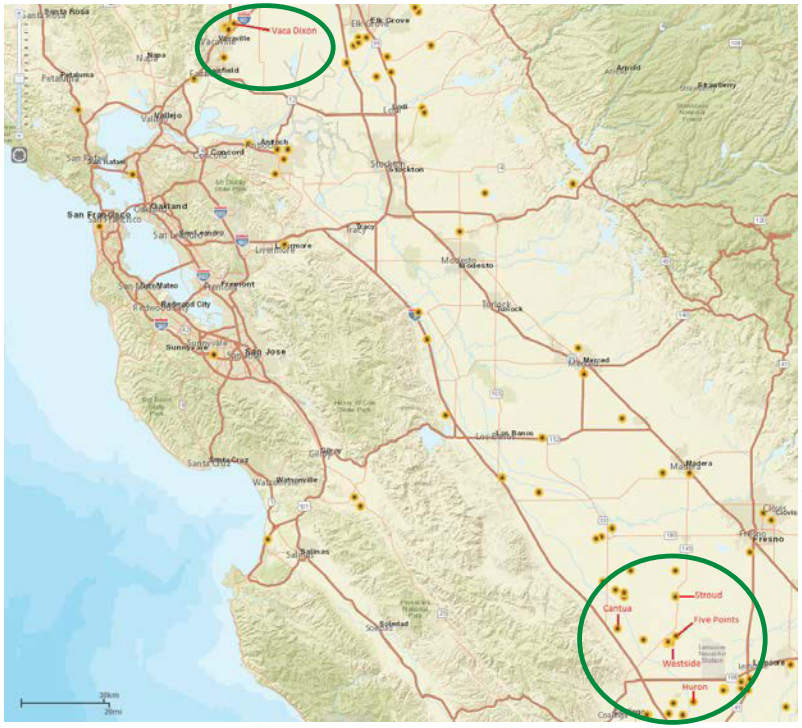

Motivation
Methods
Results: Variability of solar photovoltaic (PV) resources and locational marginal prices (LMPs)
Results: Hydrogen breakeven cost for each configuration and solar PV site
Conclusions and future work

Motivation: H2@SCALE Concept



Renewable electrolytic hydrogen can facilitate the integration of high shares of variable renewable energy by providing flexibility to renewable power plants via energy storage or as a commodity (i.e., low-cost hydrogen could be produced from otherwise curtailed electricity).

Motivation: Locational Marginal Prices



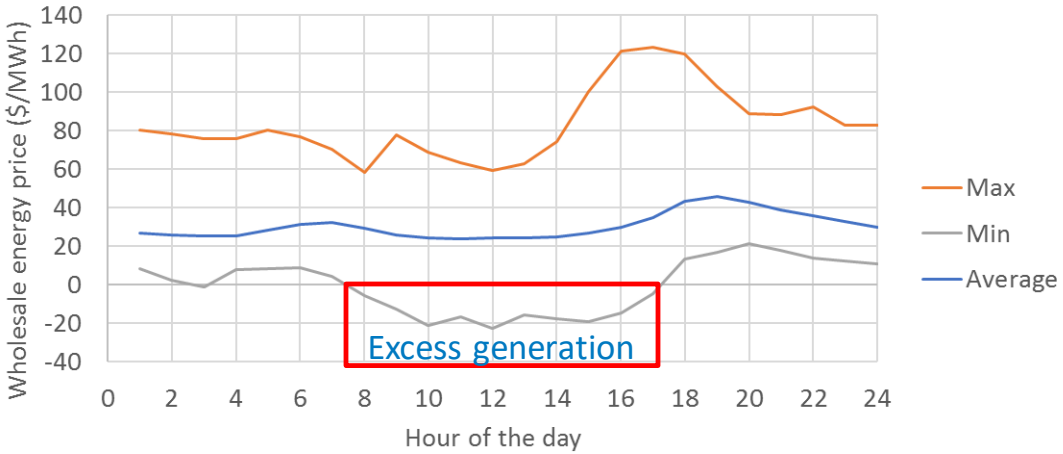
Location of selected solar power stations†

† Schedule 3 of Form EIA-860 Data: https://www.eia.gov/electricity/data/eia860/

‡ ABB Ability Velocity Suite, 2018 (see backup slides for more details)

Technical Specifications for the Selected Solar Stations†

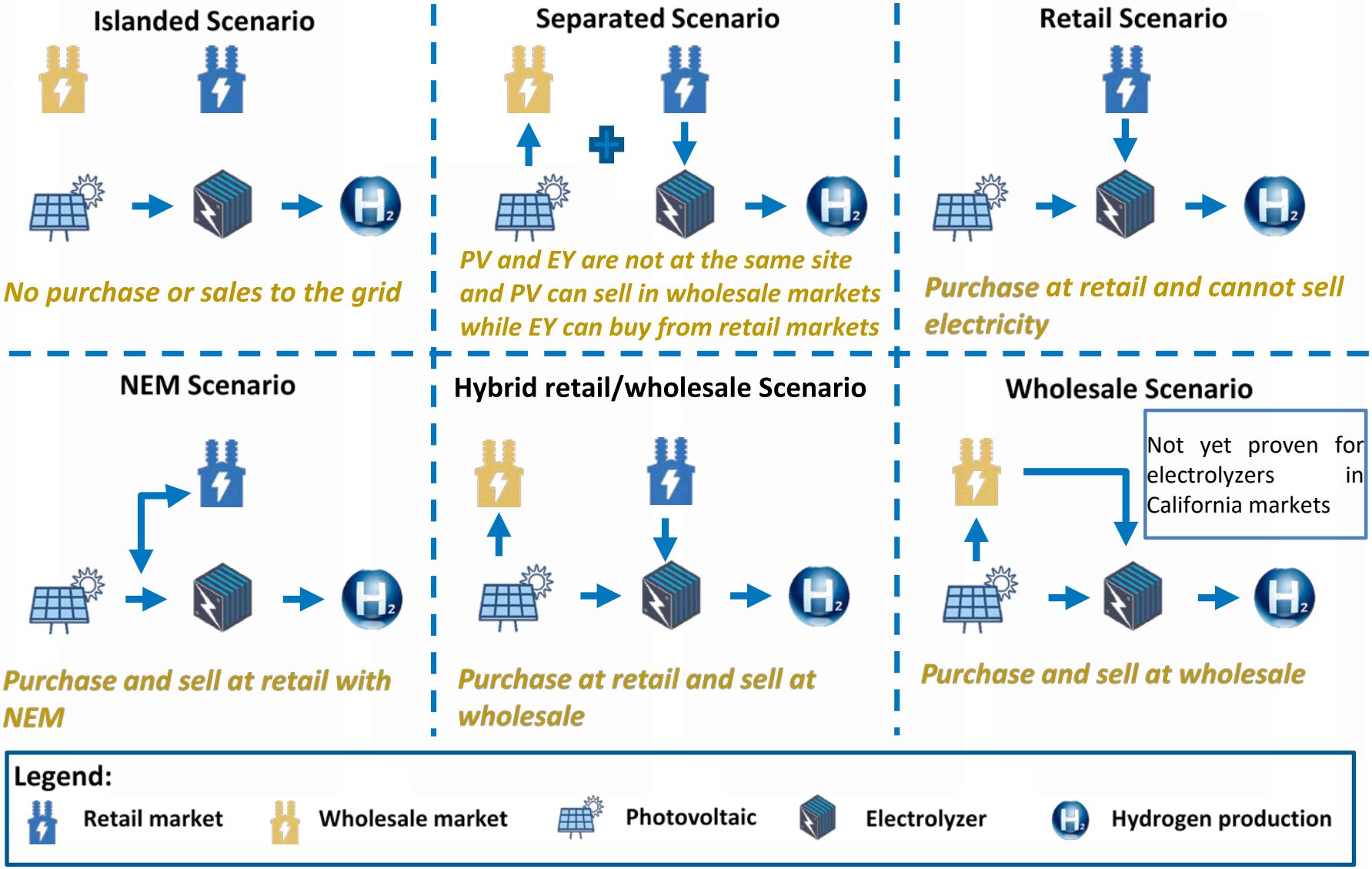
Name	DC Net Capacity (MW)	Tilt Angle	DC/AC ratio	Fixed Tilt?	Crystalline Silicon?
Vaca Dixon	2.6	30	1.30	Yes	Yes
Stroud	24.6	25	1.23	Yes	Yes
Five Points	17.6	25	1.17	Yes	Yes
Westside	18.5	25	1.23	Yes	Yes
Cantua	26.3	25	1.32	Yes	Yes
Huron	26.8	25	1.34	Yes	Yes



Average 2016 wholesale LMP prices for all six sites ‡

Lower, or even negative prices (particularly during the afternoon), challenge the business cases for new and existing PV plants.

Methods: Solar PV—Electrolyzer Market Configurations



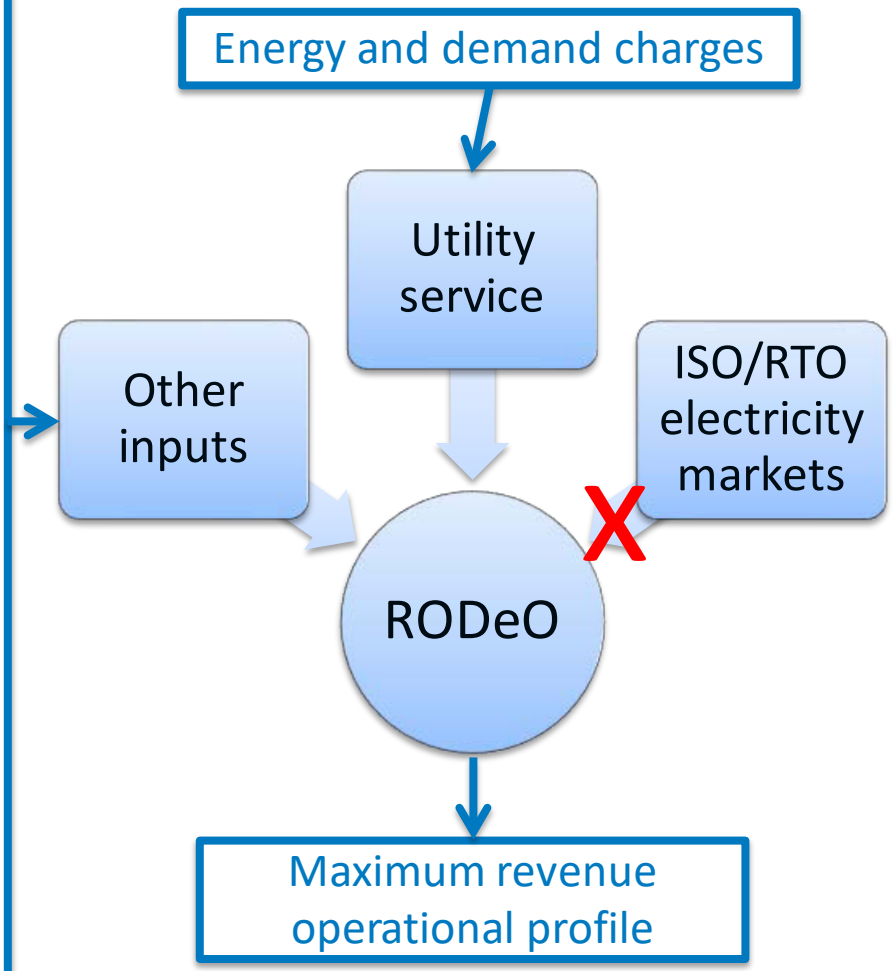
NEM: Net Energy Metering rate

Methods: Modeling Framework and Assumptions

System configurations and technology assumptions:

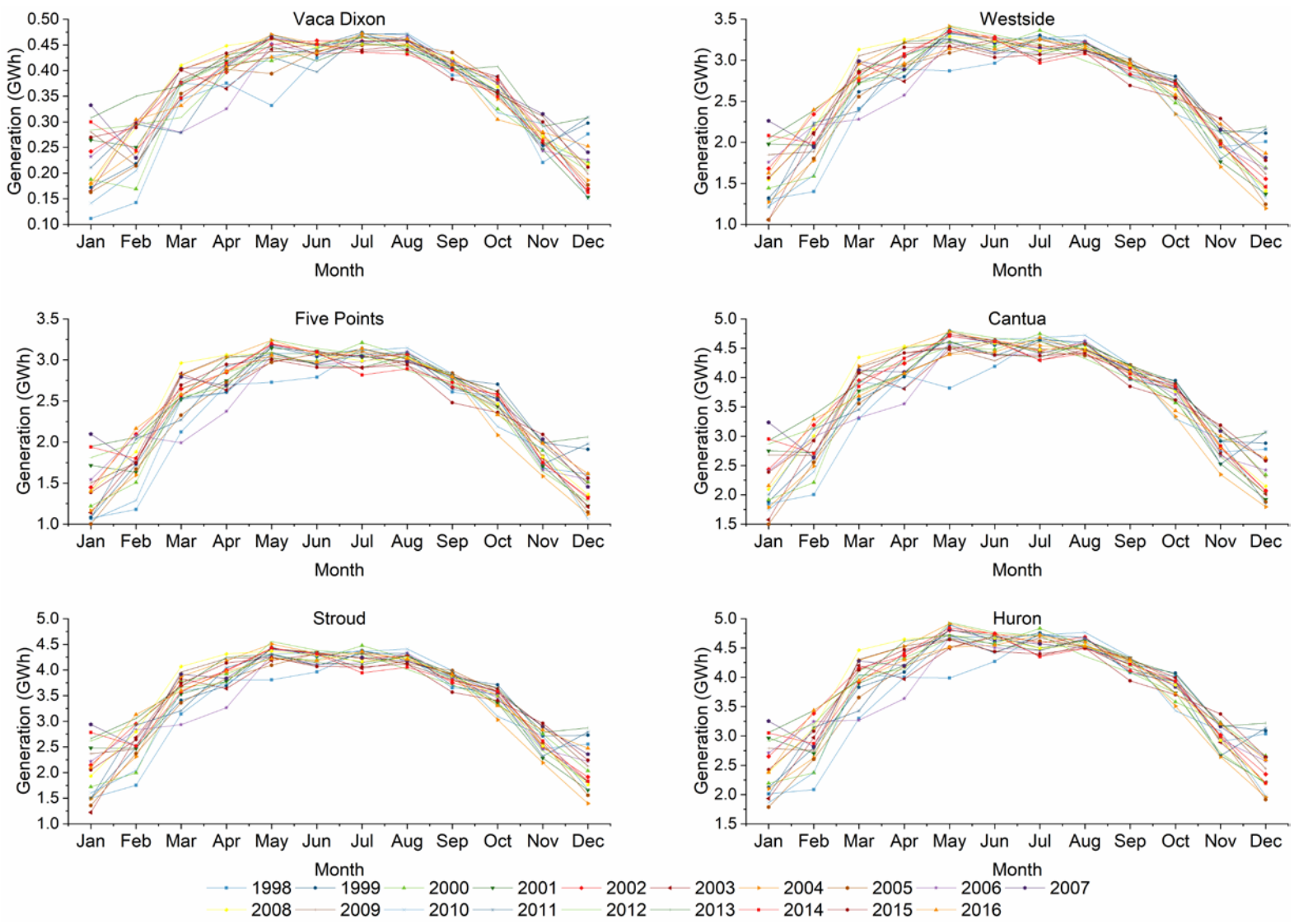
- Electrolyzer (EY) capital cost: $1,691/kW
- Solar PV capital cost: $1,343/kW
- Replacement cost: $18.64/kW-year
- H2 storage capital cost: $822 /kg
- EY fixed O&M cost: $75.2/kW-year
- Solar PV fixed O&M cost: $12.0/kW-year
- Combined federal and state taxes: 27.95%
- Lifetime: 20 years
- Interest rate: 7%
- Efficiency: 54.3kWh/kg
- Minimum part load: 10%
- Storage duration: 8 h
- Time horizon: 1 year (8,760 time periods)

Ref: Eichman J. et al. National Renewable Energy Laboratory (NREL), Golden, CO, 2016.



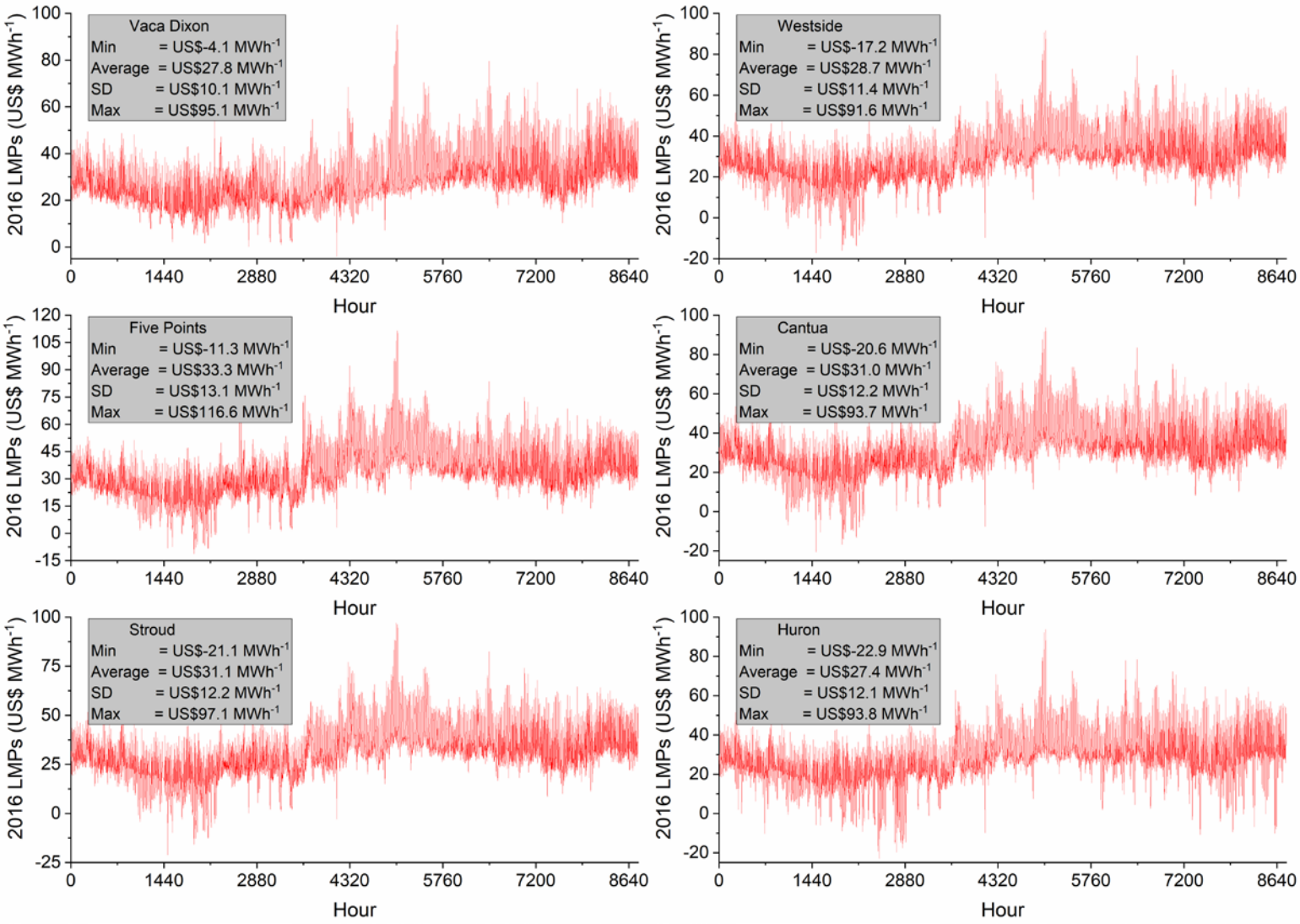
RODeO: Revenue Operation and Device Optimization price taker model. It is formulated as a mixed-integer linear programming (MILP) model in GAMS.

Results: Variability of Solar PV Resources



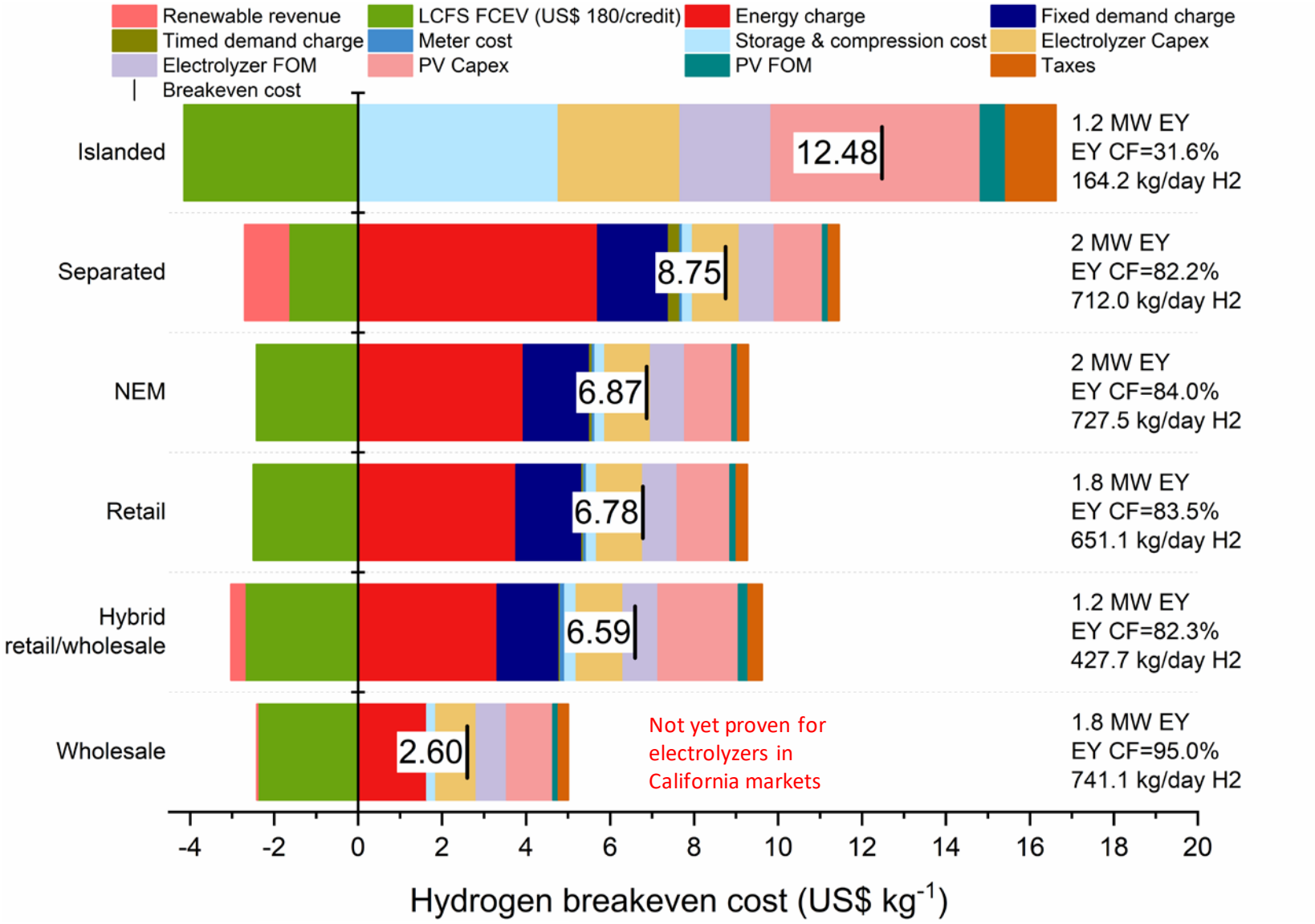
Solar PV generation varies for each month, site, and year. These variations can be used to understand the uncertainty in the calculated hydrogen production costs.

Results: Variability of Locational Marginal Prices



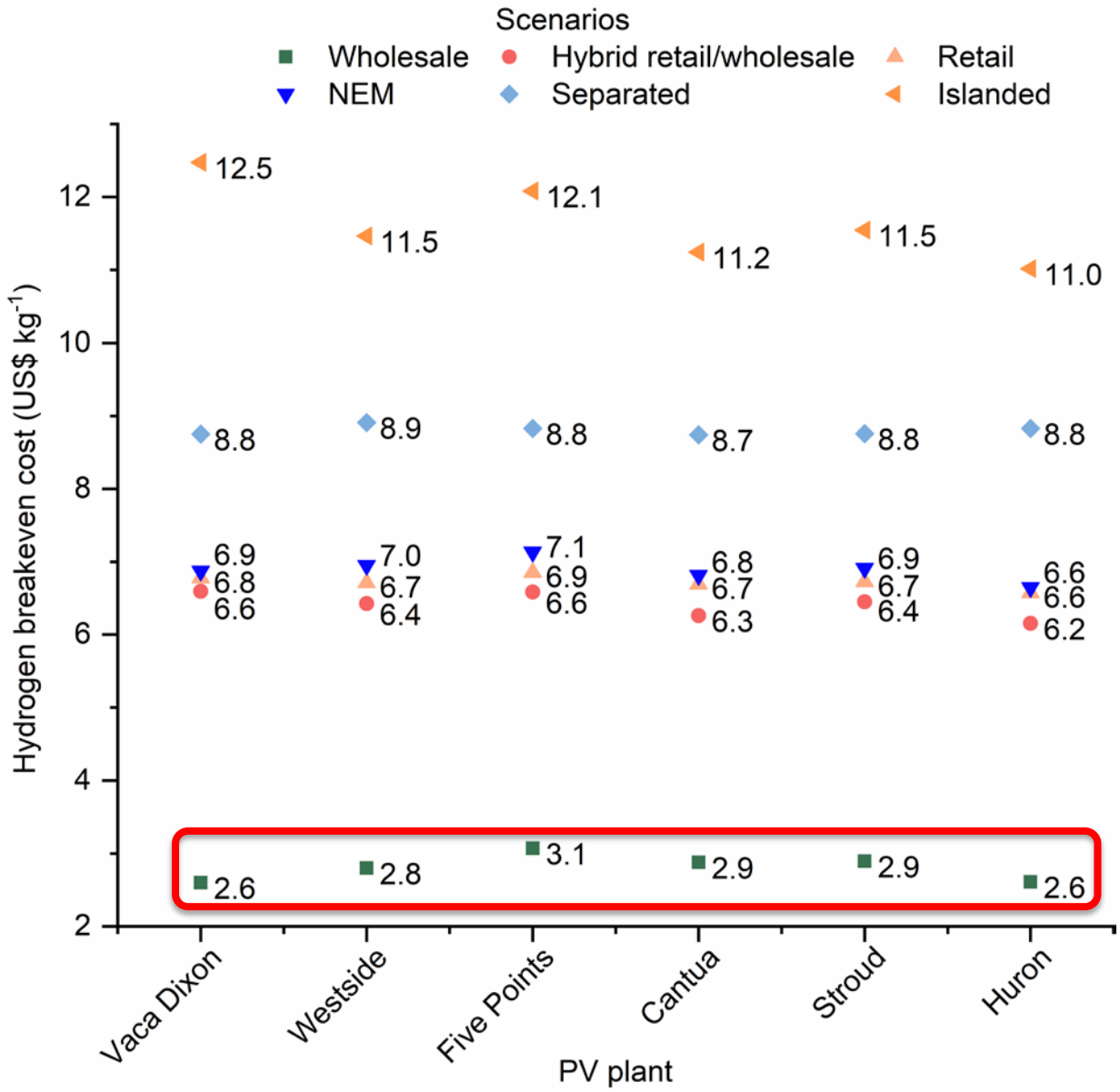
The seasonal price shapes are similar among all sites, and there are negative prices at every node (curtailment)

Results: Hydrogen Breakeven Cost for Vaca Dixon Plant



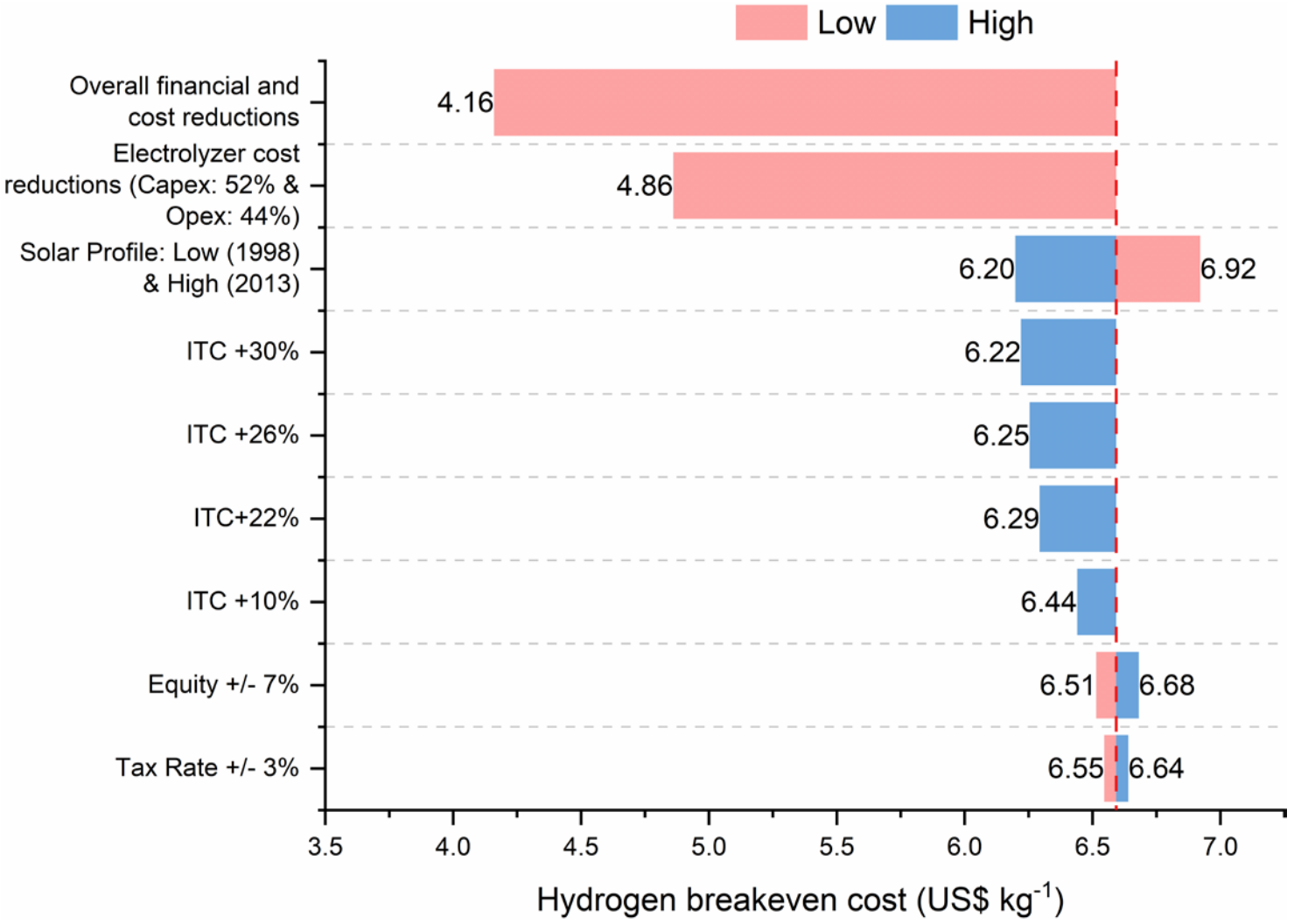
FOM: Fixed operation and maintenance, FCEV: Fuel cell electric vehicle, LCFS: Low Carbon Fuel Standard

Results: Hydrogen Breakeven Cost for the Six Solar PV Stations



Not yet proven for electrolyzers in California markets

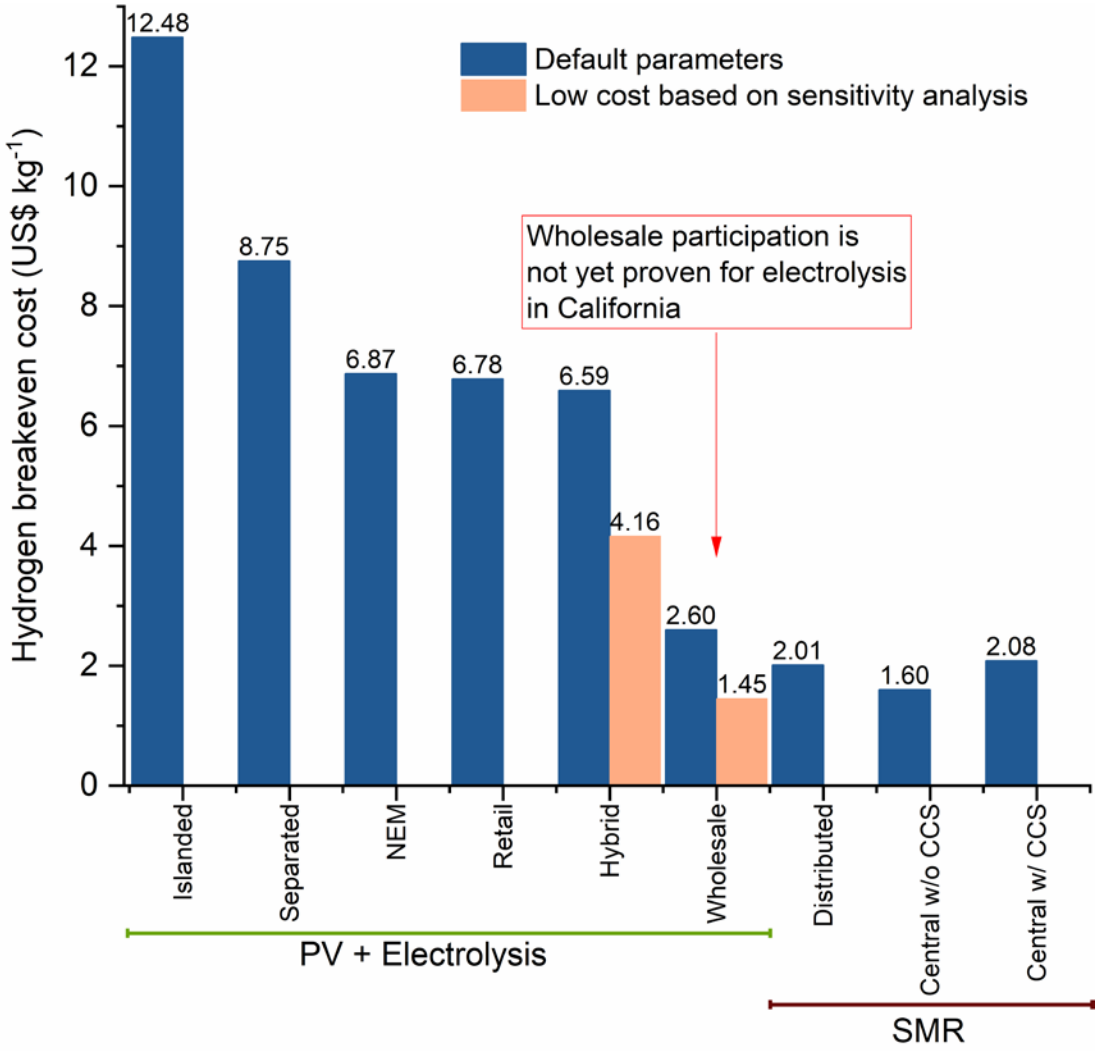
Results: Sensitivities (Vaca Dixon, Hybrid Scenario)



The biggest factors affecting the hydrogen breakeven cost are electrolyzer cost reductions, solar profile, and investment tax credit (ITC).

Financing and tax properties have a smaller impact.

Results: A Pathway to Cost-Competitiveness (Vaca Dixon Plant)



- Combining all sensitivity properties (except solar resource), the hybrid and wholesale configurations reduce significantly.
- Between hybrid and wholesale configurations, there is a spectrum of feasible and competitive solutions.

Driven by future cost reductions, we laid out a pathway to cos-competitive electrolysis solutions.

Notes: All systems include production as well as compression and storage in preparation for delivery.
DOE H2A SMR costs increased by $0.24/kg for compression and storage.
SMR: steam methane reforming, CCS: carbon capture and sequestration

Conclusions and Future Work

Conclusions

- Hybrid and wholesale configurations represent a spectrum of potential solutions for cost-competitive electrolytic hydrogen.
- Although not proven in California, access to wholesale electricity pricing provides the lowest electrolytic hydrogen cost.
- From the perspective of the solar PV owner, integration of solar PV with electrolysis provides a potential hedge against price depression and the value deflation effect as more systems are installed on the grid.

Future Work

- Integration with wind resources
- Extend analysis to other regions across the United States
- Assessment of hydrogen production mitigating transmission congestion.

Thank you!

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This work was authored in part by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Fuel Cell Technologies Office and Pacific Gas and Electric Company. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

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