Integrating Cambium Marginal Costs into Electric-Sector Decisions

Opportunities to Integrate Cambium Marginal Cost Data into Berkeley Lab Analysis and Technical Assistance

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https://emp.lbl.gov/publications/integrating-cambium-marginal-costs

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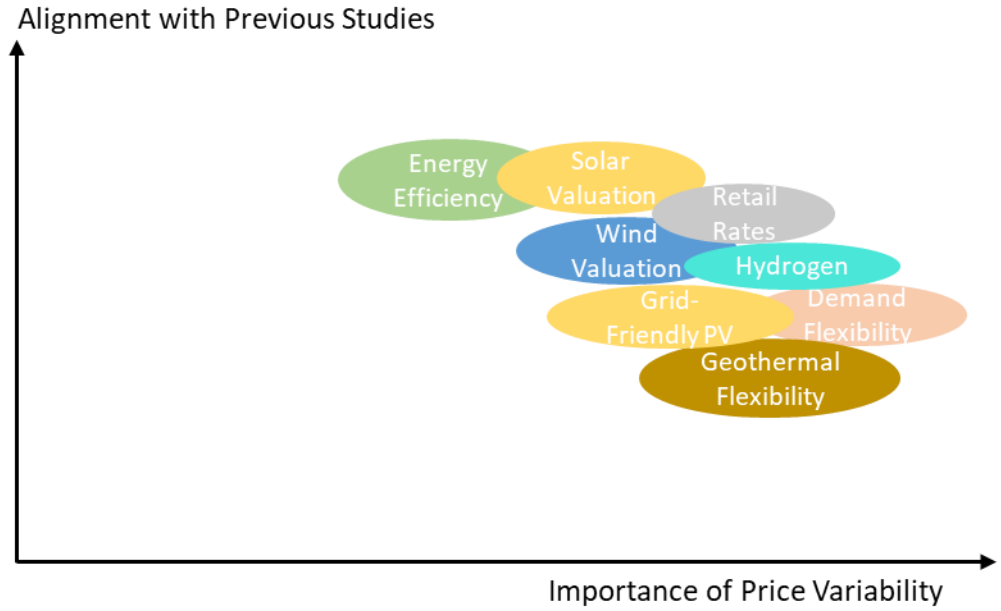
Main Findings

- Insights from several Berkeley Lab studies that originally used other price data can be reproduced with Cambium data
  - Directionality of findings is mostly the same, though magnitude of evaluated benefits may vary substantially
- Hourly marginal cost data across multiple cost categories with broad geographic scope, long-term projections to 2050, and multiple scenarios can be highly useful for time-sensitive valuation research
- Price variability may be underrepresented in the Cambium data, implications for research findings vary by case-study
- There are many promising applications of the Cambium data beyond existing Berkeley Lab projects, aided by the great wealth in available data.
- The Cambium data seems very suitable for the use by multiple DOE program offices to leverage the cohesive dataset themselves or in their sponsored research



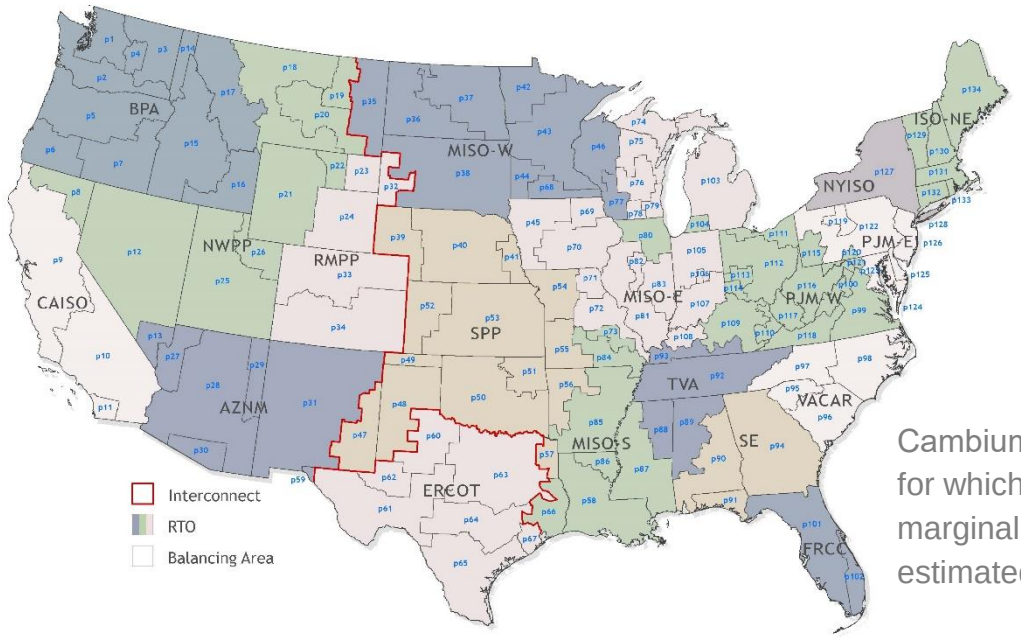
Potential Enhancements to Cambium Data to Further Increase Usefulness

- Refine representation of price variability (negative prices, price spikes, VRE* induced merit-order effects) to better capture flexibility value and VRE integration costs. Include uncommon but increasingly more frequent extreme weather events
- Align reported capacity costs more closely with empirical capacity market results
- Distinguish between transmission and generation capacity costs
- Include baseline transmission and distribution costs to allow modeling of all-in retail costs
- Include carbon constraints and associated costs in unit-commitment modeling
- Clarify effect of modeled flexibility additions (e.g. storage) and whether those explain limited VRE value erosion
- Add scenarios that allow for analysis of pressing issues (building and transport electrification, medium-term electric-sector carbon neutrality, longer-term economy-wide carbon neutrality)
- Make (load- and VRE-driving) weather and other input assumptions (e.g. fuel prices) more readily accessible
- Consider even finer geographic representation (mid-size utilities) to facilitate technical assistance

*VRE: Variable Renewable Energy

Background

- NREL's Cambium tool generates forward-looking simulations of marginal hourly wholesale electricity costs associated with NREL's Standard Scenarios between 2018 and 2050 across the continental US
- The Cambium data can serve as public and transparent data source to inform electric-sector decision-making processes
- Berkeley Lab used its expertise to evaluate the Cambium costs data and highlights how DOE program offices may use this cohesive dataset themselves or in their sponsored research. Evaluation included:
  - Comparison of Cambium's cost estimates with empirical wholesale market prices for the year 2018 in seven ISOs
  - Comparison of Cambium's cost estimates with other modeled price estimates by consulting company LCG for the year 2030 in four ISOs
  - Assessment of performance of Cambium data in eight case studies that replicate previous analysis based on other price data sets
  - Qualitative evaluation of the suitability of Cambium's marginal cost data in ten case studies of ongoing Berkeley Lab research



Cambium's 130 BAs for which hourly marginal costs are estimated 2018-2050

Role of Wholesale Price Data in Berkeley Lab's Work

DOE Office	Research Project	Description	Price Data Used in Analysis
Section 4 Case Studies: Comparative Evaluation of Cambium Data			
SETO	Solar-to-Grid	Valuation of empirical solar projects	Energy (nodal) and capacity (zonal) prices in 7 ISOs and 10 additional BAs, 2012-2019
SETO	Grid-Friendly Photovoltaics (PV)	Valuation of hypothetical solar project designs, including storage	Historical energy prices (nodal) for 7 ISOs, modeled LCG price data for 2030 for 4 ISOs
WETO	Wind Tech Market Report	Valuation of empirical wind projects	Energy (nodal) and capacity (zonal) prices in 7 ISOs, 2008-2019
EERE Strategic Analysis	High VRE Impact on Demand-Side Decisions	Valuation of Energy Efficiency (EE) portfolios, retail rate designs, and hydrogen production	Modeled LCG price data for 2030 for 4 ISOs
GTO	Geothermal Flexibility	Valuation of flexible geothermal operations	Historical energy prices (nodal) for CAISO, modeled LCG price data for 2030 for CAISO
SETO	PUC Analytical Support	Improving the Representation of DERs in Utility Integrated Resource Planning (IRP)	Indiana utility IRP energy price projections for 2020 and 2030
Section 5: General Assessment of Cambium Data			
BTO	Time-sensitive Valuation (TSV) EE Calculator	Valuation of EE measures and programs	Cambium BA-level energy and capacity costs, marginal carbon emissions
BTO	Scout Model	Valuation of EE and Flexibility Measures	Cambium BA-level total end-user costs, carbon emissions
BTO	Grid-Interactive Efficient Building (GEB) Roadmap	Valuation of EE and Demand Flexibility Measures	Cambium energy, capacity, Ancillary Service (AS) costs, carbon emissions for 22 regions
N/A (California PUC)	Demand-Response (DR) Potential Study	Project DR quantity, costs and value in California	Wholesale electricity cost and carbon emissions forecast by CPUC
BTO/SETO/ VTO/OE	Connected Communities	Valuation of EE and Flexibility Measures that maximize DER self-consumption	*Potentially* Cambium energy, capacity and AS costs at multiple locations throughout U.S.
SETO/OE (GMLC)	Multi-DER Rate Impacts	Valuation of DPV and EE system and customer benefits according to multiple retail rates and wholesale prices	Cambium energy and capacity costs
SETO	Distributed PV (DPV) +Storage Net Billing	Comparison of alignment of net-billing retail rates with system value	Historical empirical data and Cambium energy, capacity, AS costs, carbon emissions at multiple BAs
EERE Strategic Analysis	Future Drivers of Retail Rates	Forecasting electric utility fuel and purchased power budgets	Range of data sources
SETO	SEIN Utility-scale PV (UPV) Feeder Integration	Valuation of multiple UPV designs, including storage	Cambium energy costs for Rhode Island, *potentially* capacity and AS costs
WETO	Big Adaptive Rotors	Valuation of hypothetical wind project designs	Historical energy prices (nodal) for 7 ISOs, modeled LCG price data for 2030 for 4 ISOs

The table summarizes recently completed or ongoing projects at Berkeley Lab that use (or could use) historical or forward-looking wholesale price data to inform electric-sector decisions.

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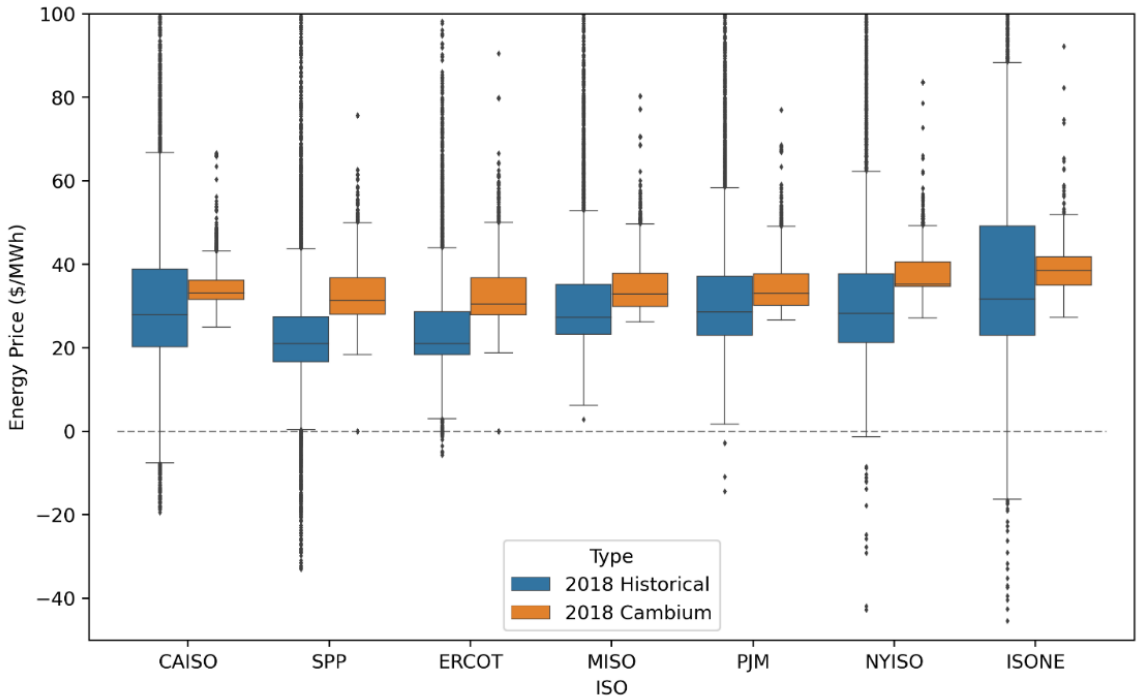
Comparison of Cambium with Other Berkeley Lab Price Datasets

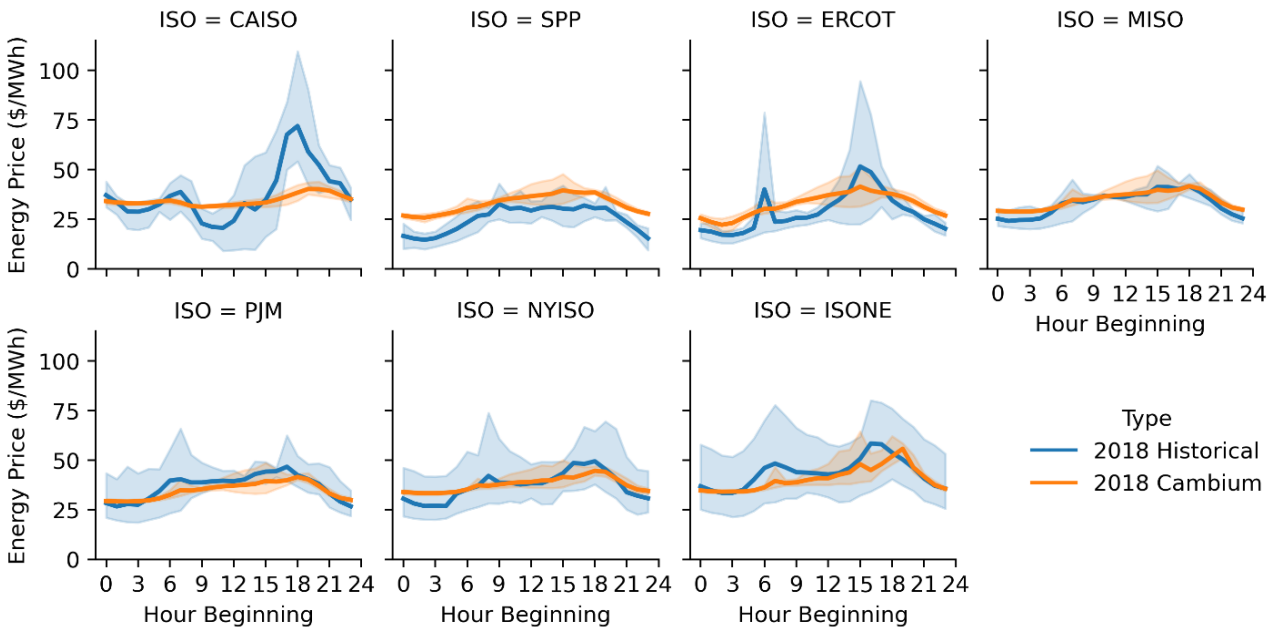
- *The report discusses:*
  - *Empirical energy, capacity and ancillary service prices from 2018 with Cambium data*
  - *Energy and capacity prices modeled by LCG for the year 2030 across multiple scenarios with Cambium data*

Comparison of Cambium with Berkeley Lab Price Datasets: 2018 Empirical Energy Prices

Cambium data approximates median empirical energy prices, but underestimates spread



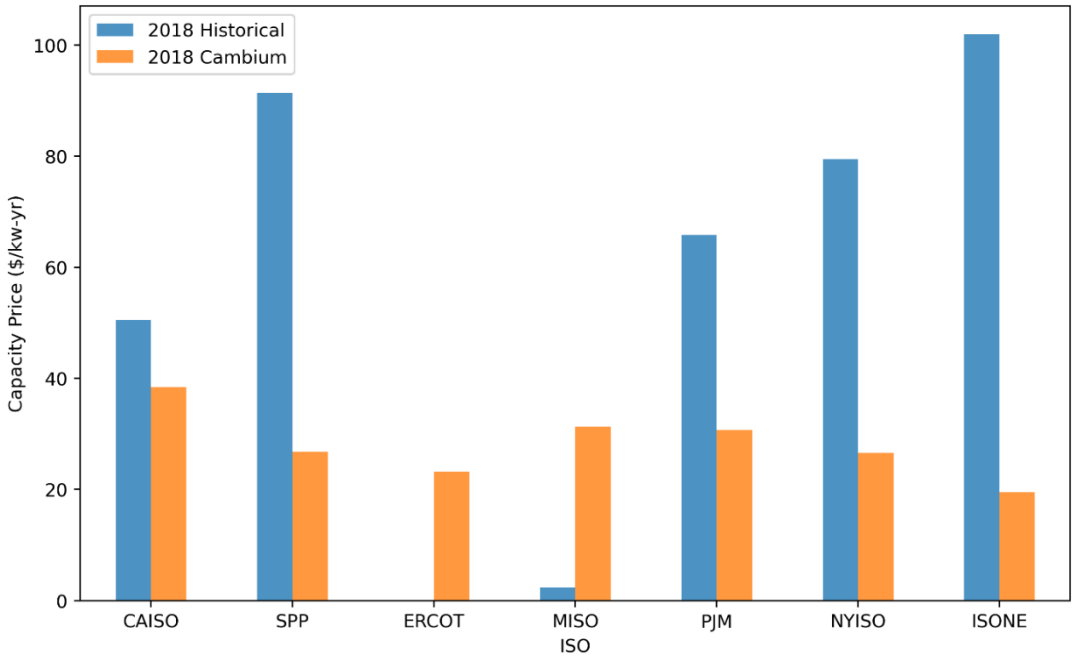
Cambium data matches profiles of empirical energy prices well in some regions, but underestimates diurnal and seasonal variability in others



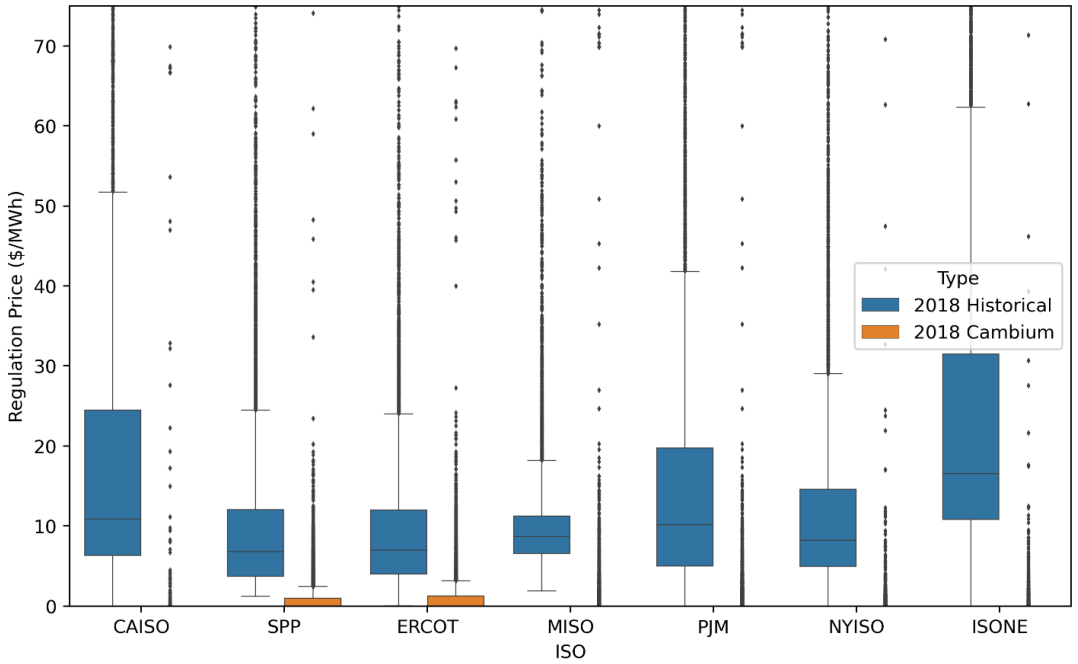
Shaded areas describe seasonal range of average price profiles

Comparison of Cambium with Berkeley Lab Price Datasets: 2018 Empirical Capacity and AS Prices

Cambium capacity costs are often lower than empirical market prices, potentially because they recognize new transmission contributions directly.

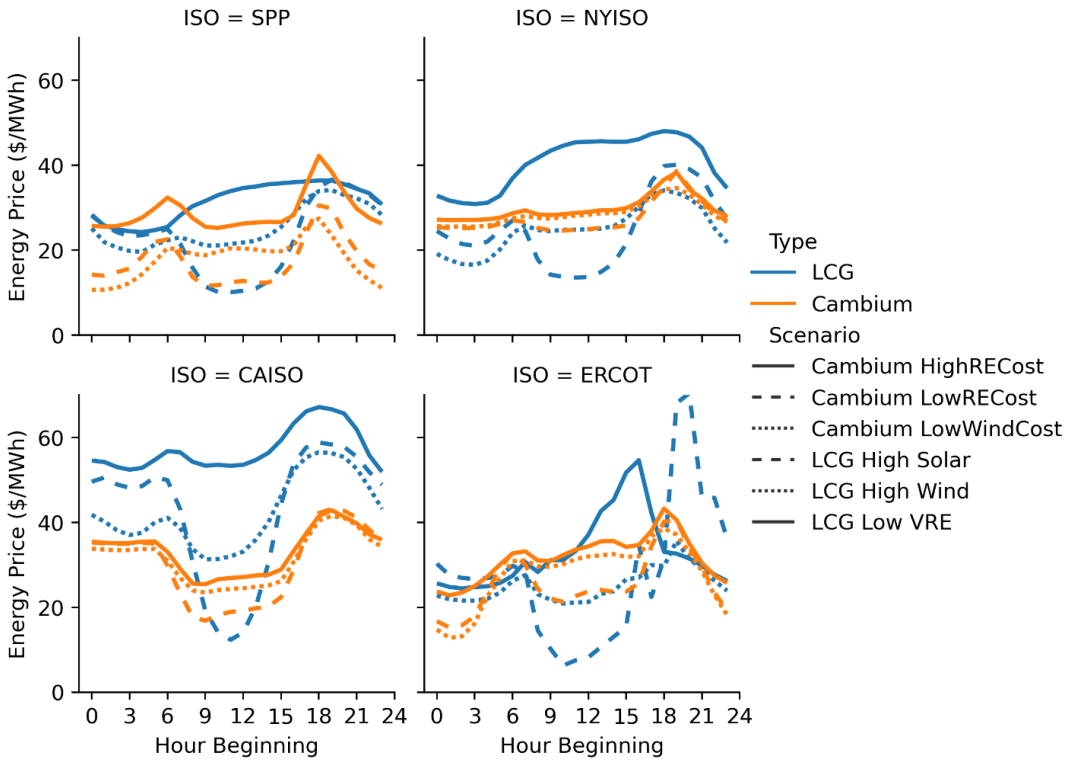


Cambium's reserve costs should not be used to represent empirical ancillary service prices

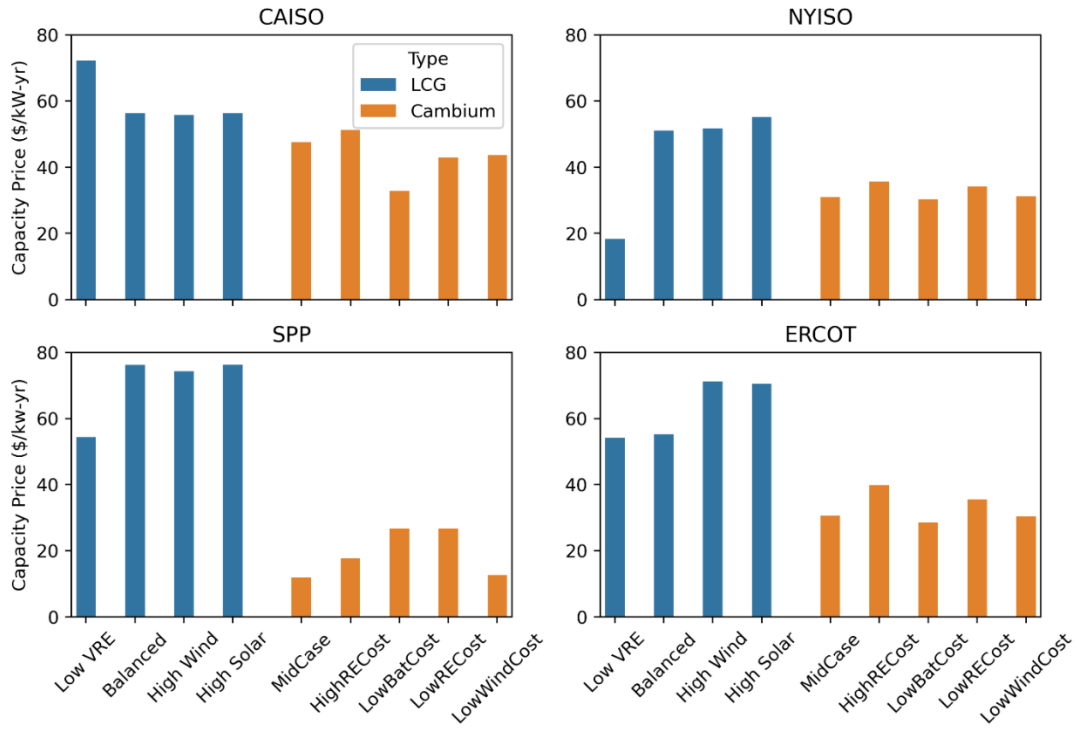


Comparison of Cambium with Berkeley Lab Price Datasets: 2030 Modeled Prices by LCG

Different scenario definitions make direct comparisons difficult. Energy cost profiles compare well for some regions but may underestimate variability in others.



Estimated capacity costs are often lower in the Cambium data.

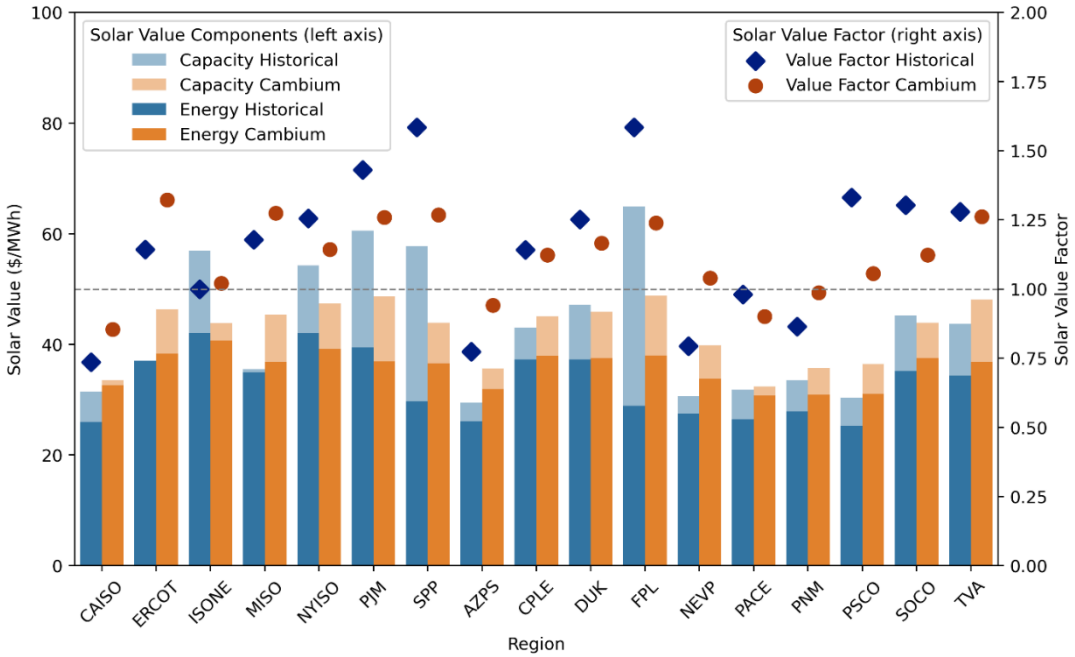


Evaluation of Cambium Costs in Select Case-Studies

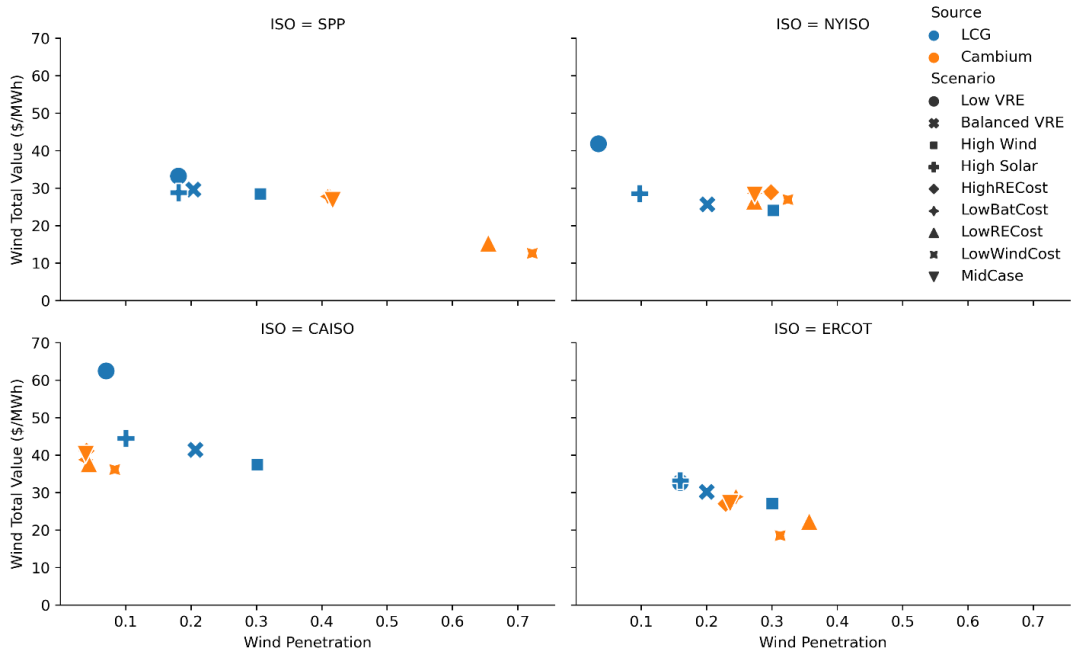
- *The report discusses for each case-study:*
  - *What was the key insight from the original Berkeley Lab study?*
  - *How similar are the results using the Cambium cost data?*
  - *What are the key price dynamics in the analysis that were either replicated or missed by Cambium?*
  - *Are there any novel insights based on using Cambium costs?*

Evaluation of Cambium Costs in Case Studies

Solar value estimates for 2018 in absolute and relative terms are often similar, differences primarily driven by deviating capacity prices



Cambium's wind value estimates for 2030 across varying penetration rates follow similar trajectory of LCG's estimates, but may underestimate wind value erosion, especially relative to a 24/7 flat block of power.



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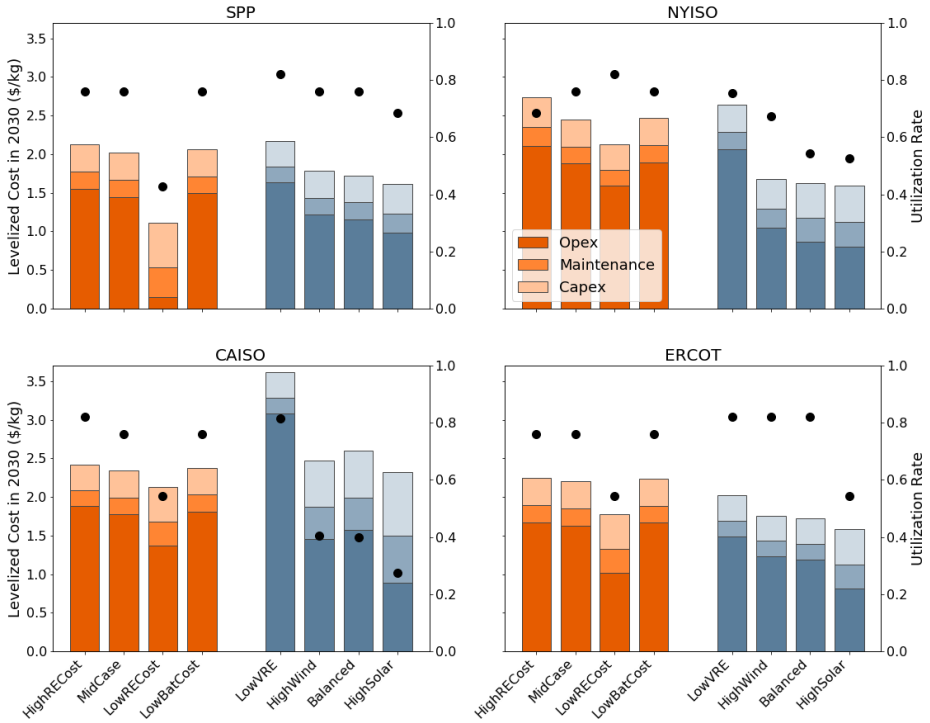
Evaluation of Cambium Costs in Case Studies

Cambium captures similar dynamics in hydrogen production cost modeling cw/ LCG price data: Higher VRE penetrations enable lower electrolyzer utilization rates and a cost shift from Opex to Capex



Energy value estimates of efficiency measures in Indiana for 2020 are often similar in overall magnitude between Cambium and utility IRPs, but seasonal valuation and measure ranking varies

Indiana Utility IRP Values, 2020

Measure	Max Seasonal Avg. Marginal Value [$/MWh]*	Avg. Annual Marginal Value [$/MWh]	Rank by Marginal Value				
			Year	Fall	Winter	Spring	Summer
C&I Appliance	$ 33.20	$ 31.94	1	1	1	1	1
Resi Envelope	$ 32.00	$ 30.86	2	3	2	2	3
Resi Appliance	$ 31.93	$ 30.48	3	4	3	5	4
C&I Refrigeration	$ 31.83	$ 30.01	4	5	4	3	6
C&I Lighting	$ 31.05	$ 29.61	5	6	6	4	5
Resi HVAC	$ 32.72	$ 29.57	6	2	9	7	2
C&I Electronics	$ 31.18	$ 29.07	7	10	5	6	10
C&I Envelope	$ 29.85	$ 28.46	8	7	N/A	9	8
Resi PoolPump	$ 29.59	$ 28.36	9	8	N/A	11	9
Resi Other	$ 30.53	$ 28.33	10	9	8	8	7
Resi Lighting	$ 29.02	$ 27.78	11	11	7	10	13
C&I Other	$ 28.24	$ 26.51	12	13	10	12	11
C&I HVAC	$ 28.19	$ 26.21	13	12	11	13	12

* Blue indicates higher seasonal value for the winter, orange for the summer

Cambium Mid-Case Busbar Energy Values, 2020

Measure	Max Seasonal Avg. Marginal Value [$/MWh]*	Avg. Annual Marginal Value [$/MWh]	Rank by Marginal Value				
			Year	Fall	Winter	Spring	Summer
Resi HVAC	$ 35.02	32.34	1	1	9	2	1
C&I Appliance	$ 33.61	32.20	2	2	2	1	2
C&I Lighting	$ 33.35	31.84	3	3	4	4	3
Resi Lighting	$ 33.01	31.66	4	12	1	5	13
Resi Other	$ 32.55	31.64	5	5	3	3	4
Resi Envelope	$ 32.51	31.49	6	4	6	12	5
Resi Appliance	$ 32.50	31.25	7	7	7	10	6
C&I HVAC	$ 32.22	31.24	8	8	10	6	8
C&I Other	$ 32.49	31.21	9	8	8	11	9
C&I Refrigeration	$ 32.04	31.15	10	9	5	7	9
C&I Envelope	$ 31.42	30.97	11	10	N/A	8	10
Resi PoolPump	$ 31.24	30.87	12	11	N/A	11	11
C&I Electronics	$ 31.21	30.55	13	13	11	13	12

* Blue indicates higher seasonal value for the winter, orange for the summer

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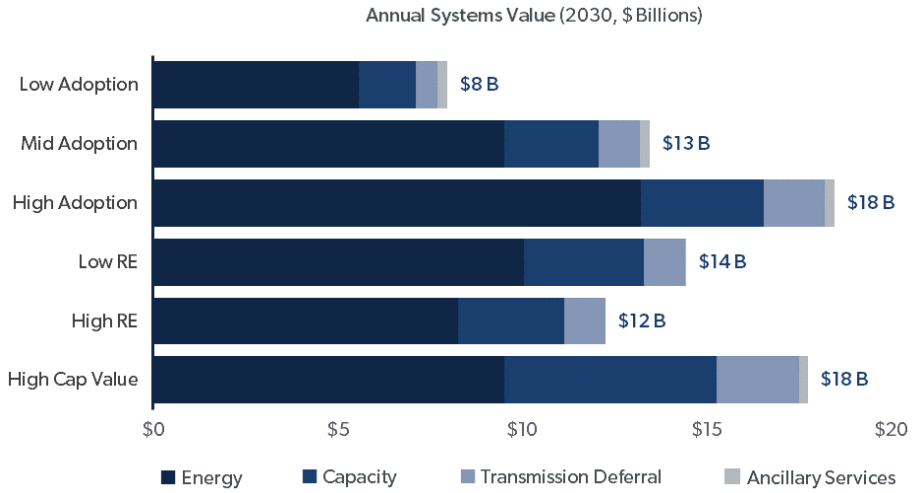
Suitability of Cambium Costs in Ongoing Berkeley Lab Studies

- *The report discusses for each case-study:*
  - *Project description and goal*
  - *Role of wholesale prices in the analysis*
  - *Key characteristics of wholesale price data used*
  - *Suitability of Cambium data for the project*

Cambium's Scenarios of Electric System Costs Evolution can be used in many Analyses

- Time-sensitive Value of Efficiency and Flexibility
  - Efficiency Calculator: load shapes and system cost estimates
  - Scout Model: hourly price intensities
  - GEB Roadmap Analysis: system cost estimates
  - CA Demand Response Potential: price changes with load variation

- VRE Valuation
  - Rate Impact Analysis for DER customers: energy and capacity costs
  - DPV Net Billing Analysis: energy and capacity costs
  - UPV Distribution Feeder Integration: energy costs
  - Large Rotor Benefits for Wind Turbines: *energy and capacity costs if wind data was available*



Estimates of annual power system benefits of grid-interactive efficient buildings (GEB). Energy, Capacity, and AS benefits were derived from Cambium data. Supported BTO's GEB Roadmap

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For more information

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