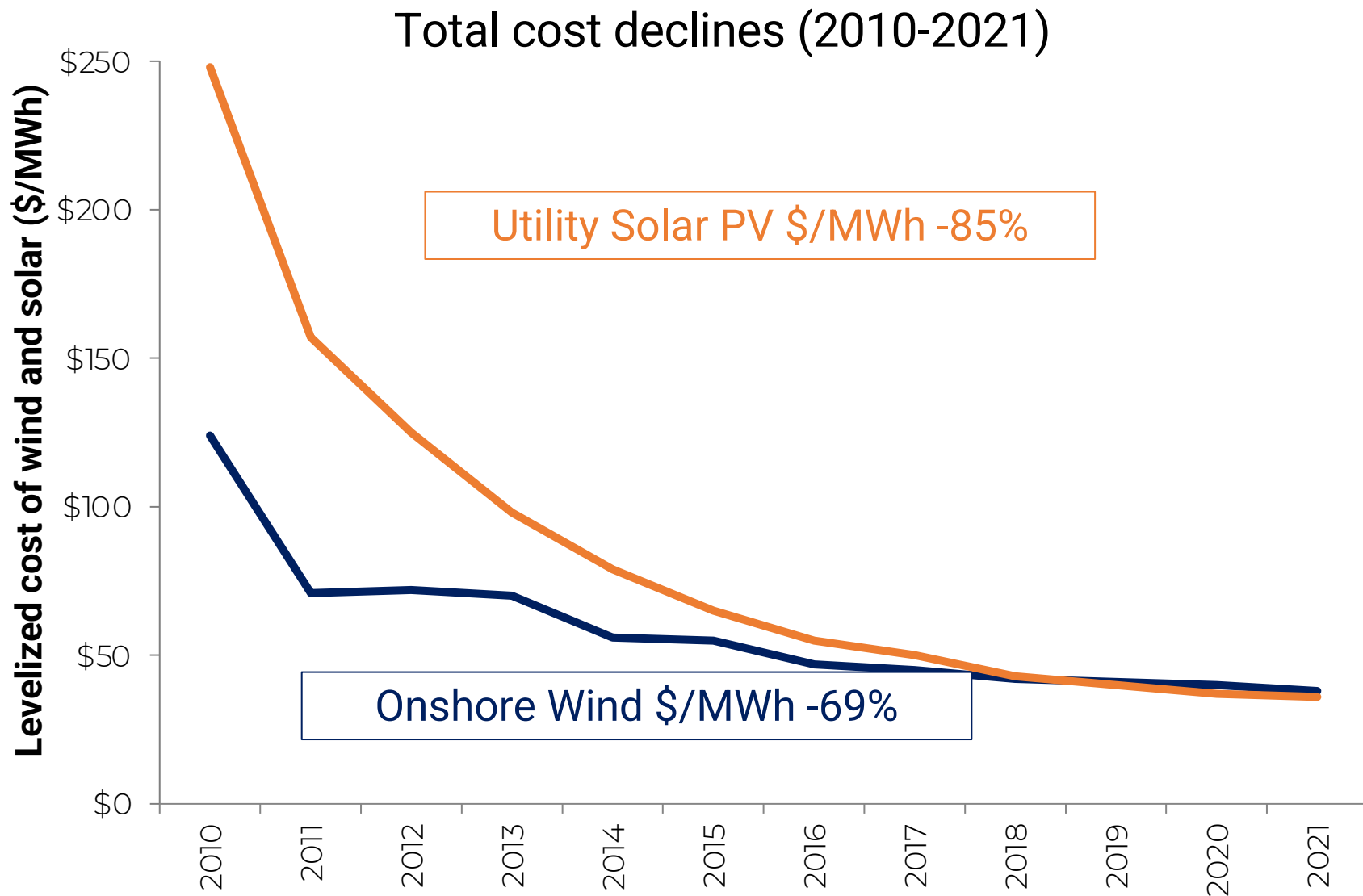




# 24/7 Carbon-free Electricity Procurement: The Next Frontier?

Prof. Jesse D. Jenkins  
New England Restructuring Roundtable  
December 9, 2022

# Voluntary Clean Energy Purchasing Can Have Transformative Impact



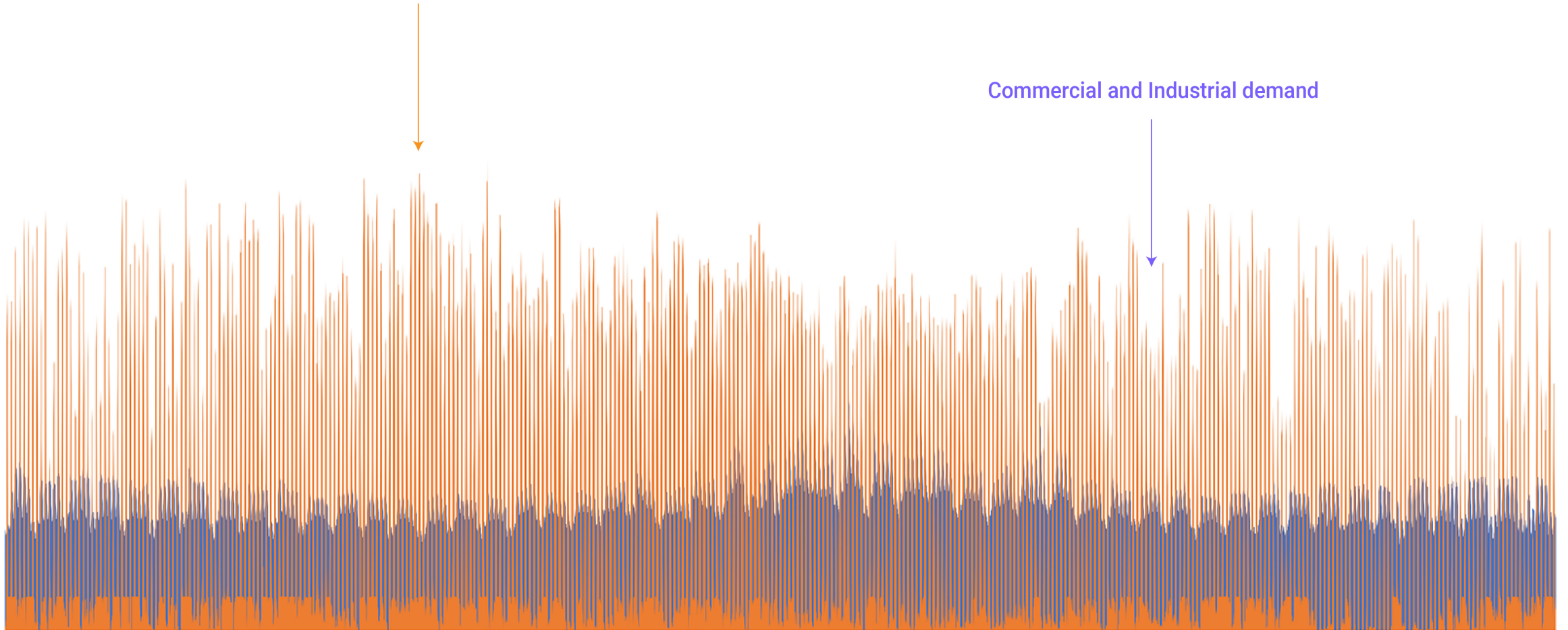
Large energy buyers procured 11.06 gigawatts of new renewable energy in 2021, ~40% of all U.S. renewable energy capacity additions that year.

# 100% Annual Matching Has Its Limits

**Example annual time profile of hourly renewable energy generation contracted to match 100% of annual participating commercial and industrial demand in PJM.**

Contracted Renewable Energy Generation

Commercial and Industrial demand



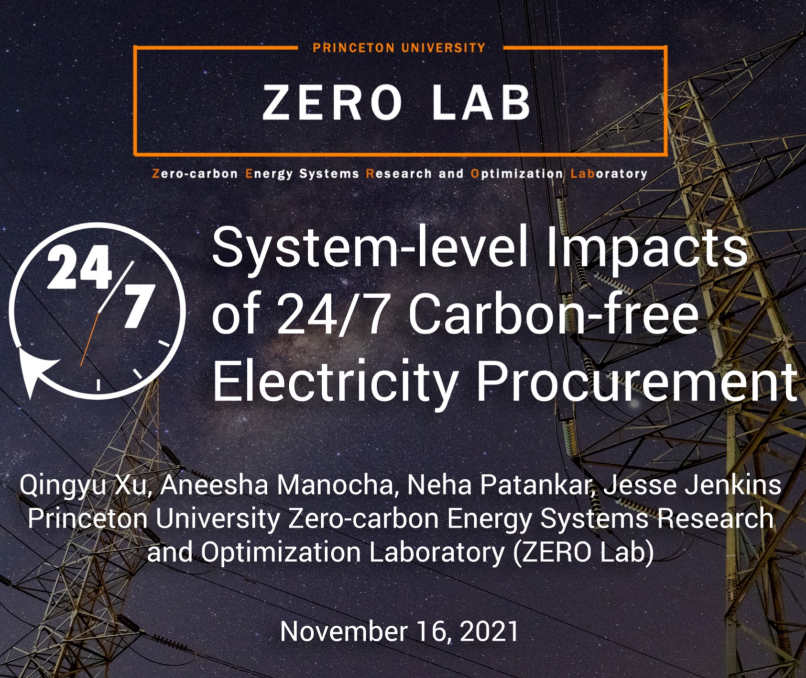
# The Next Frontier In Clean Energy Procurement

**The next frontier in clean energy procurement is to match a buyer's electricity demand, hour-by-hour, 24/7, with corresponding clean electricity generation from within the same electricity grid region as the buyer's operations.**

**This is 24/7 carbon-free electricity procurement or hourly matching.**



# ZERO Lab has published the first-ever analysis of the electricity system-level impacts of 24/7 carbon-free energy procurement



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**ZERO LAB**  
Zero-carbon Energy Systems Research and Optimization Laboratory

**24/7**

## System-level Impacts of 24/7 Carbon-free Electricity Procurement

Qingyu Xu, Aneesha Manocha, Neha Patankar, Jesse Jenkins  
Princeton University Zero-carbon Energy Systems Research and Optimization Laboratory (ZERO Lab)

November 16, 2021



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**ZERO LAB**  
Zero-carbon Energy Systems Research and Optimization Laboratory

## Electricity System and Market Impacts of Time-based Attribute Trading and 24/7 Carbon-free Electricity Procurement

By Qingyu Xu and Jesse D. Jenkins, Princeton University

September 15, 2022

### Minimizing emissions from grid-based hydrogen production in the United States

Wilson Ricks<sup>1</sup>, Qingyu Xu<sup>1</sup> and Jesse D. Jenkins<sup>1</sup>

<sup>1</sup> Andlinger Center for Energy and the Environment, Princeton University, Princeton, NJ, USA

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November 2022

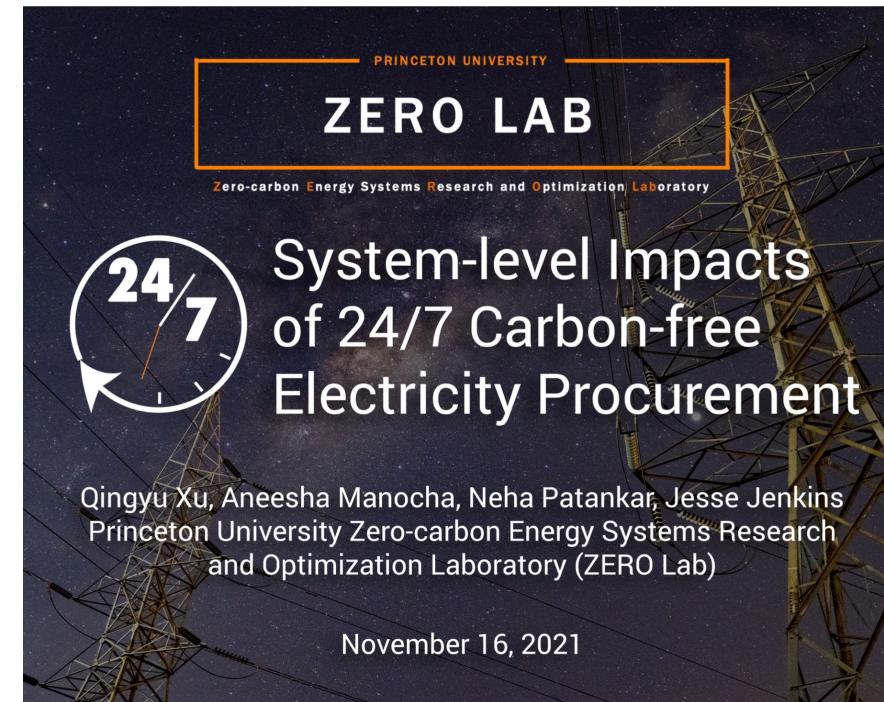
**Abstract.** Low-carbon hydrogen could be an important component of a net-zero carbon economy, helping to mitigate emissions in a number of hard-to-abate sectors. The United States recently introduced an escalating production tax credit (PTC) to incentivize production of hydrogen meeting increasingly stringent embodied emissions thresholds. Hydrogen produced via electrolysis can qualify for the full subsidy under current federal accounting standards if the input electricity is generated by carbon-free resources, but may fail to do so if emitting resources are present in the generation mix. While use of behind-the-meter carbon-free electricity inputs can guarantee compliance with this standard, the PTC could also be structured to allow producers using grid-supplied electricity to qualify subject to certain clean energy procurement requirements. We use electricity system capacity expansion modeling to quantitatively assess the impact of grid-connected electrolysis on the evolution of the power sector in the western United States through 2030 under multiple possible implementations of the clean hydrogen PTC. We find that subsidized grid-connected hydrogen production has the potential to induce additional emissions at effective rates worse than those of conventional, fossil-based hydrogen production pathways, particularly in regions where coal is a large part of the generation mix. Emissions can be minimized by requiring grid-based hydrogen producers to match 100% of their electricity consumption on an hourly basis with physically deliverable, 'additional' clean generation, which ensures effective emissions rates equivalent to electrolysis exclusively supplied by behind-the-meter carbon-free generation. While these requirements cannot eliminate indirect emissions caused by competition for limited clean resources, they consistently outperform alternative approaches relying on relaxed time matching or marginal emissions accounting. Added hydrogen production costs from enforcing an hourly matching requirement rather than no requirements are less than \$1/kg, and can be near zero if clean, firm electricity resources are available for procurement.

<https://acee.princeton.edu/24-7/>

<https://zenodo.org/record/7349406>

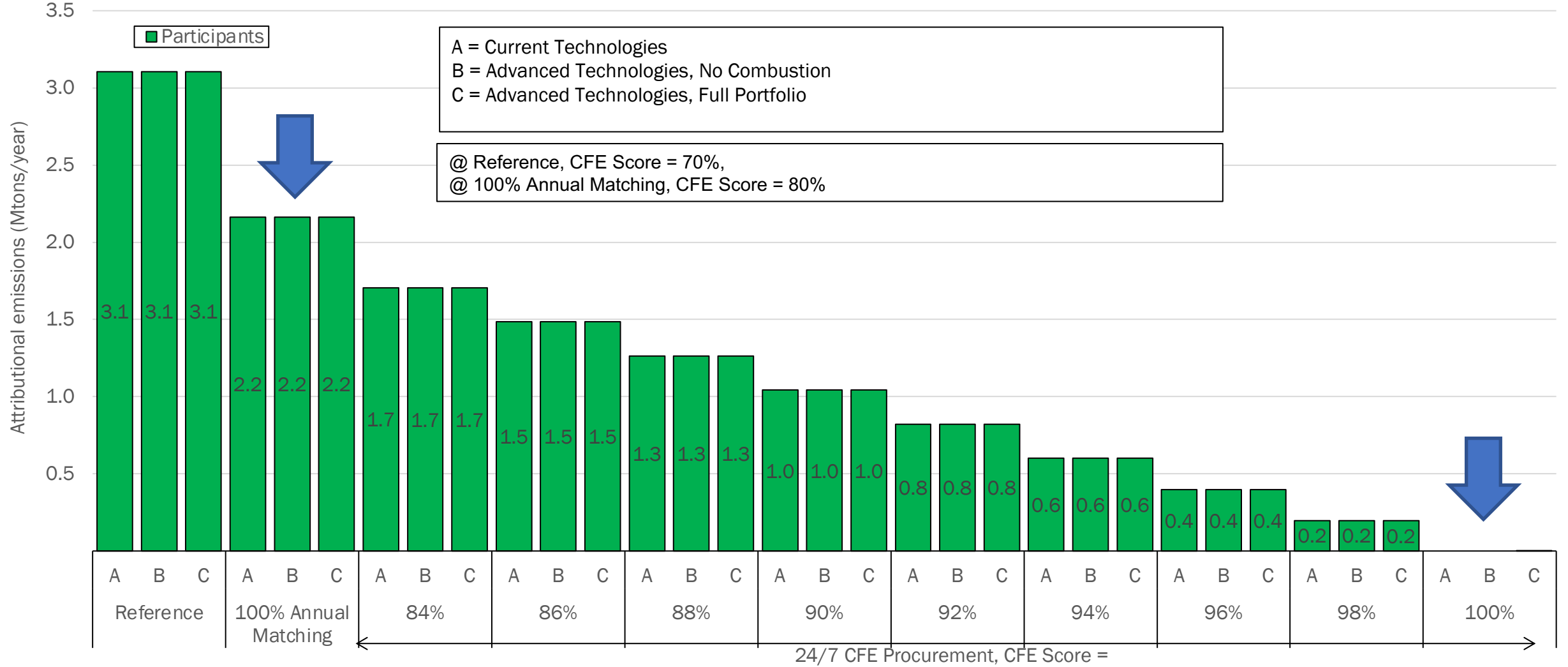
# Key Insights

1. 24/7 carbon-free procurement enables **deeper emissions reductions** than 100% annual matching.
2. 24/7 carbon-free procurement **drives early deployment of advanced technologies** including clean firm generation and long-duration energy storage.
3. 24/7 carbon-free procurement can carry **a significant cost premium** for early leaders (although procuring hourly supply for a *portion* of demand is an option).



# 24/7 CFE procurement can eliminate attributional emissions from a buyer's electricity consumption, going beyond the impact of 100% annual matching with renewable energy

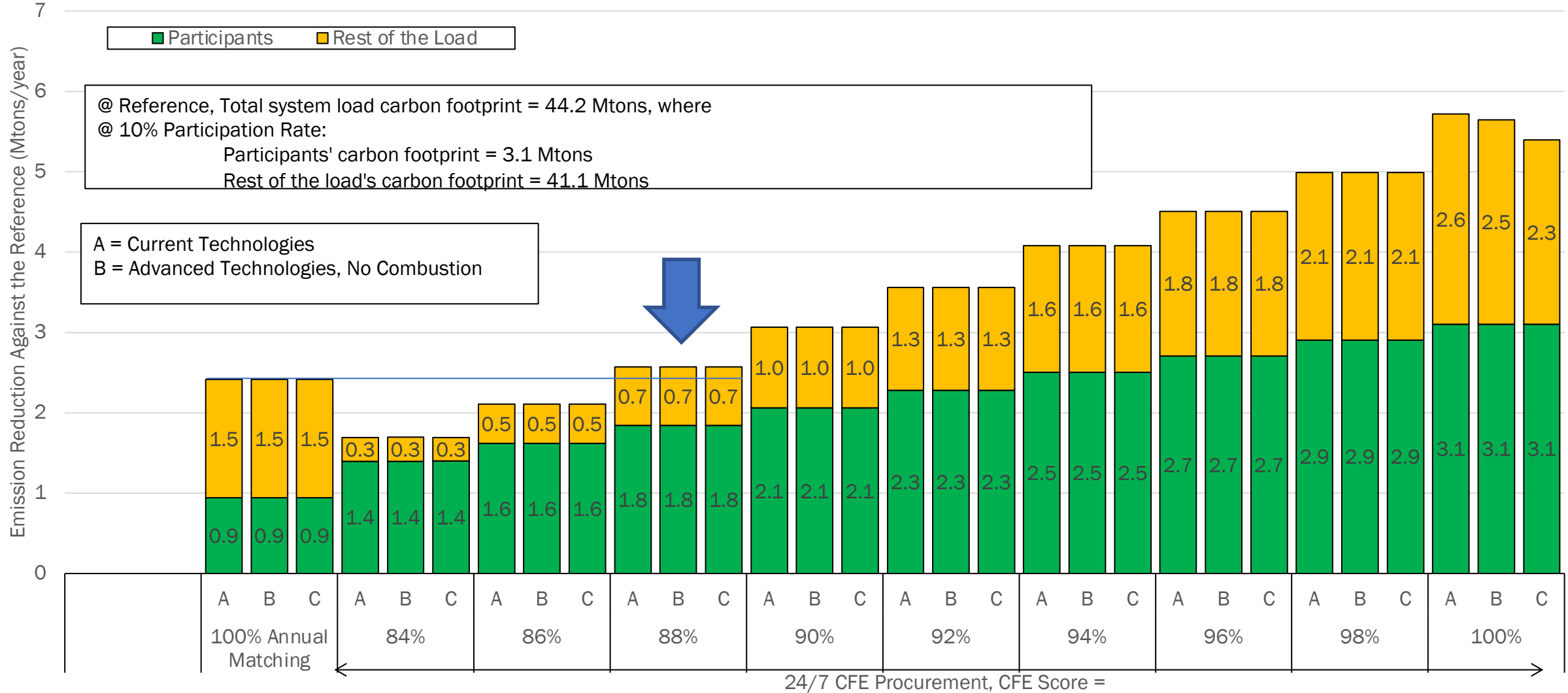
California Participants' attributional emissions, 10% C&I Participation





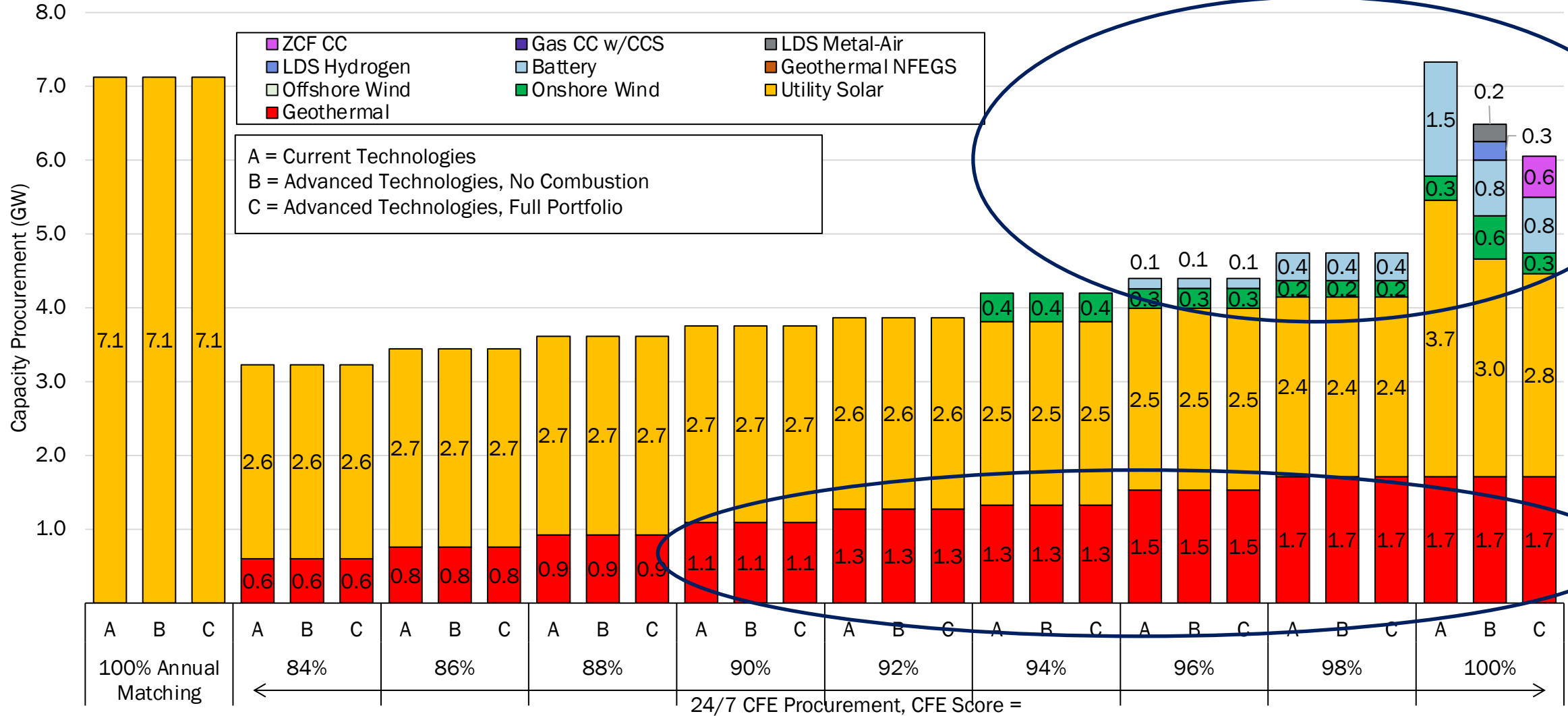
# 24/7 CFE procurement can drive greater system-level consequential emissions reductions than 100% annual matching if the CFE target is high enough

**California** system consequential emissions *reduction*, 10% C&I Participation

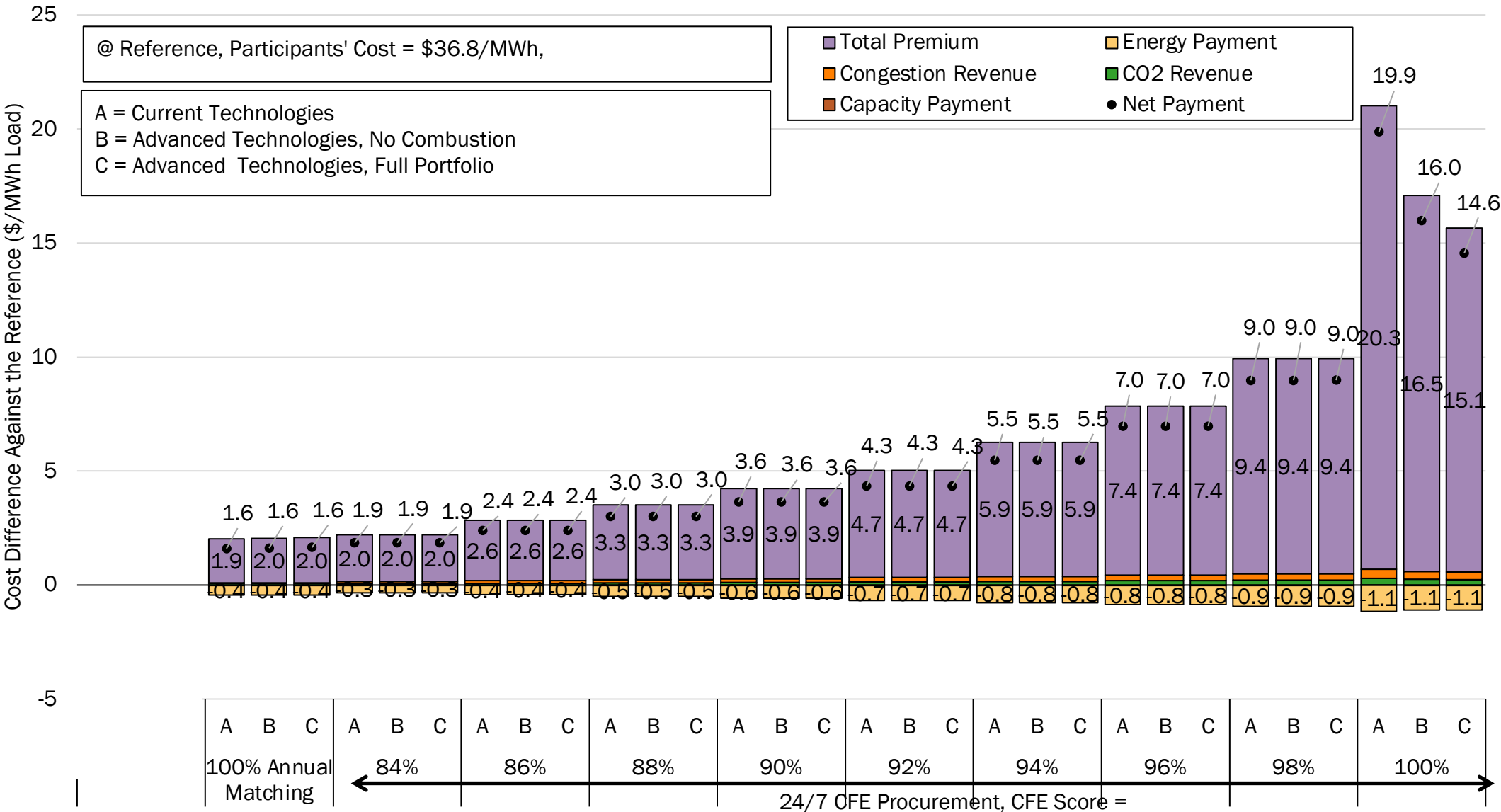


# 24/7 clean electricity procurement drives deployment of advanced, "clean firm" generation and/or long-duration energy storage

California Participants' capacity procured, 10% C&I Participation



# 24/7 CFE procurement comes at a more significant cost premium relative to 100% annual matching; reduced with full portfolio of clean firm resources and/or CFE <100%.

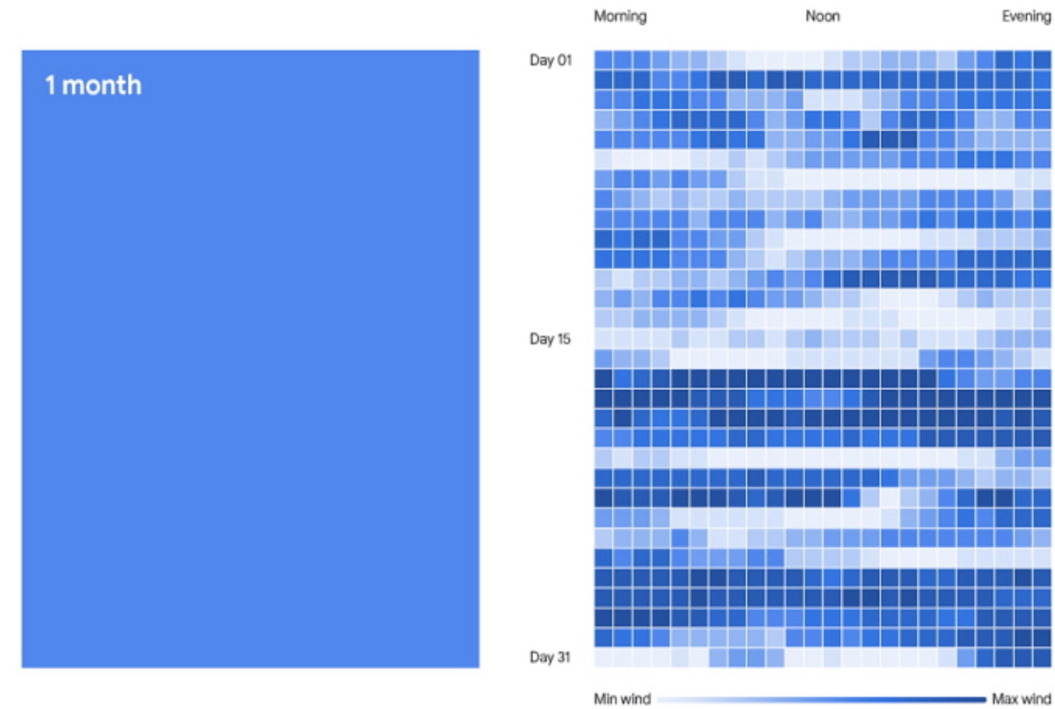


**Enabling vibrant markets for 24/7 carbon-free electricity procurement will depend on the implementation of time-based energy attribute certificates — T-EACs.**

RECs/GOs

T-EACs


 Google-contracted wind production in the Midwestern US



RECs vs. T-EACs associated with Google renewable energy purchasing. RECs indicate how much energy wind or solar farms produce in a month, but not precisely when it is generated. In contrast, each of the 744 hours in a 31-day month has its own T-EAC, with a corresponding amount of electricity produced.

Source: <https://cloud.google.com/blog/topics/sustainability/t-eacs-offer-new-approach-to-certifying-clean-energy>

# The value of having an organized T-EACs market

The image shows the cover of a report from ZERO LAB, Princeton University. The logo is at the top, followed by the title 'Electricity System and Market Impacts of Time-based Attribute Trading and 24/7 Carbon-free Electricity Procurement'. Below the title is the authors' names and the date 'September 15, 2022'. The background features a stylized power grid with glowing nodes and lines.

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**Electricity System and Market Impacts of  
Time-based Attribute Trading and  
24/7 Carbon-free Electricity Procurement**

By Qingyu Xu and Jesse D. Jenkins, Princeton University

September 15, 2022

- Improving the economic efficiency, affordability, and accessibility of 24/7 Carbon-free Energy (CFE) Procurement
- Generating hourly price signals to incentivize clean energy investment and operation when and where it is needed most
- Helping 24/7 CFE participants hedge against uncertainties like forecast errors



# T-EACs also a useful compliance mechanism

## Minimizing emissions from grid-based hydrogen production in the United States

Wilson Ricks<sup>1</sup>, Qingyu Xu<sup>1</sup> and Jesse D. Jenkins<sup>1</sup>

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**Abstract.** Low-carbon hydrogen could be an important component of a net-zero carbon economy, helping to mitigate emissions in a number of hard-to-abate sectors. The United States recently introduced an escalating production tax credit (PTC) to incentivize production of hydrogen meeting increasingly stringent embodied emissions thresholds. Hydrogen produced via electrolysis can qualify for the full subsidy under current federal accounting standards if the input electricity is generated by carbon-free resources, but may fail to do so if emitting resources are present in the generation mix. While use of behind-the-meter carbon-free electricity inputs can guarantee compliance with this standard, the PTC could also be structured to allow producers using grid-supplied electricity to qualify subject to certain clean energy procurement requirements. We use electricity system capacity expansion modeling to quantitatively assess the impact of grid-connected electrolysis on the evolution of the power sector in the western United States through 2030 under multiple possible implementations of the clean hydrogen PTC. We find that subsidized grid-connected hydrogen production has the potential to induce additional emissions at effective rates worse than those of conventional, fossil-based hydrogen production pathways, particularly in regions where coal is a large part of the generation mix. Emissions can be minimized by requiring grid-based hydrogen producers to match 100% of their electricity consumption on an hourly basis with physically deliverable, 'additional' clean generation, which ensures effective emissions rates equivalent to electrolysis exclusively supplied by

- T-EACs can be used for policy compliance to demonstrate low/zero carbon intensity (e.g., 45V hydrogen PTC).
- Can be used by states for augmented Clean Electricity Standard policies that phase-in hourly matching requirements to advance markets for clean firm and long-duration storage resources.


## Closing Opening Thoughts

- 24/7 carbon-free electricity (CFE) procurement can be the next step on the road to zero emissions can be for corporate, government, and institutional leaders and enable next-generation policy instruments.
- 24/7 procurement presents added challenges and raises electricity costs relative to 100% annual matching, but also enables a buyer to eliminate emissions associated with a buyer's electricity usage (and demonstrate zero attributional emissions for compliance purposes).
- Alternative procurement strategies optimized to maximize generation during periods of high grid carbon intensity rather than match demand may deliver greater *near-term* emissions reductions for a given budget (but may not have equivalent long-term tech-forcing impact).

## Closing Opening Thoughts

- The heart of the matter for 24/7 carbon-free procurement is the pursuit of transformative impact on electricity systems via accelerated innovation.
- 24/7 procurement drives early deployment of advanced clean firm generation and long-duration energy storage technologies, offering the potential to accelerate innovation, maturity, financeability, and widespread availability of these critical ingredients in the broader societal transition to a 100% carbon-free grid.
- Just as 100% annual matching helped transform wind and solar PV from expensive “alternative energy sources” to mainstream, affordable options for the world, 24/7 procurement can have similar transformative impacts on clean firm resources.





Leadership isn't just  
about doing one's part.  
It is about making it  
easier for others to follow.

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