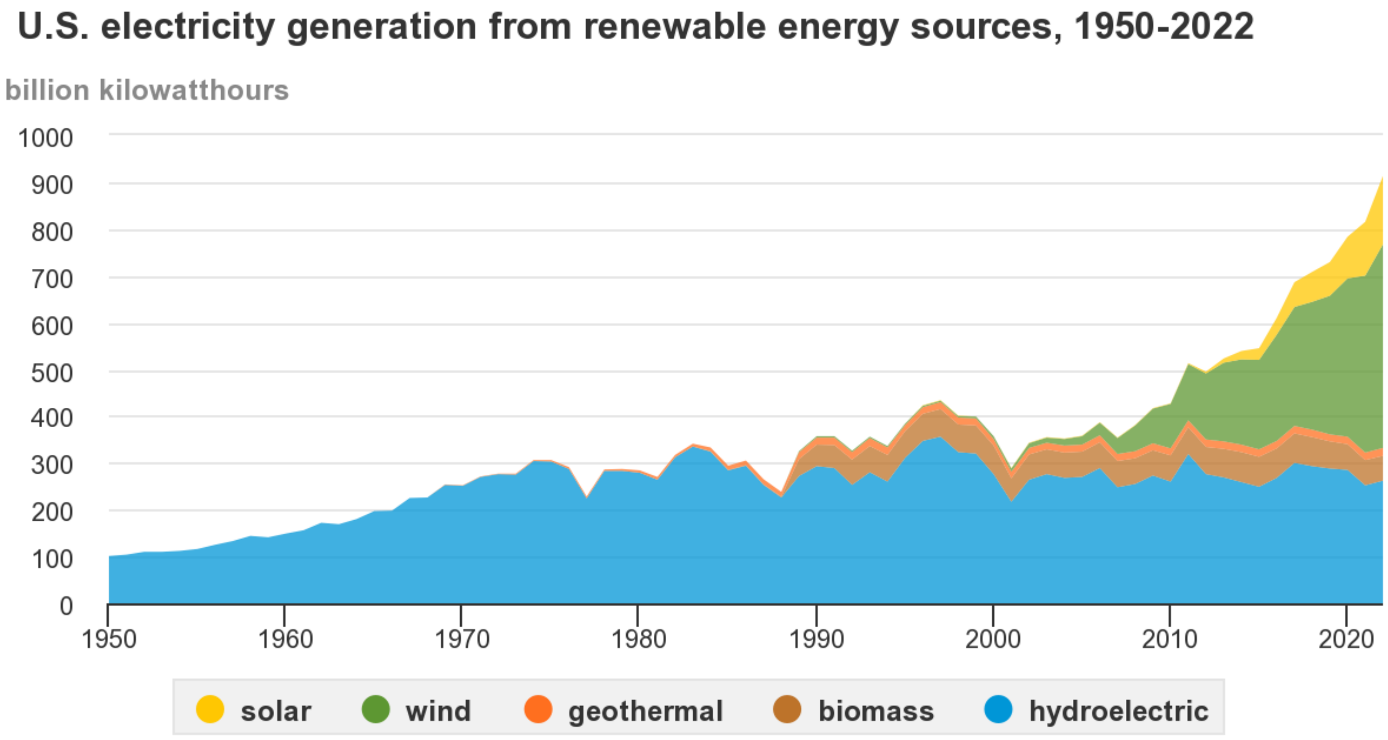
System-Level Impacts of Voluntary Carbon-Free Electricity Procurement Strategies

Wilson Ricks and Jesse D. Jenkins

Andlinger Center for Energy and the Environment | Princeton University

Energy Systems Integration Group | September 12, 2023

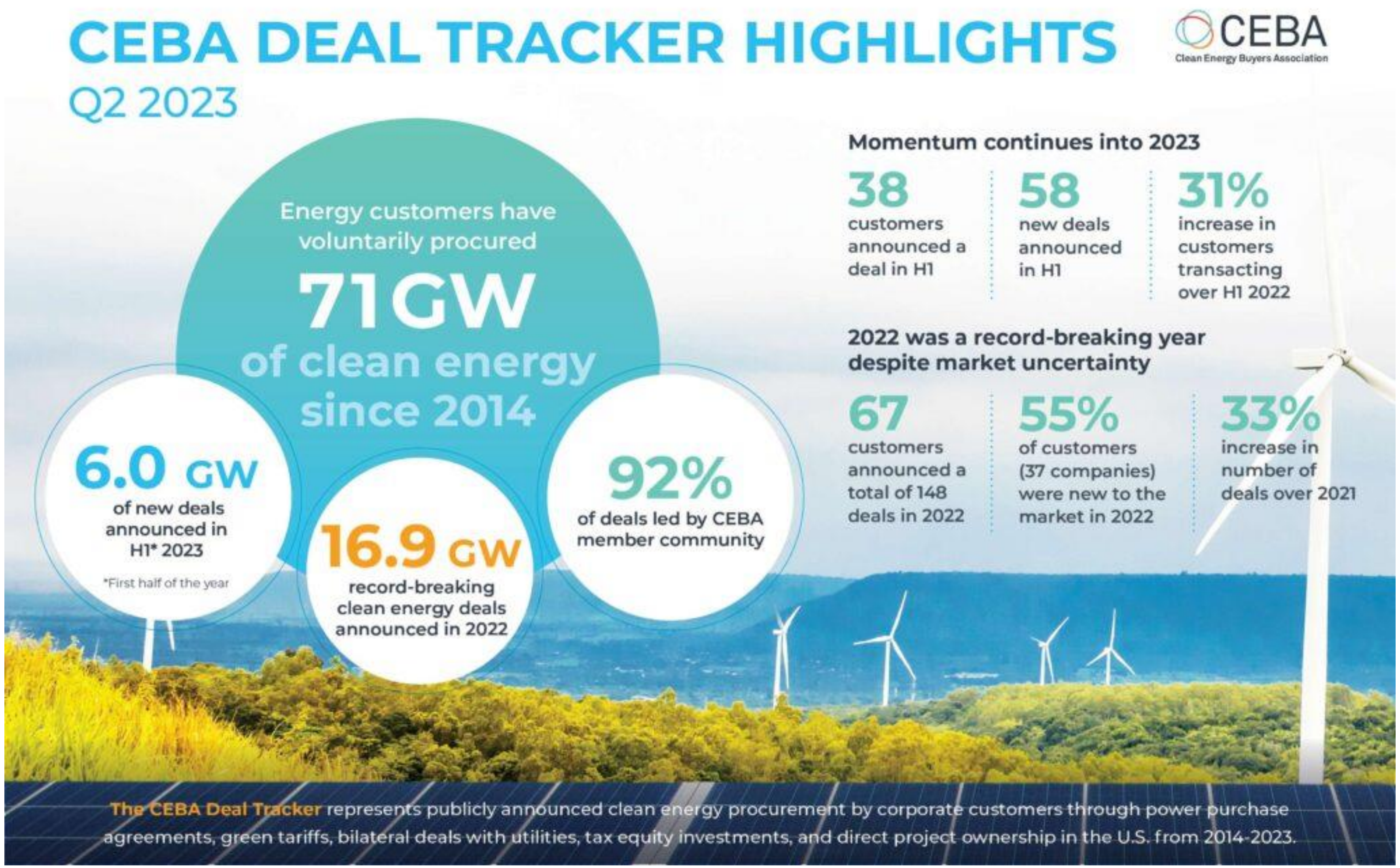
What Drives Clean Electricity Growth?



Data source: U.S. Energy Information Administration, *Monthly Energy Review* and *Electric Power Monthly*, February 2023, preliminary data for 2022
Note: Includes generation from power plants with at least 1 megawatt electric generation capacity. Hydroelectric is conventional hydropower.

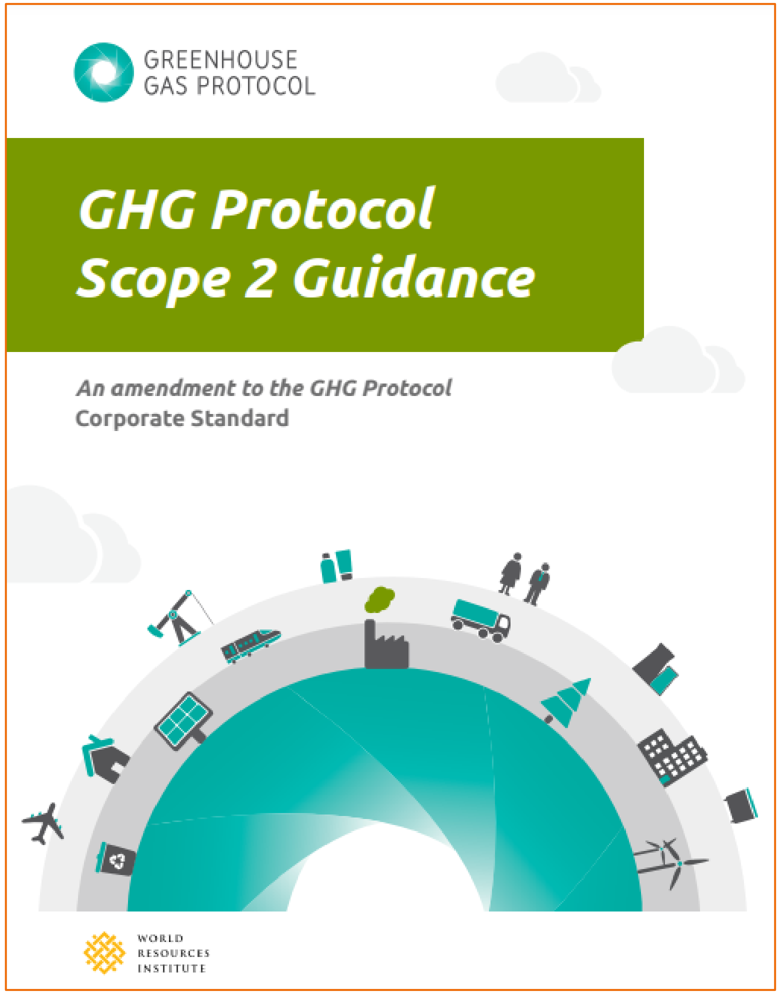
Voluntary Clean Energy Procurements

- Are made by corporations, institutions, or individuals with the aim of accelerating decarbonization
- Account for ~1/3 of U.S. wind and solar capacity additions to date
- Are an integral part of corporate emissions accounting
  - 'Scope 2' emissions include those from electricity consumption



What does it mean when a company claims to use clean electricity?

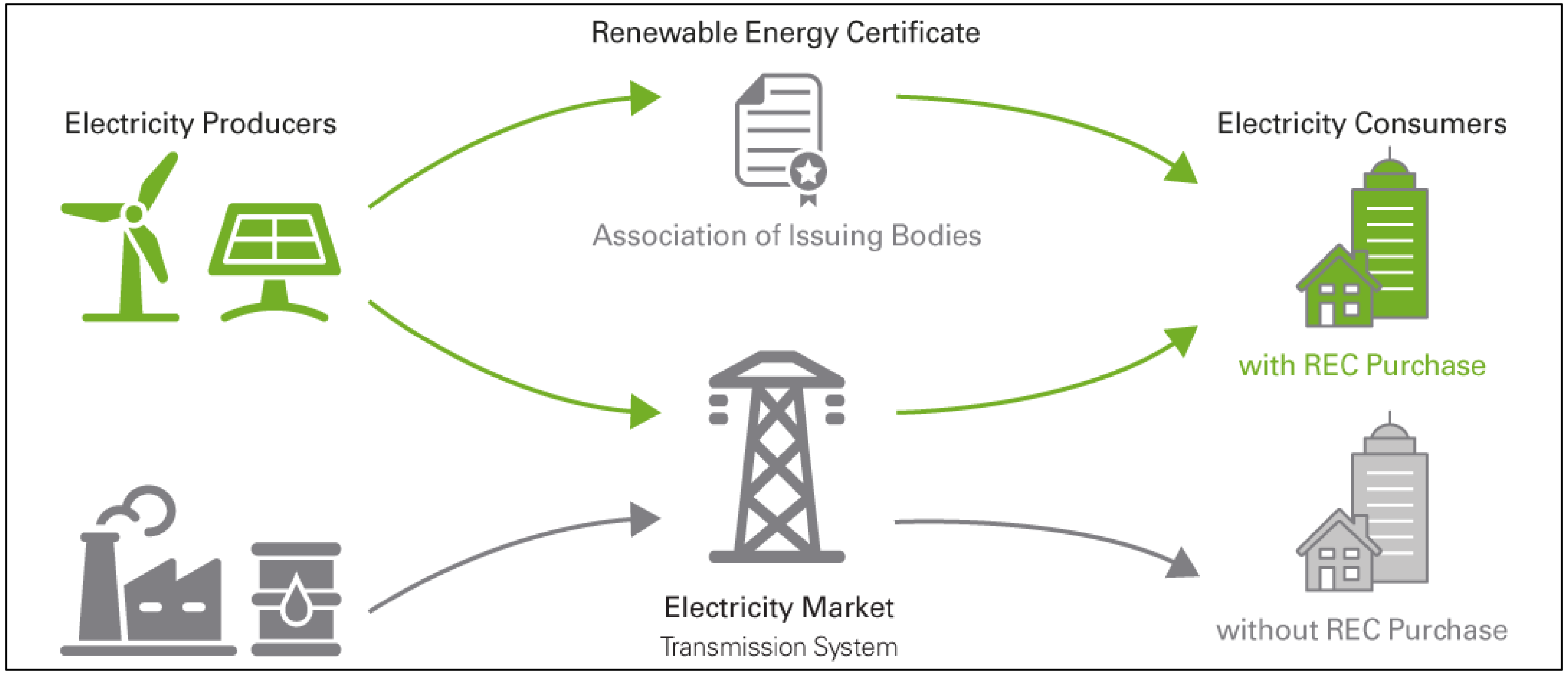
- Typically involves transfer of 'energy attribute certificates' representing clean megawatt-hours
- EACs can be acquired 'unbundled' or coupled to physical electricity purchases
- Corporate emissions accounting systems (e.g., the GHG Protocol) allow EAC purchases to reduce an institution's reported emissions from electricity consumption



How can these systems be designed?

Voluntary Procurement Accounting Systems: Volumetric Matching

- The 'conventional' method, currently used by the U.S. EPA and GHG Protocol
- Participants can claim 1 MWh of carbon-free electricity use for every qualifying EAC they purchase in a certain year
- Claiming 100% carbon-free electricity use in a given year means purchasing enough EACs to match total electricity consumption in that year



Credit: Lazard

Criticisms of Volumetric Matching

- **Coarse temporal accounting** leads to a poor assessment of emissions impacts
- Lack of **EAC scarcity** means a failure to drive additional clean energy deployment
- Decoupled from a consumer's physical electricity use and reliability needs

Criticisms have lead to alternative proposals…

Joule CellPress

COMMENTARY

Why 100% Renewable Energy Is Not Enough

Jacques A. de Chalendar[1,*] and Sally M. Benson[1]

tute for Energy, and Director of the Global Climate and Energy Project at Stanford University. Formerly, Benson was at Lawrence Berkeley National Laboratory, where she held a variety of key positions, including Deputy

energy" do not guarantee commensurate emissions reductions.

Carbon accounting is challenging. Determining the impact on the environment from generating energy at a given

nature climate change

ARTICLES

https://doi.org/10.1038/s41558-022-01379-5

Check for updates

Renewable energy certificates threaten the integrity of corporate science-based targets

Anders Bjørn[1,2,3], Shannon M. Lloyd[1,3], Matthew Brander[4] and H. Damon Matthews[2,3]

The Washington Post

Democracy Dies in Darkness

CLIMATE Environment Weather Climate Solutions Climate Lab Green Living Business of Climate

Buying renewable energy doesn't mean what you think

The popular method of buying renewable 'credits' for emissions inflates green power claims

By Shannon Osaka and Hailey Haymond

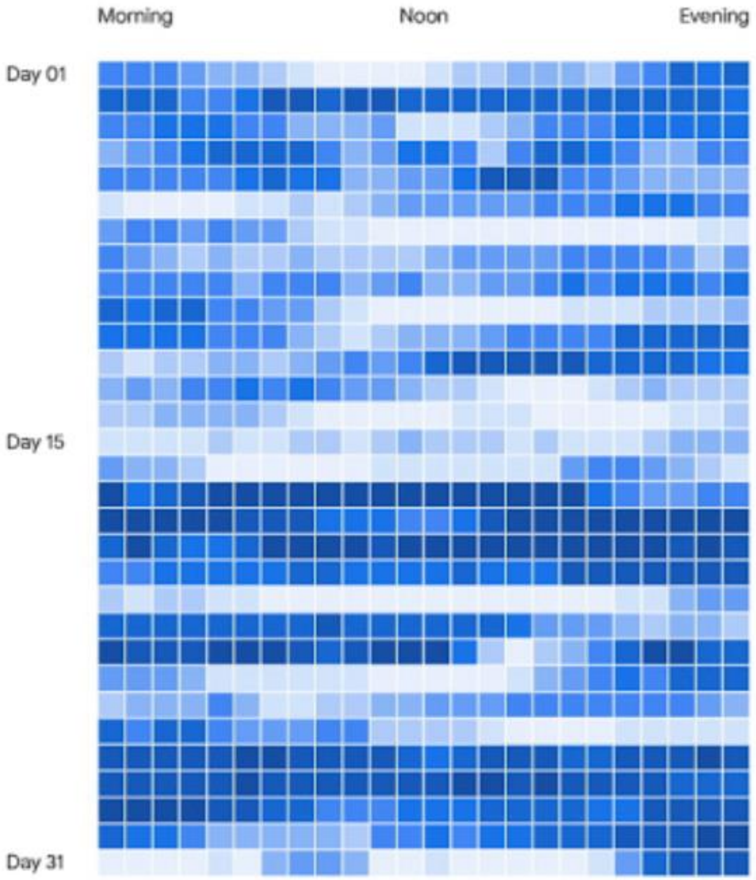
June 21, 2023 at 6:30 a.m. EDT

Alternative Systems: Temporal Matching

- Participants can purchase EACs to claim carbon-free electricity use in the same hour in which the EAC was generated

- Claiming 100% carbon-free electricity use in a given year means purchasing enough EACs to match or exceed your electricity consumption in every hour of the year

- Claimed Advantages:
  - Hourly requirement increases EAC scarcity
  - Encourages deployment of advanced technologies



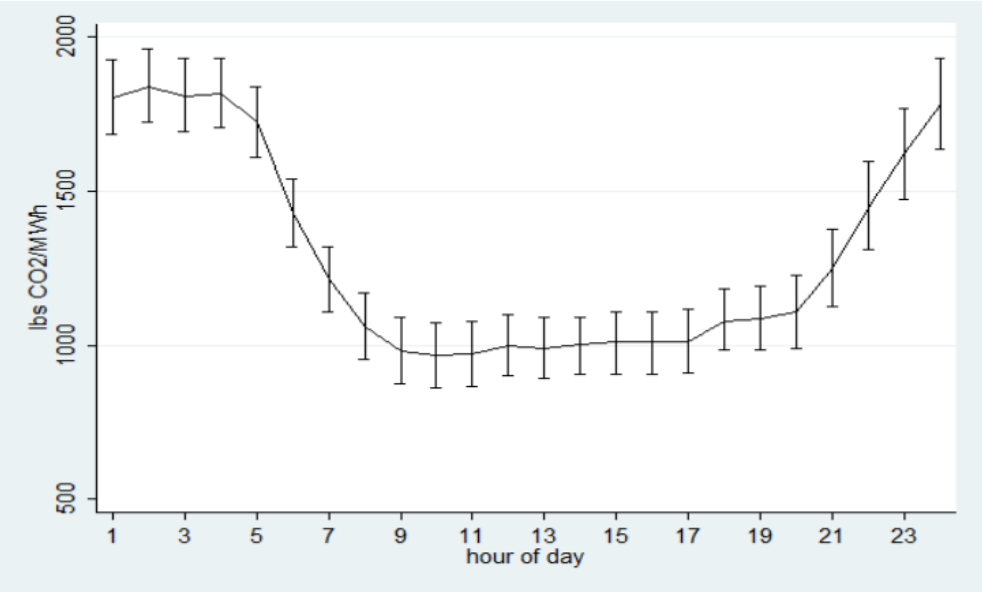
All hours assessed individually

Credit: Google

Alternative Systems: Emissions Matching

- Measures **emissions impacts of consumption and production** based on local hourly **short-run marginal emissions rates** (SRMER, the calculated change in grid emissions resulting from an instantaneous change in electricity demand *assuming no change in generating capacity*)
- **Aims for net-zero measured emissions impact over a year**
- **Claimed Advantages:**
  - Accurately reflects emissions impacts of procurements
  - Encourages most cost-effective abatement actions

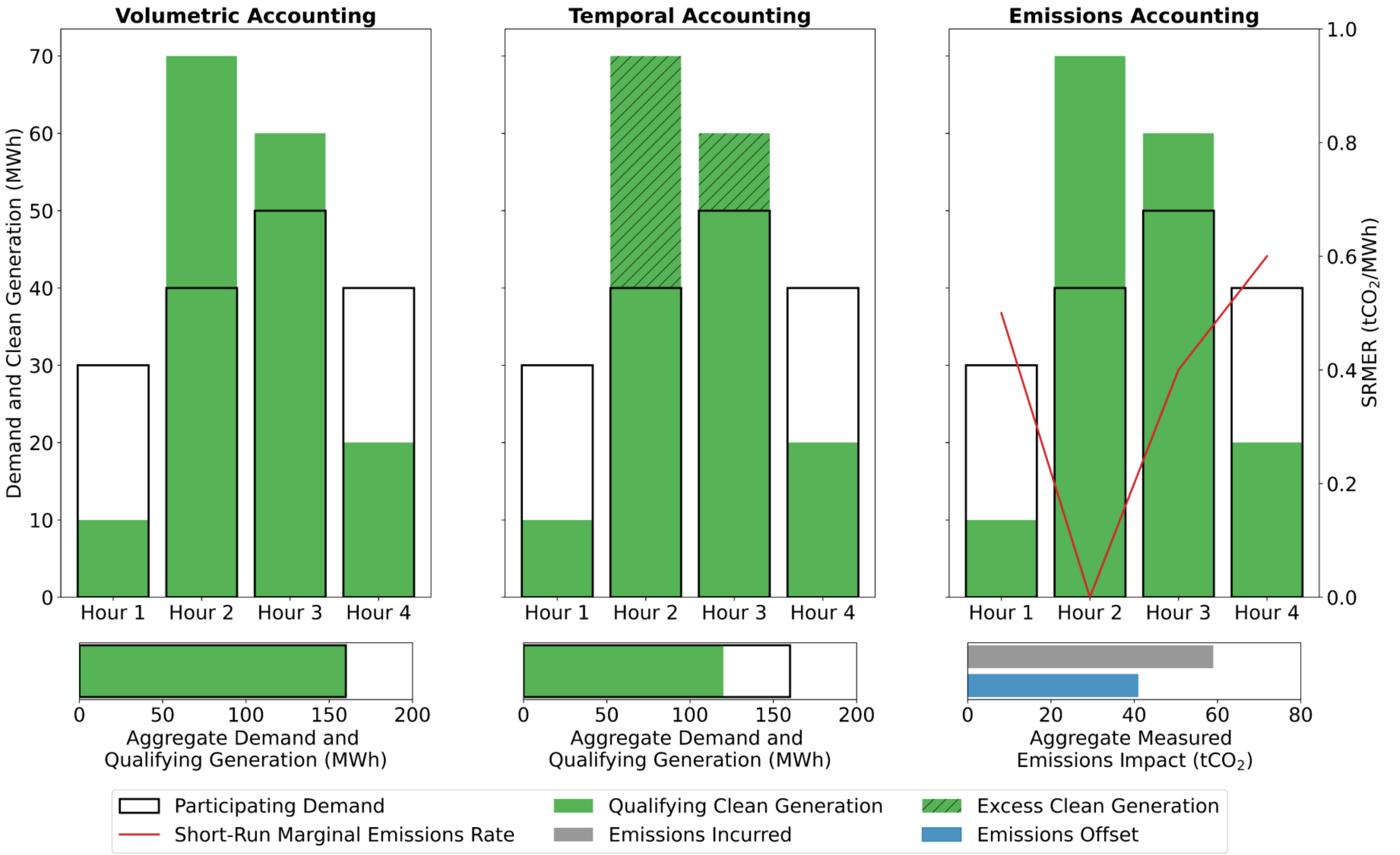
Figure 1: Seasonal marginal operating emissions rate profile (NYISO)



Callaway et al. 2017

Comparing the Three Strategies

- Each proposed system has a different definition of success
- Different metrics incentivize different actions



The Big Question

If a company takes steps to achieve 100% carbon free electricity use as defined under one of these proposed matching strategies…

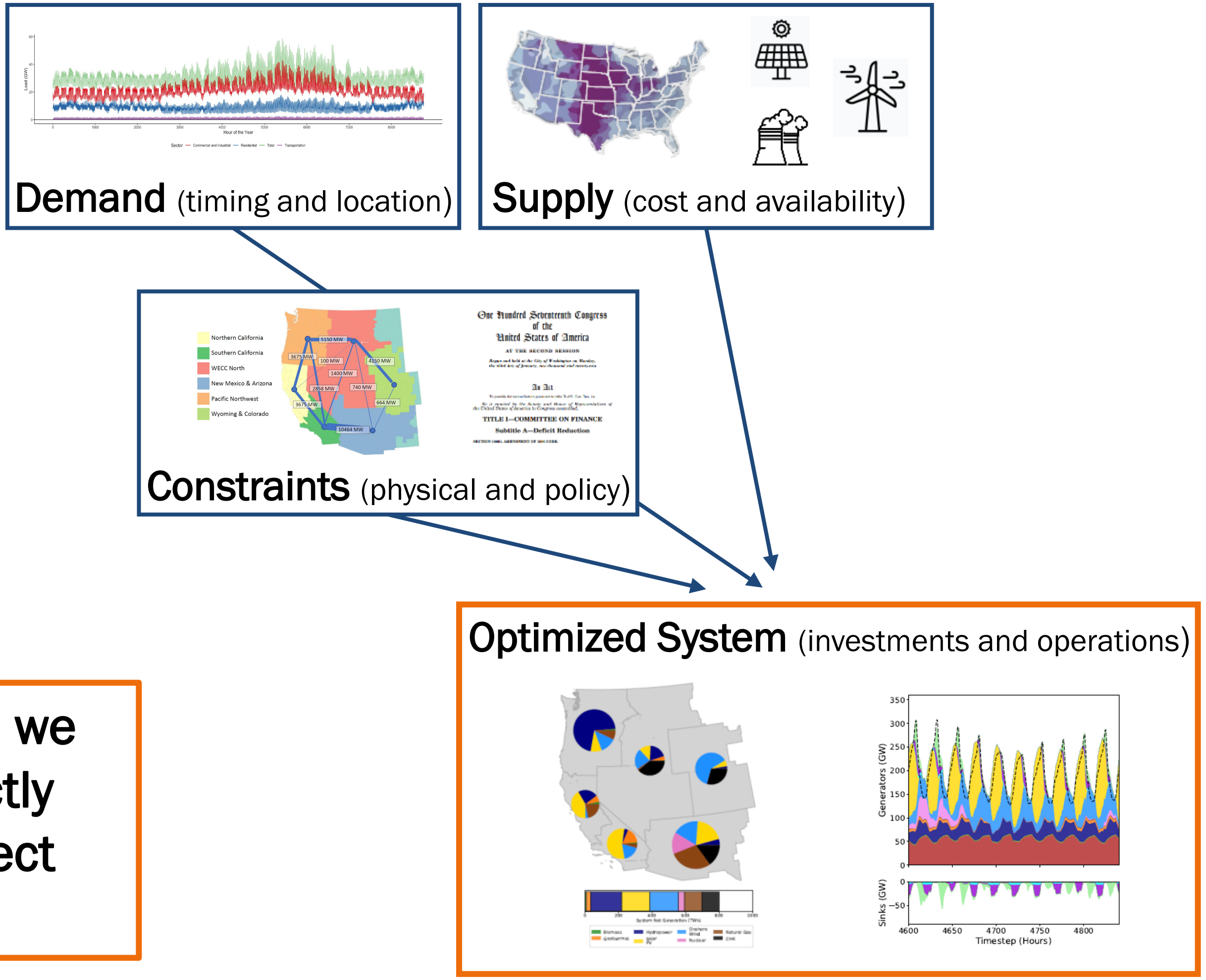
…how do its actions affect greenhouse gas emissions at the level of the entire electricity system?

Our Research

Our Approach

Capacity expansion modeling:

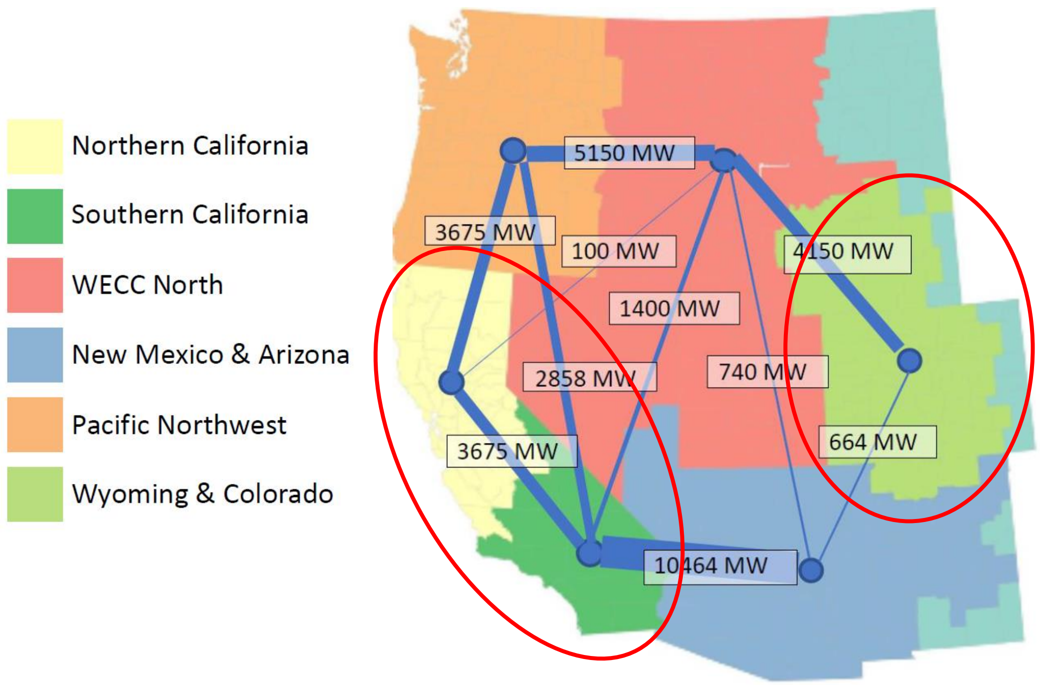
- Given assumptions of current and future conditions, optimizes the configuration *and* operations of the entire electricity system to meet electricity demand in a given period at least cost
- Simulates outcomes under a fully competitive electricity market or an optimal centrally-planned system



Because we model the entire electricity system, we can compare counterfactual scenarios to directly observe how individual voluntary decisions affect overall outcomes.

The Present Study

- Uses GenX, an open-source capacity expansion planning tool with high temporal resolution
- Explores system-level impacts of multiple voluntary carbon-free electricity procurement strategies
- Experimental setup:
  - 6-zone representation of the U.S. Western Interconnection
  - 2030 planning year (2021 base)
  - Latest federal and state policies
  - Multiple technology availability scenarios
  - Voluntary clean energy purchases made by commercial and industrial (C&I) customers in California and the Mountain West

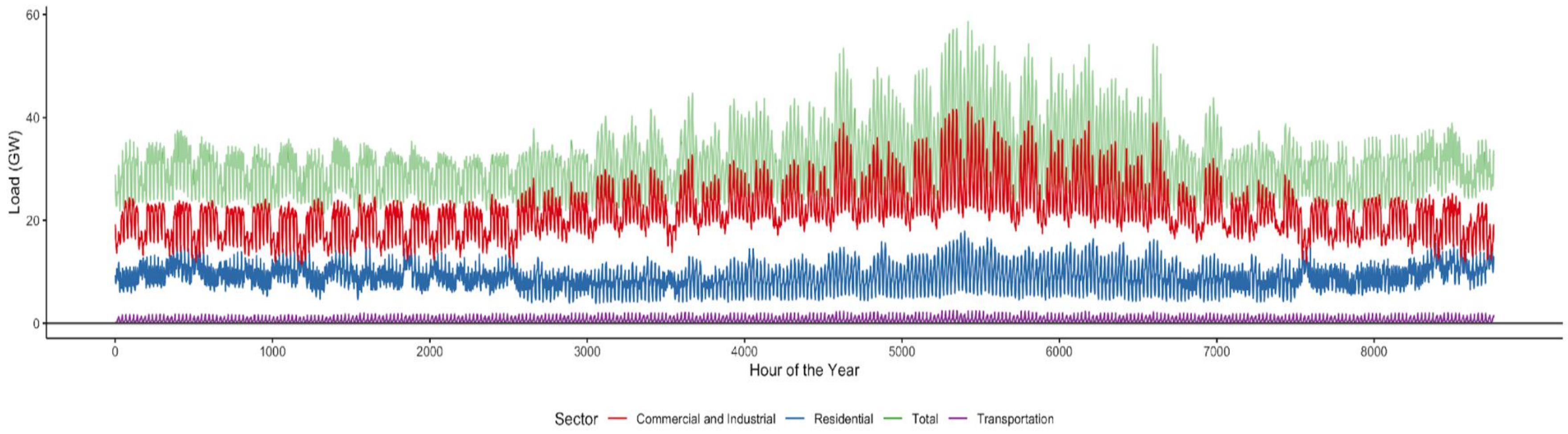


Six-zone model of the U.S. Western Interconnection, with target zones circled

Modeling Voluntary Procurement

- Assume a certain % of C&I customers in the target region jointly pursue voluntary carbon-free electricity procurement under one of three strategies: volumetric, temporal, or emissions matching

- Must procure clean attributes from new-build carbon-free resources located in the same model region as the participating demand



California 2030 electricity demand, broken down by category. C&I demand in red.

Modeling Voluntary Procurement

- A **new-build requirement** maximizes the chance that a given matching strategy reduces emissions
  - Procurement of existing resources does not reduce emissions *unless* the resources in question are at risk of early retirement, *or* there is more demand for EACs from existing resources than there is supply
- A **regionality requirement** enables simplified comparison of matching approaches while maintaining conditions compatible with each
  - Avoids the impact of major transmission bottlenecks between supply and demand
  - Note that the model's assumption of no in-region congestion is an oversimplification of reality

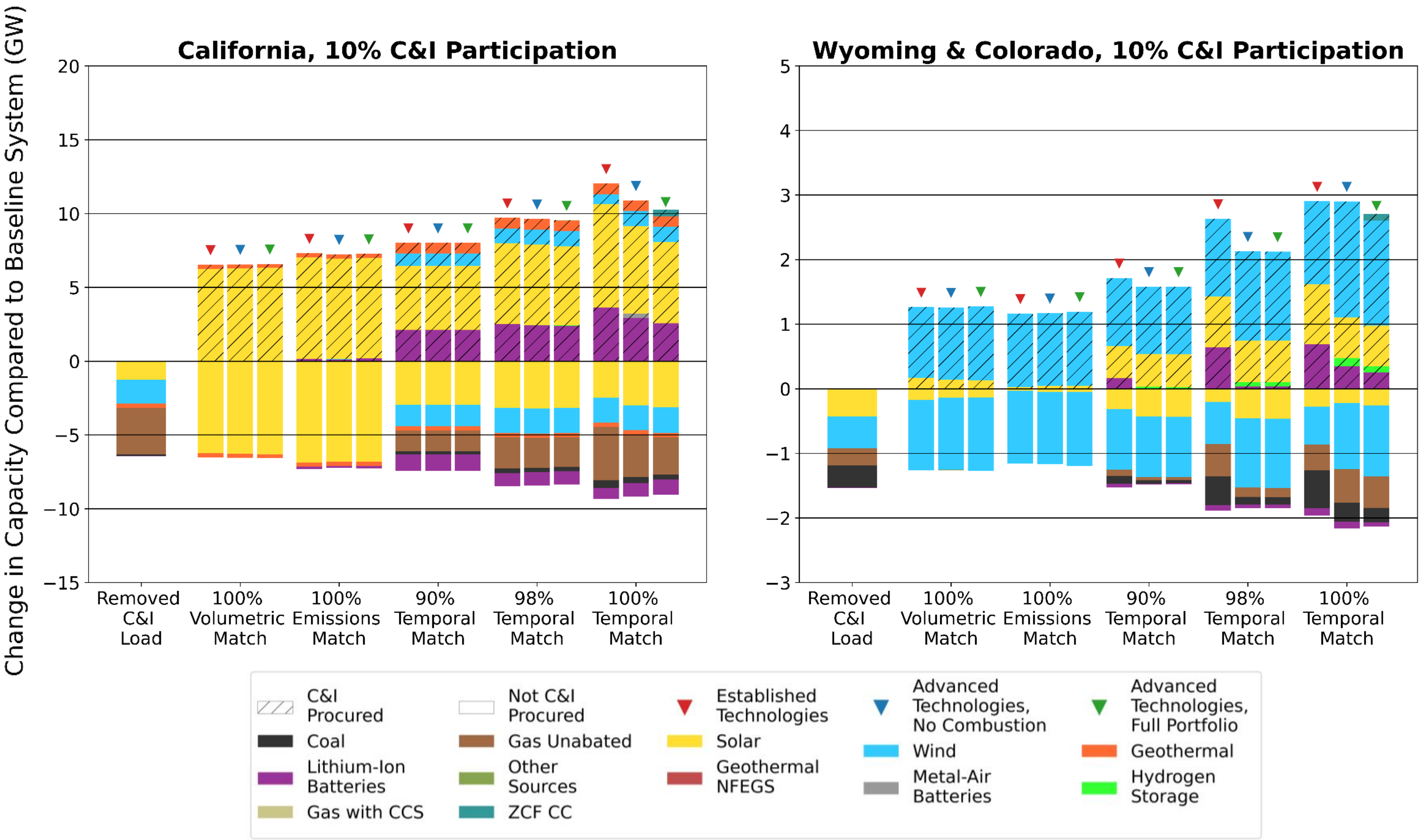
1. Focus on system-level outcomes, e.g. total CO_2 emissions from the Western Interconnection
2. Use counterfactual scenarios to isolate the consequential impacts of a participant's actions

$$\textit{consequential emissions impact} = \Big((\textit{system emissions without voluntary procurement}) - (\textit{system emissions with voluntary procurement})\Big) \div (\textit{participating demand})$$

Results

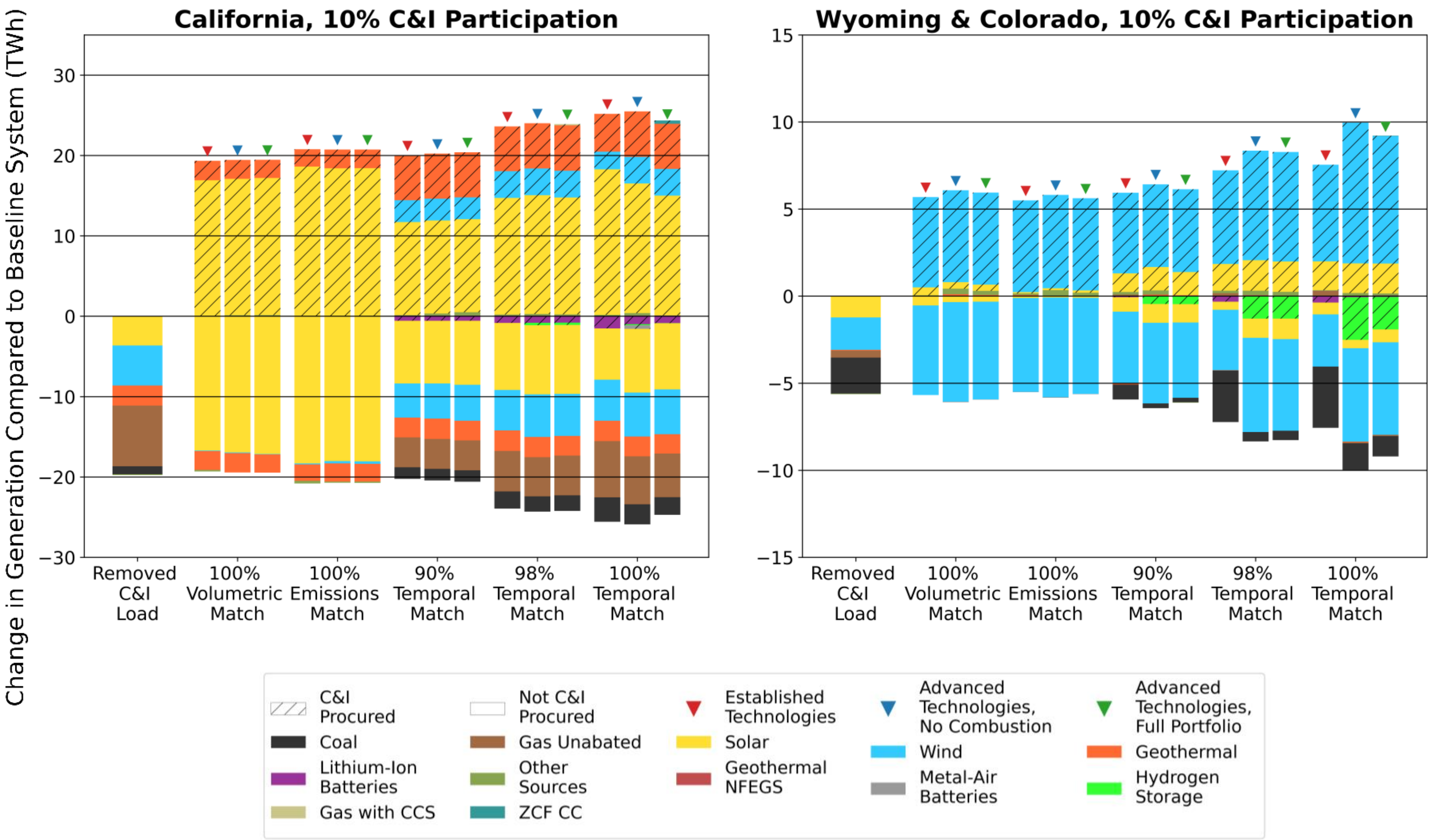
Cost-Optimal Portfolios

- Volumetric and emissions matching **incentivize procurement of cheapest renewable option**
- Temporal matching incentivizes a mix of resources, **including clean firm and LDES**



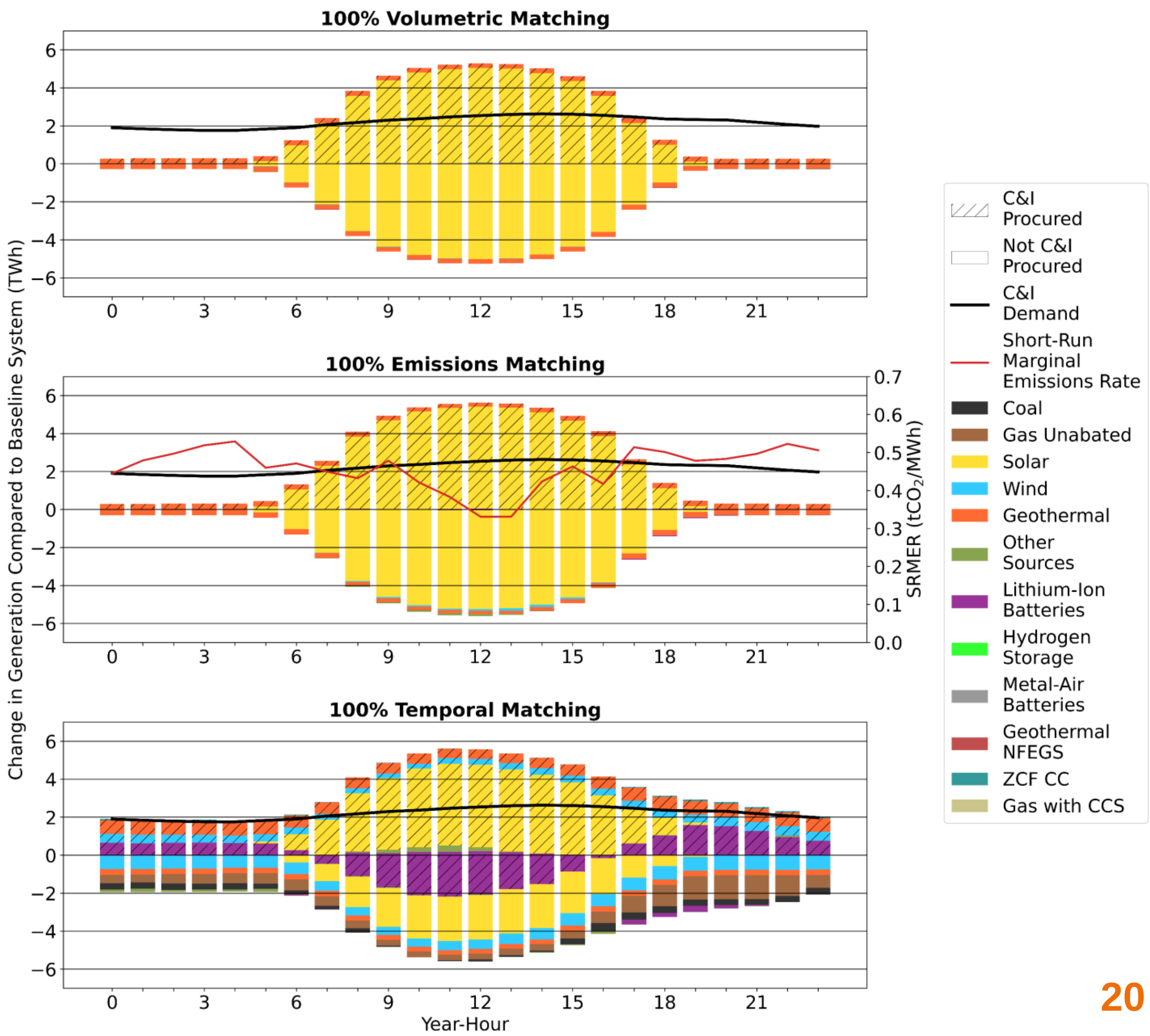
Impacts on the Energy Mix

- Energy procured under volumetric and emissions matching **displaces an equivalent amount of clean energy from third-party developers**
- Procurements made under temporal matching **displace a mix of clean and fossil**



Explaining the Outcomes

- Under volumetric matching, participants' procurements *directly compete with other commercial renewables*
- Under emissions matching the buyer assumes its solar is offsetting marginal fossil generation, *but it is actually 'offsetting' competing solar projects that would otherwise have been built*
- Under temporal matching, new clean supply must be brought online *even in hours when fossil generation would be economically preferable,* leading to fossil displacement



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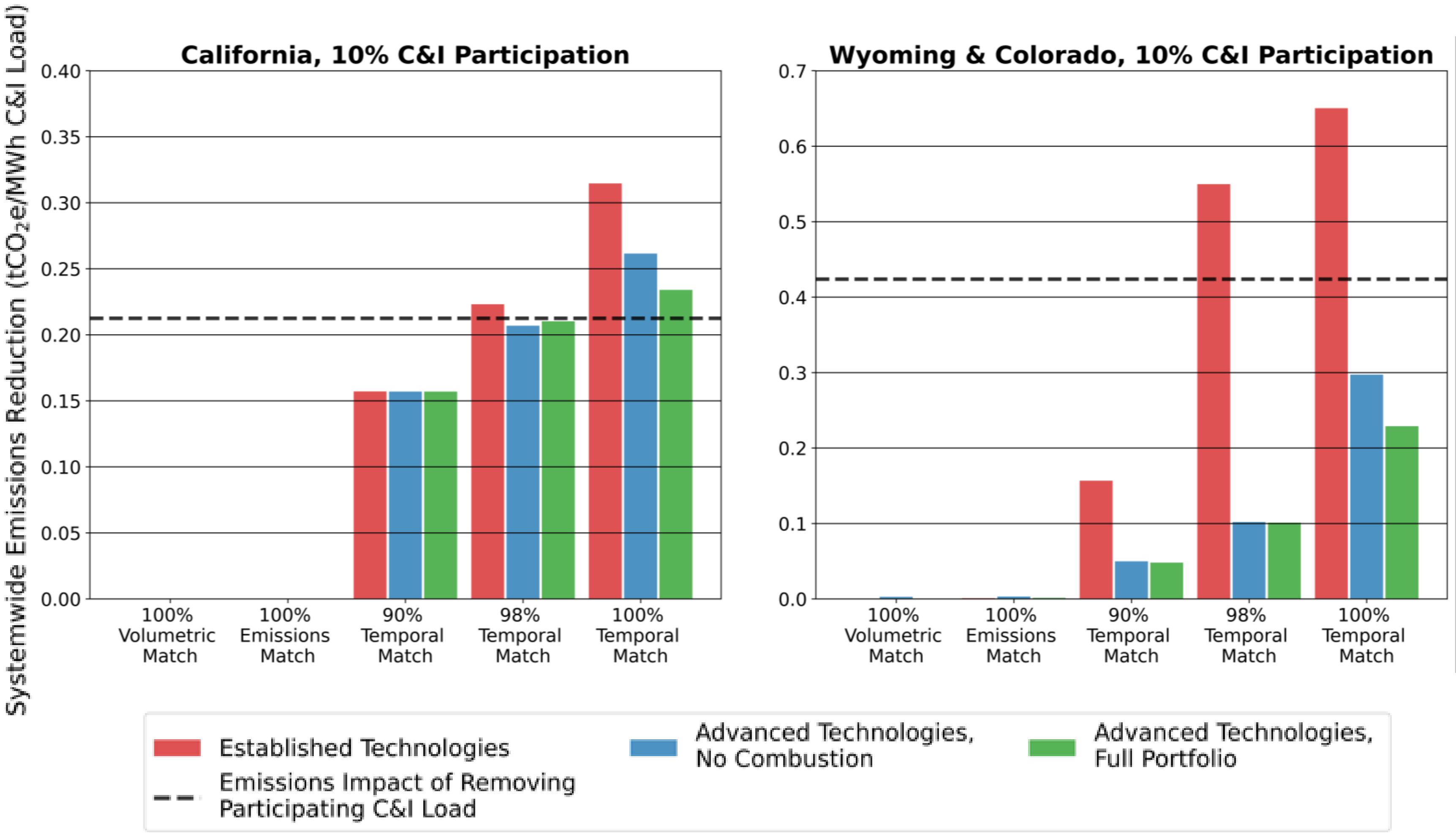
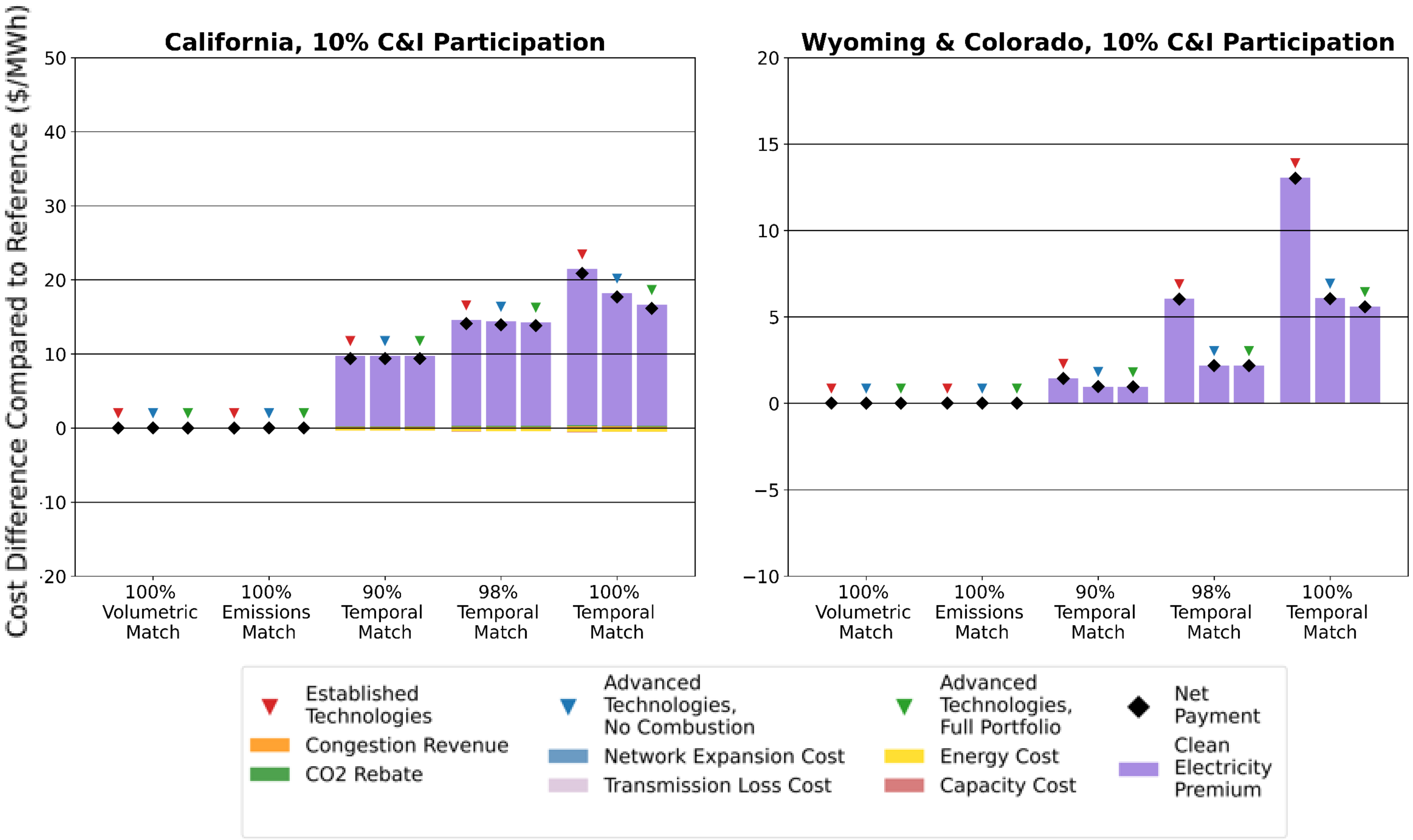
Emissions Impacts

- No emissions reductions for volumetric or emissions matching at 10% participation
  - Small reductions in CA at 25% participation and above
- Increasing reductions for increasing temporal matching, typically (but not always) exceeding benchmarks



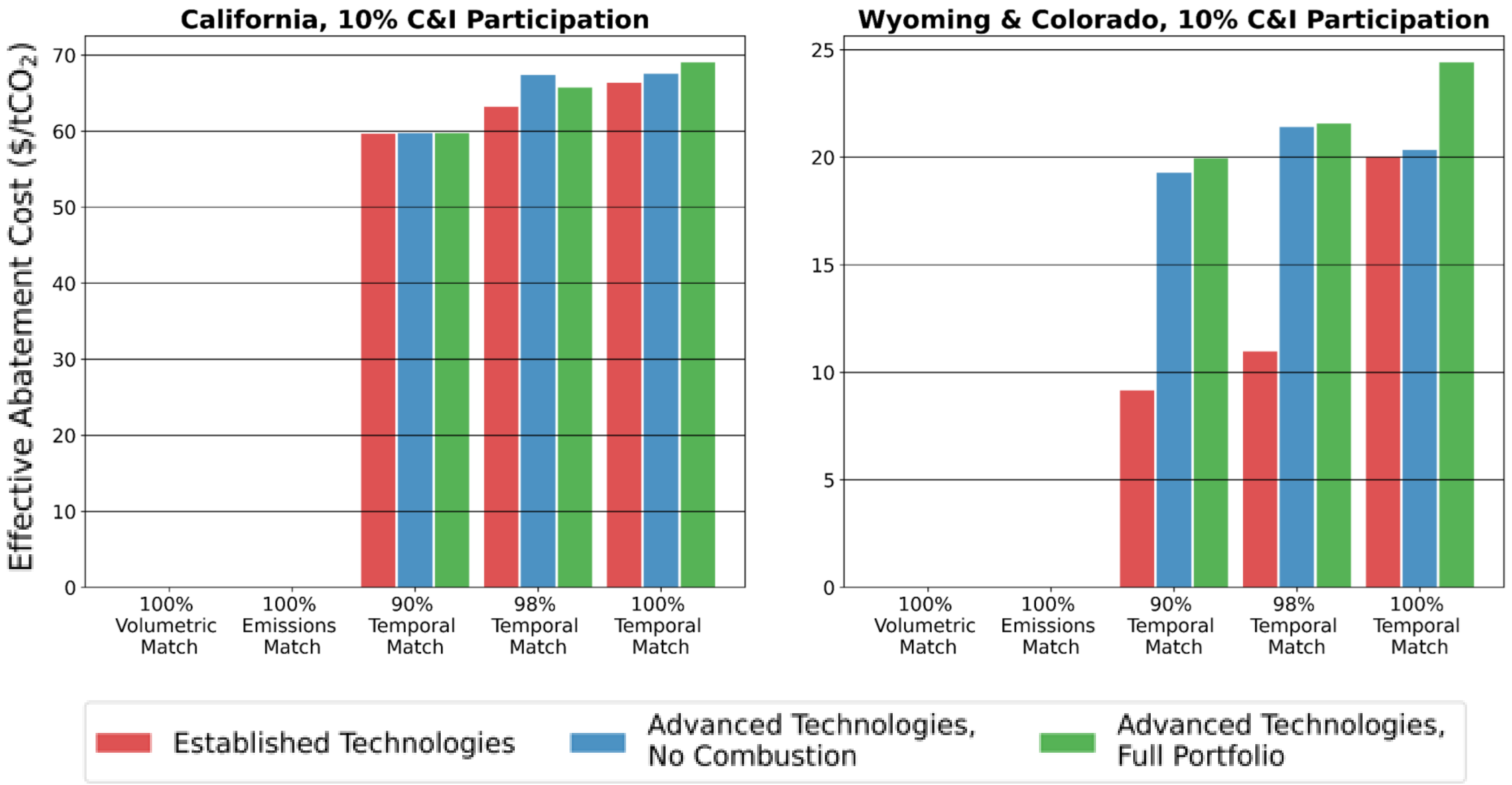
Cost to Participants

- Volumetric and emissions matching **have low or zero added cost**
- Temporal matching **can have cost premiums greater than $20/MWh**
  - Premiums are reduced when advanced technologies are available



Effective Abatement Cost

- Effective cost per ton CO_2 abated by temporal matching is $60-70/ton in California and less than $25/ton in Wyoming & Colorado

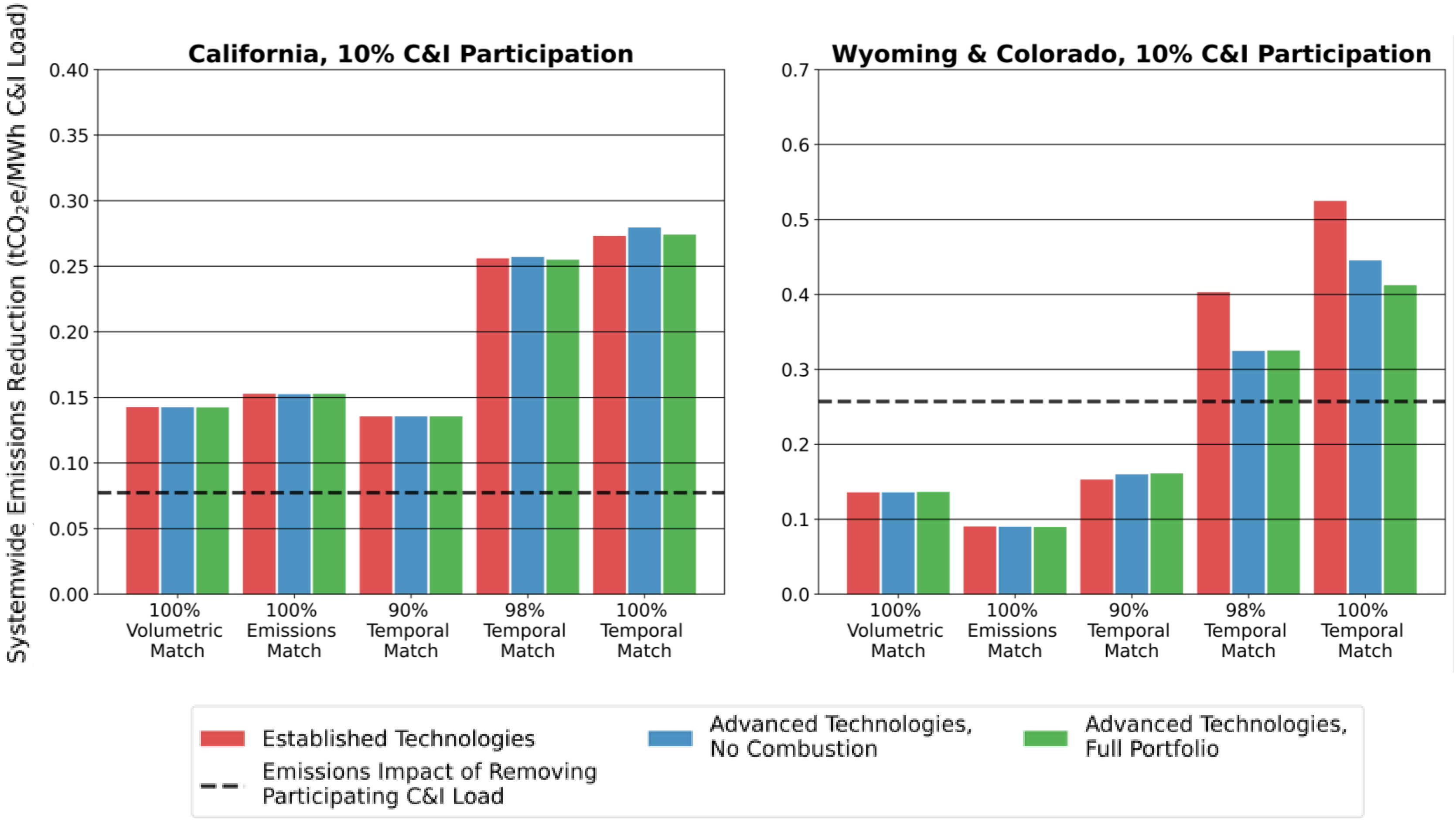


Impact of Policy

- Failure to drive emissions reductions is traceable to a lack of additionality
- Voluntary carbon-free energy buyers are incentivized to target resources that would have been built anyway
- The recently-passed Inflation Reduction Act dramatically increases the supply of EACs without increasing demand
- Modeled additional cases with a hypothetical federal 80% clean electricity standard, which makes EAC demand the primary driver of supply

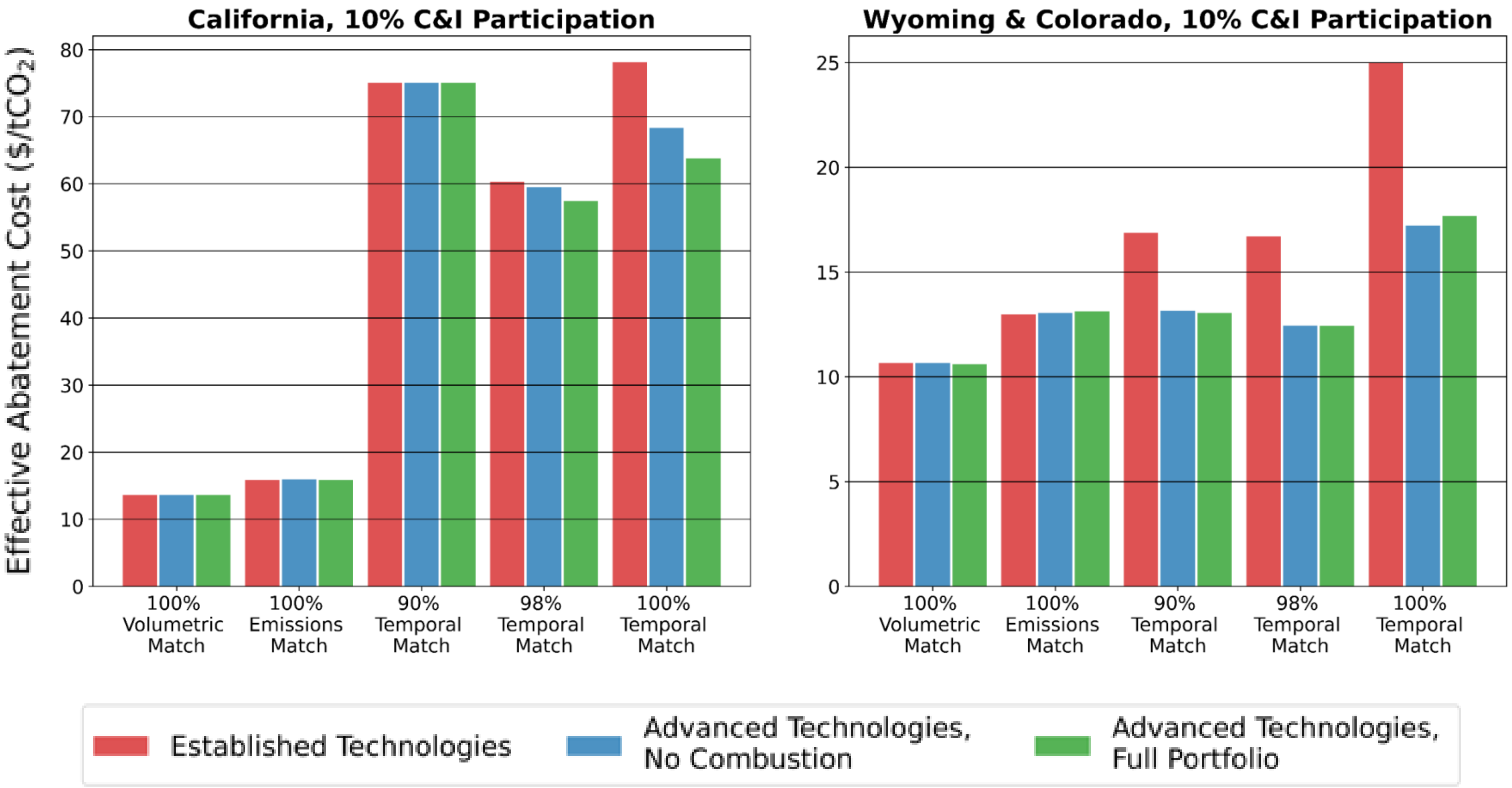
Outcomes with an 80% CES

- Optimal portfolios are nearly identical to the non-CES case, but…
- All matching strategies consistently reduce emissions
- Reductions are still greater (roughly double) under temporal matching



Outcomes with an 80% CES: Effective Abatement Cost

- With a system-level CES, volumetric matching is the most cost-effective means of emissions abatement



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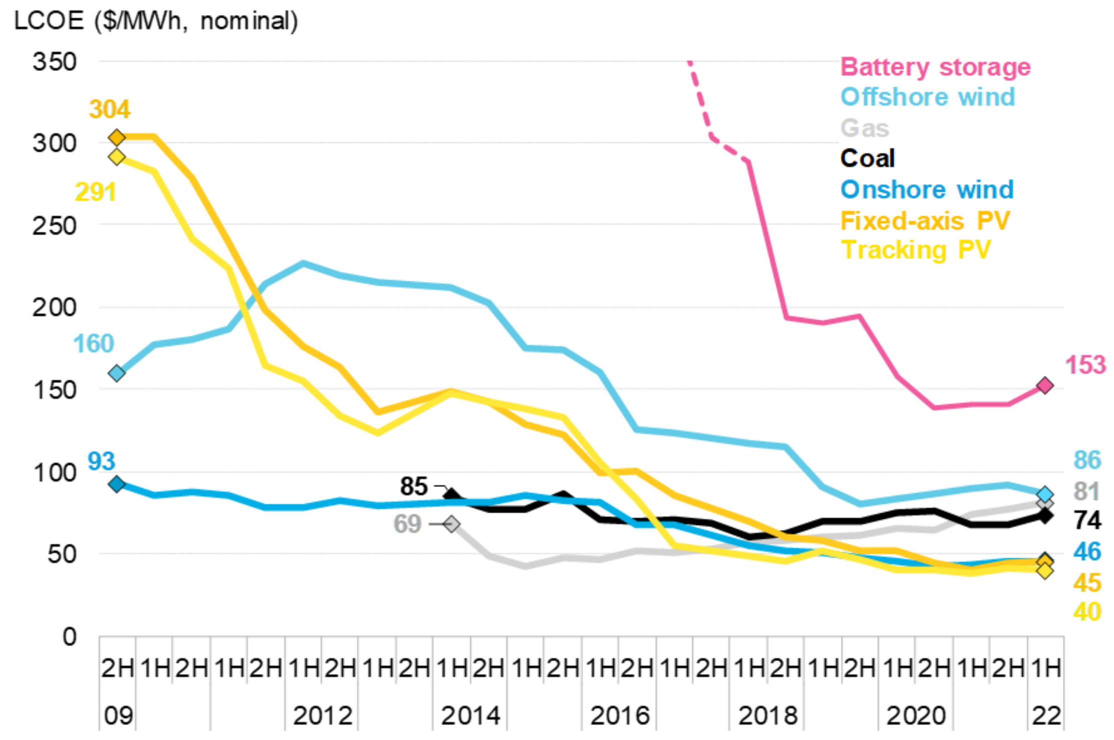
Implications

Implications: Volumetric Matching

- **Volumetric matching** can drive **truly additional clean generation** only when (price-inelastic) **EAC demand exceeds supply**
- This was **true in the past** when renewables were too expensive to see market uptake, but is **unlikely in the U.S. going forward**
- Even if the generation is additional, volumetric matching is **not guaranteed to eliminate** a consumer's emissions impact

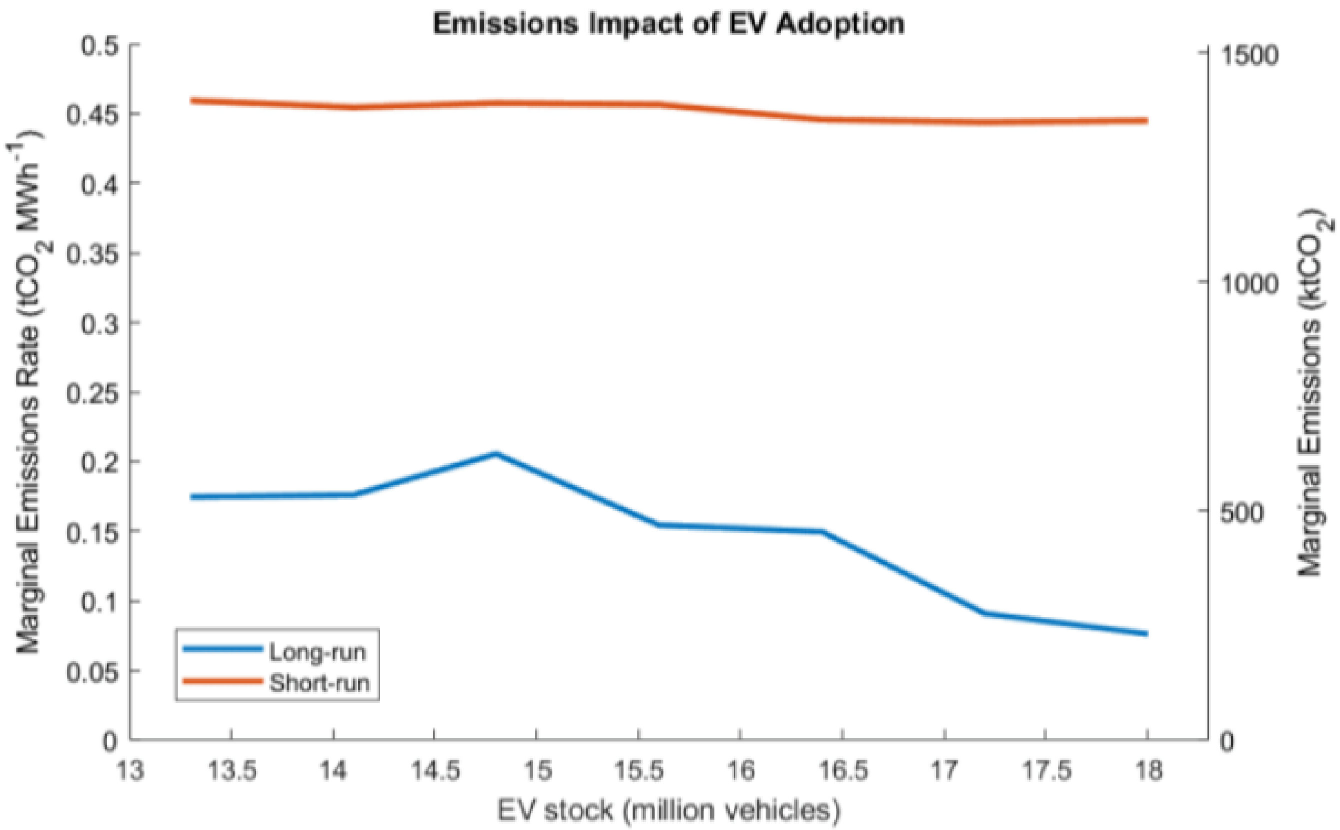
Figure 1: Global levelized cost of electricity benchmarks, 2009-2022



Source: BloombergNEF. Note: The global benchmark for PV, wind and storage is a country-weighted average using the latest annual capacity additions. The storage LCOE is reflective of a utility-scale Li-ion battery storage system with four-hour duration running at a daily cycle and includes charging costs.

Implications: Marginal Emissions Accounting

- What is the emissions impact of adding EV demand to the grid?
- If using the same fixed set of generators, the additional generation will be nearly all fossil
- But if we assume that developers respond to new demand, new renewables will be deployed to meet much of it



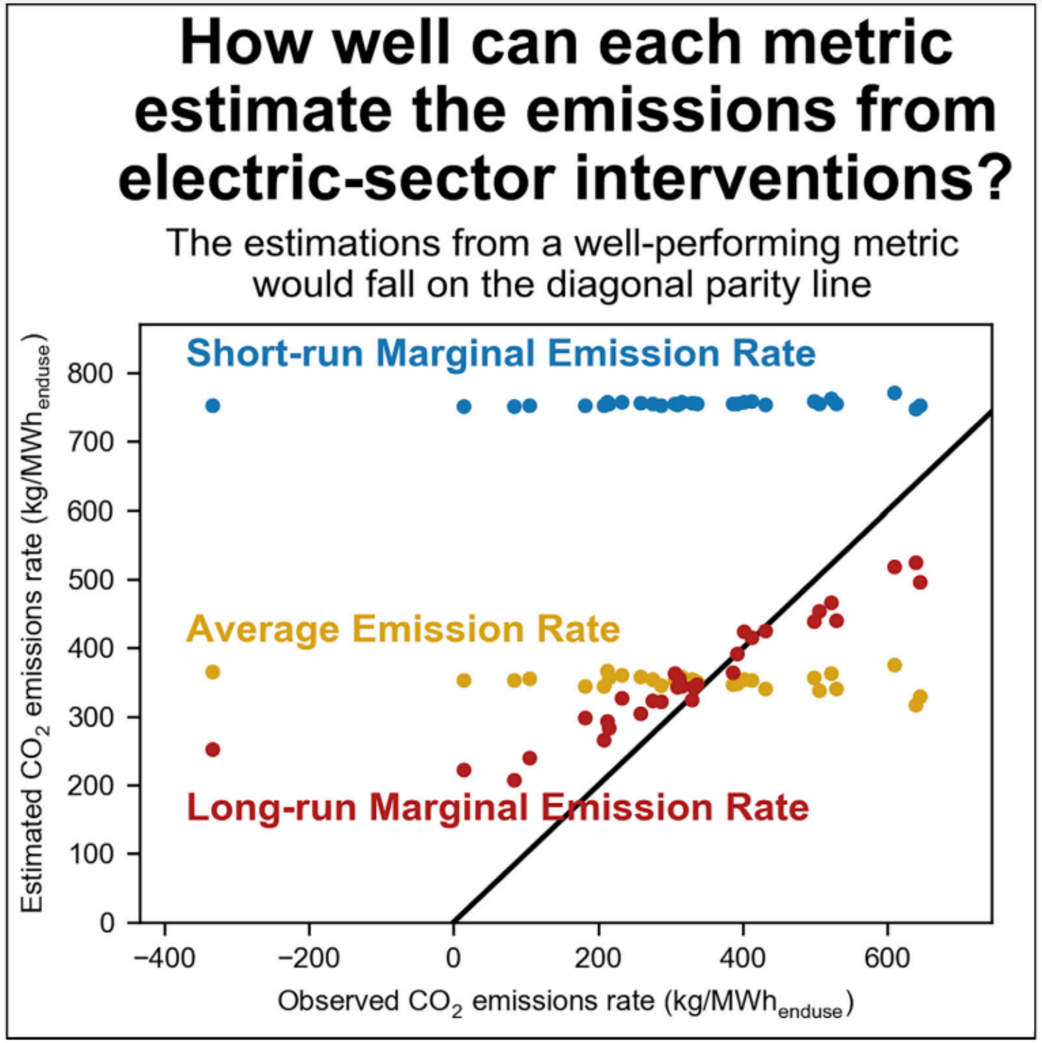
Short-run and long-run emissions impacts of EV adoption (Bandarkar 2023)

Implications: Marginal Emissions Accounting

- **SRMERs cannot accurately estimate emissions impacts** because they ignore capacity deployments and retirements

- **Long-run marginal emissions rates (LRMERs)** that *do* incorporate these impacts would be a theoretically-optimal alternative

- Unfortunately, **LRMERs are unobservable in the real world** and can only be roughly projected using electricity system models



Gagnon et al. 2022

Implications: Temporal Matching

- Temporal Matching effectively mitigates a consumer's long-run marginal emissions impact without needing to know LRMERs
  - (As long as the clean power comes from new resources and is physically deliverable)

- Outcomes are roughly equivalent to eliminating a consumer's electricity demand or supplying it entirely with on-site clean power

$$Approximate\ Net\ Emissions\ Impact = \underbrace{(Demand\ - Clean\ Supply)}_{\text{Always} \leq 0} \times \underbrace{LRMER}_{\text{Unknown}}$$

Always ≤ 0

Unknown

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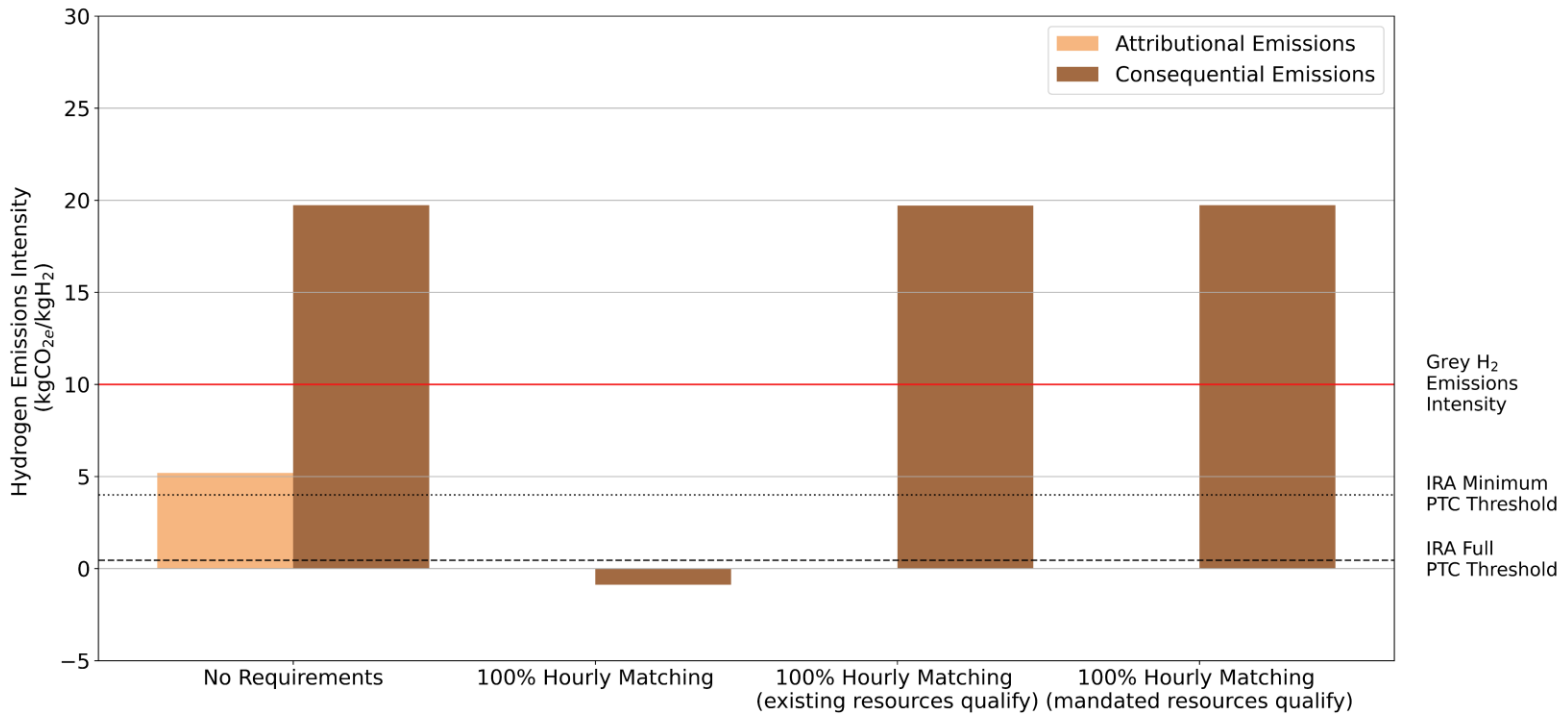
Thank You

New Power Procurement

- **If procurements are not made from *new* sources**, voluntary clean energy purchases will likely have **negligible consequential impact under any strategy**

- There is enough existing carbon-free power to satisfy large amounts of voluntary demand (even time-matched) in many regions



Example: using existing carbon-free resources to match hydrogen electrolysis load in California leads to zero emissions reductions

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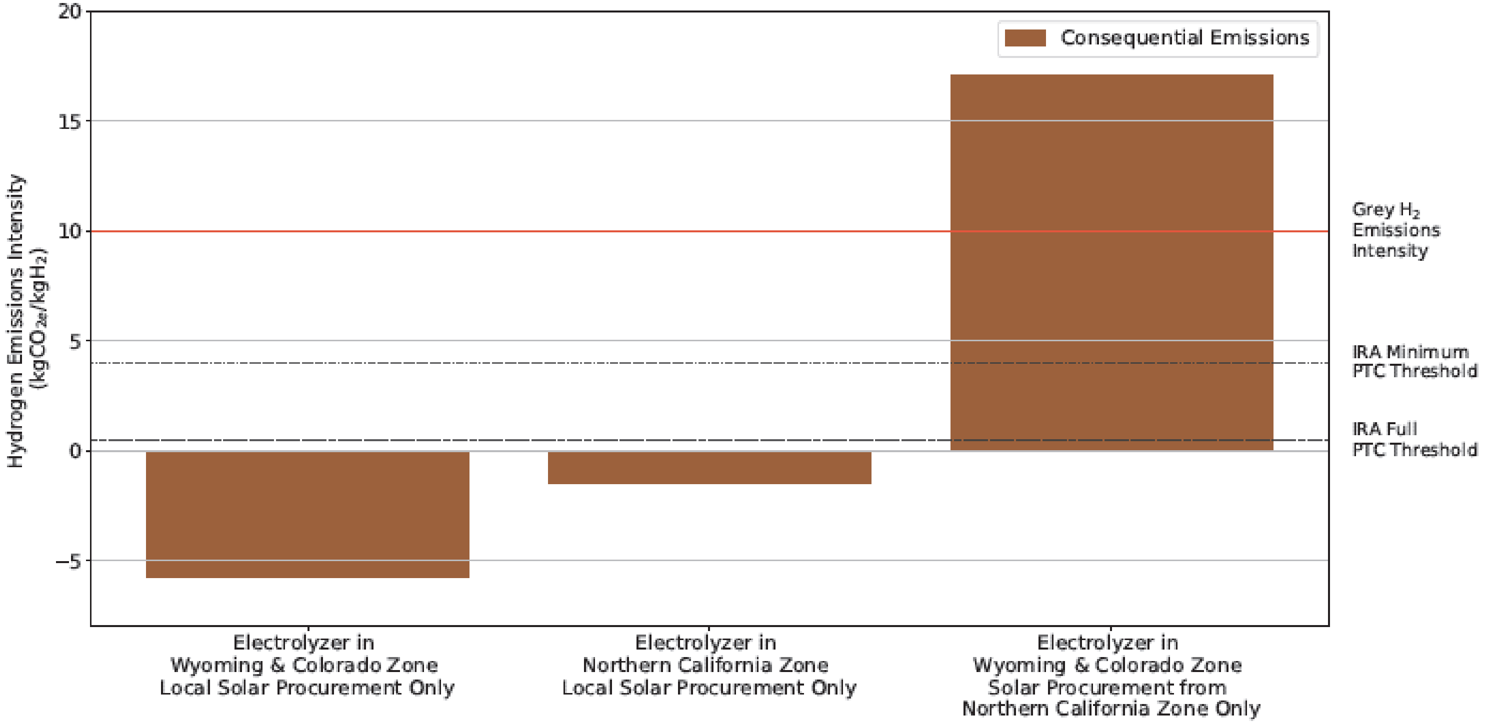
Deliverability

- Previous work has demonstrated that **procurement across transmission bottlenecks** can inhibit impact

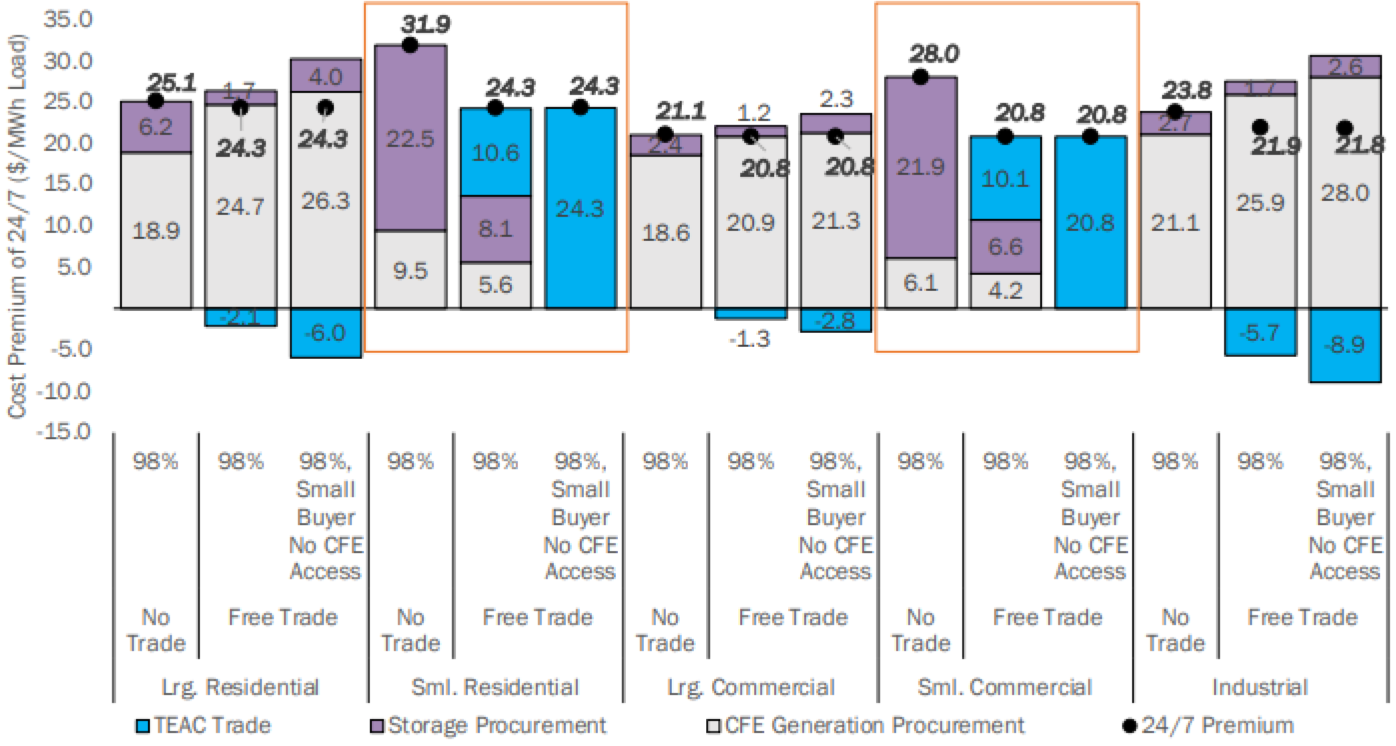
- Especially important when siting both new load and generation



Impact of deliverability constraints on emissions from hourly-matched electrolysis (Ricks et al. 2023)

Markets

- PPAs are the most robust means of ensuring a causal relationship between clean attribute procurement and additional clean generation
- But markets allowing EAC trading may help with hedging, and would allow smaller players to participate
- Market prices can send demand signals and help price PPAs



EAC trading between players with different purchase capabilities