Paths to Carbon Neutrality

A Comparison of Strategies for Tackling Corporate Scope II Carbon Emissions

EXECUTIVE SUMMARY

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Global climate change has pushed carbon emissions to the forefront of public scrutiny and scientific inquiry. At center stage are industries producing carbon emissions by generating electric power (Scope 1 emissions), as well as corporations whose consumption of electricity drives much of that production (Scope 2 emissions).

At the same time, ongoing efforts to develop "clean energy" alternatives have lowered costs for sources that were once thought to be niche, such as solar and wind energy. Corporations that are large consumers of electricity — among them Amazon, Google, Microsoft, and Meta, which all have global networks of data centers— have increasingly turned to investment in these clean energy sources, striving to shrink their carbon footprints.

These companies have taken different approaches to investment in clean energy, such as the RE100 initiative, Google's 24/7 Carbon-Free Energy plan, Microsoft's 100/100/0 vision, and the Emissions First partnership led by Meta and Amazon. All these approaches involve investment in new clean energy projects to balance grid electricity consumption with clean energy generation.

In our study we explore the costs and impact of these different approaches, looking at three strategic questions facing large electricity consumers:

- What is the most effective clean energy procurement strategy in terms of total cost ($/MWh of customer load) and CO_2 abatement cost ($/metric ton of CO_2 displaced)?
- How do energy-matching strategies compare to an emissions-focused strategy in terms of avoided emissions and reaching carbon neutrality?
- How do customer location and load profile affect the impact and cost of each strategy?

To answer these questions, we look at four different clean energy procurement strategies being used by large electricity consumers and perform a detailed analysis of each strategy's costs and the results it delivers. If the intent is to maximize emission reductions per dollar of capital allocation, accelerating overall grid decarbonization, which strategy cuts the most carbon for the least expense?

Factors in the Analysis

We evaluated 10 different large electricity customers pursuing four different clean energy procurement strategies in the year 2025.

We compared customers with two different load profiles:

- A load profile representing stand-alone, commercial retail buildings.
- A flat load profile representing the data centers or industrial installations.

In parallel, we studied customer load in five different balancing authorities (BAs), selected for geographical and regulatory diversity:

- The California Independent System Operator (CAISO)
- The PJM Interconnection (PJM)
- Duke Energy Carolinas (DUKE)
- Portland General Electric (PGE)
- The Los Angeles Department of Water and Power (LADWP).

CAISO and **PJM** are large system operators that cover broad geographic regions and operate wholesale power markets. **DUKE** is a vertically integrated electric utility (VIEU) region. **PGE** and **LADWP** are municipal areas each served by a vertically integrated electric utility.

Under some strategies, clean energy could also be procured in three additional ISO/RTO power markets: The Electricity Reliability Council of Texas (ERCOT), the Southwest Power Pool (SPP), and the Midcontinent Independent System Operator (MISO).

We evaluated four clean energy procurement strategies:

1. **Annual energy matching.** (The current industry standard.) The customer must match their load with generation from procured clean energy on an annual basis. Clean energy can be procured in the customer's local balancing authority or from any of the five ISO/RTO balancing authorities in this study: CAISO, PJM, MISO, ERCOT, or SPP. The annual energy matching strategy in this study meets the RE100 requirements.
2. **Local annual energy matching**. This is identical to annual energy matching, except that the customer must procure clean energy within the balancing authority where their load is located.
3. **Hourly energy matching**. The customer must match their load on an hourly basis with generation from clean energy procured within the balancing authority where their load is located. In addition, the customer may utilize battery storage to shift clean energy between usage hours. This strategy meets the 24/7 Carbon-Free Energy requirements.
4. **Carbon matching**. The customer must reach *carbon neutrality*, which is defined as having avoided emissions (carbon emissions displaced by incremental clean energy procurement) that equal or exceed the carbon emissions attributable to their load on an annual basis. Clean energy can be procured within the customer's local balancing authority, or from any of the five ISO/RTO balancing authorities in this study — CAISO, PJM, MISO, ERCOT, or SPP.

We calculated carbon emissions attributable to load ("load emissions") and carbon displacement attributable to generation ("avoided emissions") from procured clean energy by using Locational Marginal Emission Rates (LMERs) from the long-term Tabors Caramanis Rudkevich (TCR) market forecast.[1]

LMERs provide an accurate, transparent measurement of the change in power system emissions created by a change in electricity supply, demand, or transmission at any specific location and time. The most reliable sources for marginal emission rates are balancing authorities. They have access to the most granular operating data, and they run the dispatch algorithms that identify marginal generators.

Currently LMERs are not widely available, but there is broad movement to provide increased access to this data for carbon accounting and carbon-aware operating decisions. For example, The Infrastructure Invest and Jobs Act (IIJA) specifically calls for the U.S. Energy Information Administration (EIA) to collect and report hourly locational marginal greenhouse gas emission rates.[2] PJM and ISONE have begun reporting marginal emission rates, and others may follow.

For individual customers, LMERs can be used to translate into a single carbon footprint electric consumption and generation that occurs at different locations and times. We used LMERs to calculate,

[1] "Carbon displacement" and "avoided emissions" are used interchangeably in this paper – both refer to the counterfactual carbon emissions that are not emitted due to incremental clean energy generation on the power grid, calculated using marginal emission rates.

[2] Infrastructure Investment and Jobs Act, Pub. L. No. 117–58, § 40418 (2021). https://www.congress.gov/bill/117th-congress/house-bill/3684/text.

for each customer and strategy, *net carbon footprint* (total of load emissions and avoided emissions) and *CO_2 abatement cost* (dollars spent per metric ton of CO_2 displaced).

Customers' costs for procuring clean energy were calculated using PPA index prices, or using LCOE values where PPA index prices were not available. The value of energy sold from the projects was determined using locational marginal prices (LMPs) in ISO/RTO regions and using avoided cost/feed-in tariff rates[3] in regulated utility regions. Hourly LMERs and LMPs were sourced from TCR's long-term market forecast for the year 2025. All costs were annualized to that year.

For the *annual* energy-matching strategies and the carbon matching strategy, the customer procured the least-cost clean energy to meet the strategy goal. For *hourly* energy matching, customer actions were modeled using a least-cost linear optimization formula to determine clean energy procurement, battery procurement, and battery operation. We acknowledge that there are other factors involved in corporate decision-making on procurement of clean energy, for example, local employment or community investment. Because those choices are situation-specific, we did not attempt to quantify them in this analysis.

Key Findings

Carbon matching is the **most effective strategy** in terms of both strategy cost and carbon abatement potential.

Both in terms of total cost per MWh of load served (see Figure ES-1) and in terms of CO_2 abatement cost for all location and load-profile scenarios, carbon matching emerged as the most effective strategy. Because this strategy moves customers beyond megawatt-hour matching to focus on the quantified emissions impact of their electricity consumption and generation, it allows customers to:

- **Consistently achieve carbon neutrality.** In our analysis, we found that carbon matching was the only annual matching strategy to consistently achieve carbon neutrality, regardless of customer load profile and location.
- **Target investment in areas and projects that maximize carbon displacement for each dollar investment.** Translating MWh of energy to carbon emissions means customers no longer must consider balancing authority boundaries. All customers, regardless of their load location, can procure projects with the highest carbon displacement potential. In the analysis depicted by Figure ES-1, the project with the highest carbon displacement potential is a utility PV project in southern SPP — an area with high-quality solar resources and considerable coal generation, which results in high LMERs. This project was selected by all customers pursuing the carbon matching strategy.

[3] Although merchant projects can sell at market prices in some parts of the country (*e.g.,* WECC), this study uses avoided cost and feed-in-tariff as a proxy for value of energy because avoided cost and feed-in-tariff rates are guaranteed for qualifying facilities. More discussion in methodology section.

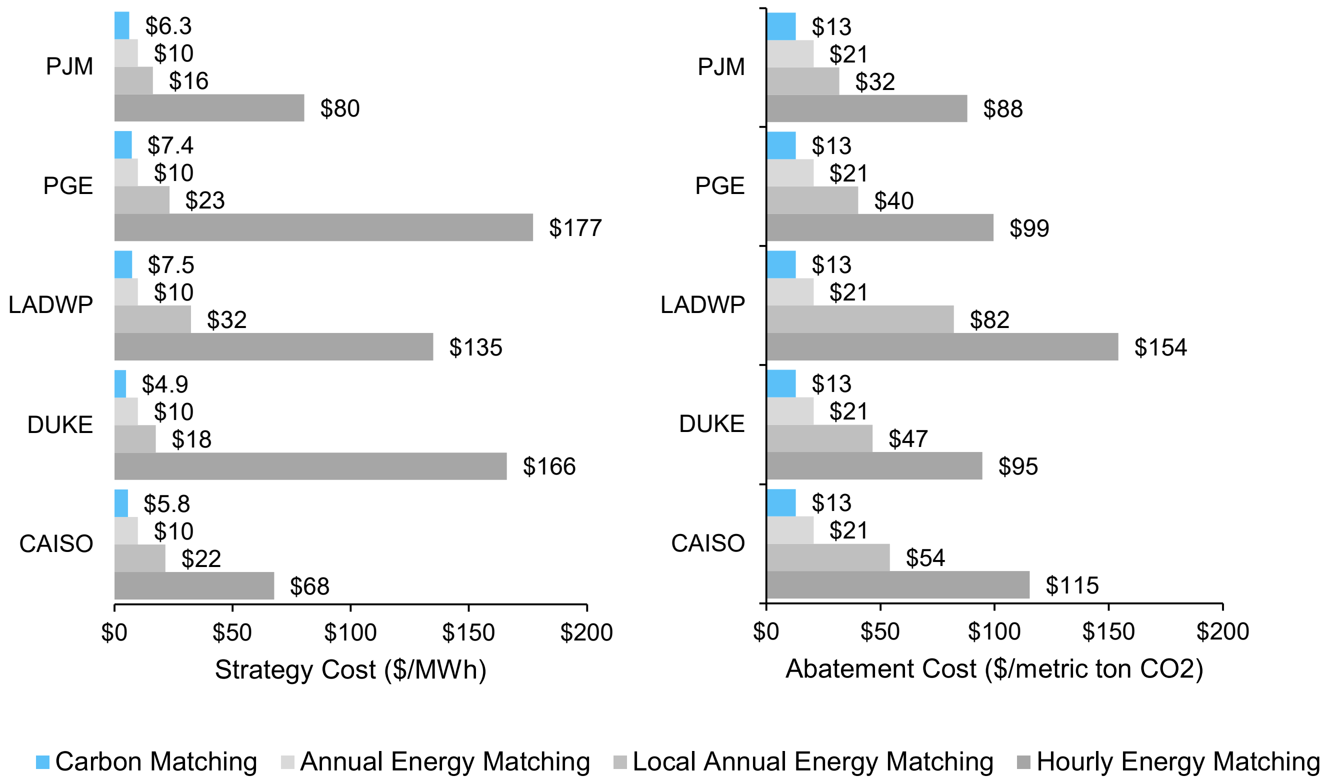

Figure ES-1: Strategy cost per MWh of customer load, for each strategy in each balancing authority. Results are shown for the customer with a commercial load profile. For hourly energy matching, the target CFE score is 100%.

Energy matching does not guarantee carbon neutrality.

Because energy matching strategies focus on units of energy rather than units of carbon emissions, they do not guarantee achievement of carbon neutrality. In our analysis across all five balancing authorities, neither annual energy matching nor local annual energy matching achieved annual carbon neutrality.

The hourly energy matching strategy fails to achieve carbon neutrality on an hourly basis, despite local hourly matching of energy. It only achieves annual carbon neutrality — at a high cost — by significantly over-procuring energy (>200% of load).

The annual energy matching strategy only achieved carbon neutrality for customers in two of the five balancing authorities studied: CAISO and DUKE. This reflects the lower carbon intensity of the grid at those load locations. CAISO and DUKE have relatively higher generation from zero-emission energy sources, so emissions attributable to load in these two balancing authorities are lower than those in LADWP, PGE, and PJM.

Local annual energy matching requires customers to procure clean energy in the same balancing authority as their load. Advocates of this approach argue that the procured clean energy thus more closely "matches" load. But we found that while localizing procurement did increase cost, it did not consistently improve carbon displacement. Only two of the balancing authorities using local annual energy matching — PJM and PGE — achieved carbon neutrality.

Localized energy matching strategies **decrease** carbon displacement efficiency.

Both local annual energy matching and hourly energy matching aim to locate clean energy procurement within the same balancing authority as the customer's load location to better to "match" or "offset" load. We found that although localizing energy procurement increased customer costs, it did not guarantee a lower carbon footprint than non-localized annual energy matching. In many cases it actually raised the customer's net carbon footprint because it limited clean-energy procurement options.

The lowest-cost clean energy projects in our analysis were PV projects in ERCOT, while the most cost-effective projects for carbon abatement were PV projects in southern SPP (see Figure ES-2). The annual energy matching and carbon matching strategies allow customers to procure energy from these projects regardless of load location.

However, customers choosing the local annual energy matching and the hourly energy matching strategy cannot access these most efficient projects unless their load is in ERCOT and SPP. For example, under the local energy matching strategy, a customer in CAISO can only procure energy from PV projects in CAISO, which cost significantly more than those in ERCOT and are much less effective at displacing carbon than those in SPP.

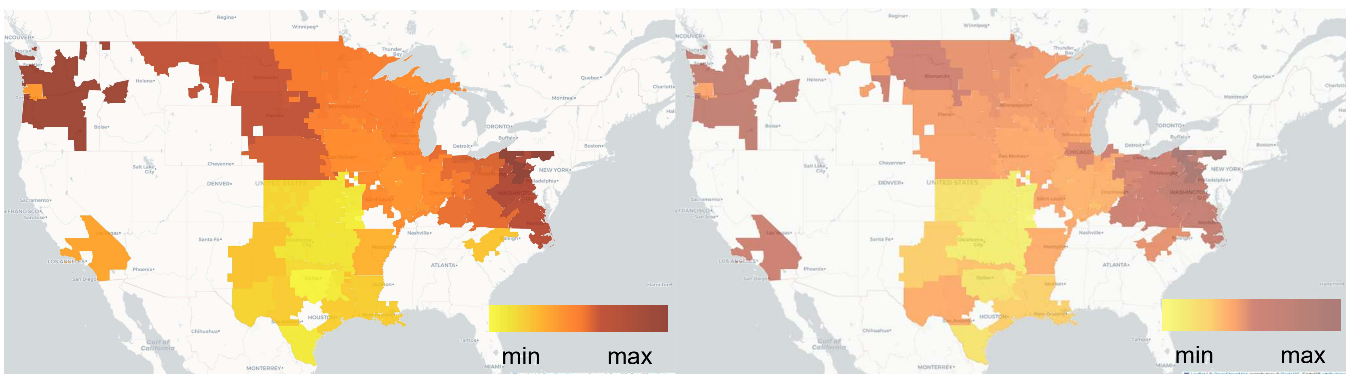

Figure ES-2: PV procurement cost in $/MWh load (left) and carbon abatement cost in $/metric ton CO_2 (right).

Hourly energy matching is the **least** efficient strategy at displacing carbon emissions.

The hourly energy matching strategy ensures that the customer's load is matched with clean energy on an hourly basis within the same balancing authority. But to achieve this, the customer must procure significantly *more* clean energy than in any other strategy studied, and they must procure battery storage to maintain clean energy use during periods of low wind generation and solar generation. This pushes the cost an order of magnitude higher than the costs of the carbon matching and annual energy matching strategies.

Despite the additional clean energy procurement and hourly matching of load, hourly energy matching also carries the highest abatement cost of any strategy (Figure ES-3). In contrast, carbon matching and annual energy matching strategies allow customers to achieve higher emission reductions at a lower cost.

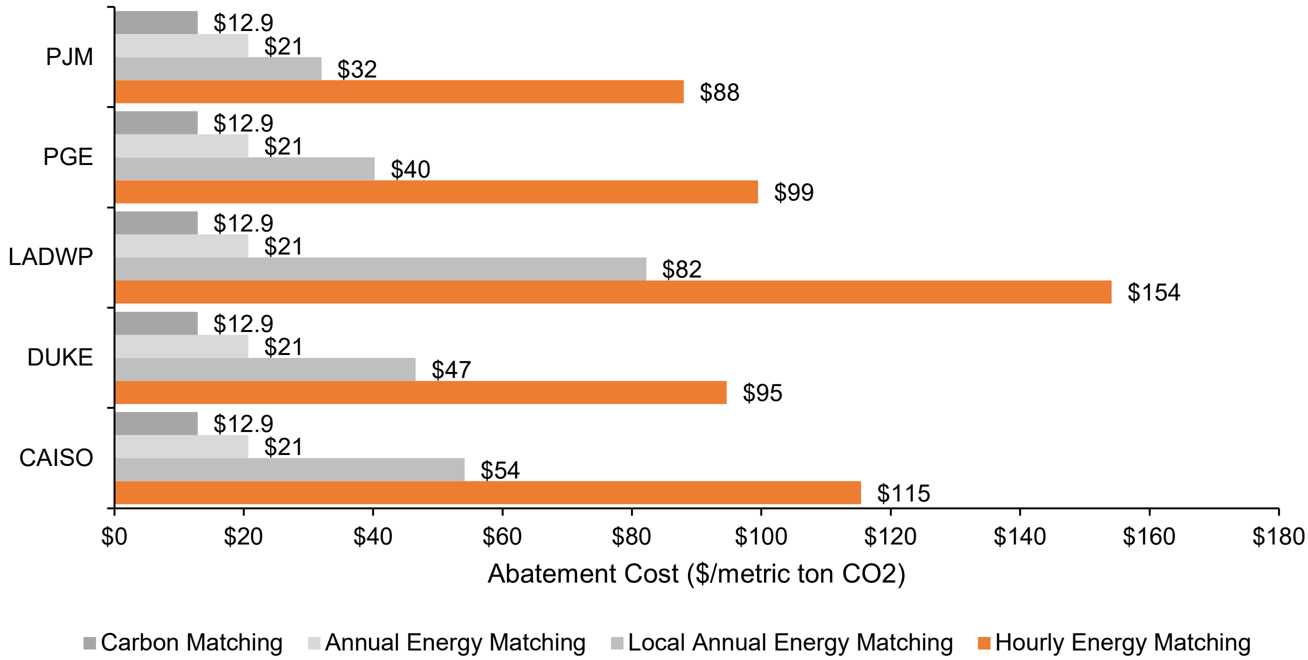

Figure ES-3: CO_2 emissions abatement cost ($ spent per metric ton of CO_2 displaced), for each strategy in each balancing authority. Results are shown for the customer with a commercial load profile. For hourly energy matching, the target CFE score is 100%.

Costs to implement the **hourly energy matching strategy** vary significantly, depending on customer load location and load profile.

Implementing hourly energy matching can cost as little as $68/MWh of load in CAISO, due to access to firm zero-emission geothermal energy — or as much as $181/MWh in DUKE (see Figure ES-4). This wide gap in strategy costs may limit adoption, especially for customers with load spread across multiple balancing authorities and customers who have load in balancing authorities with limited clean energy resources.

In contrast, annual energy matching and carbon matching have a consistent cost. All such customers in this analysis had the same annual energy matching cost, and their carbon cost only varied slightly, based on the emission rates in the balancing authority where their load was located.

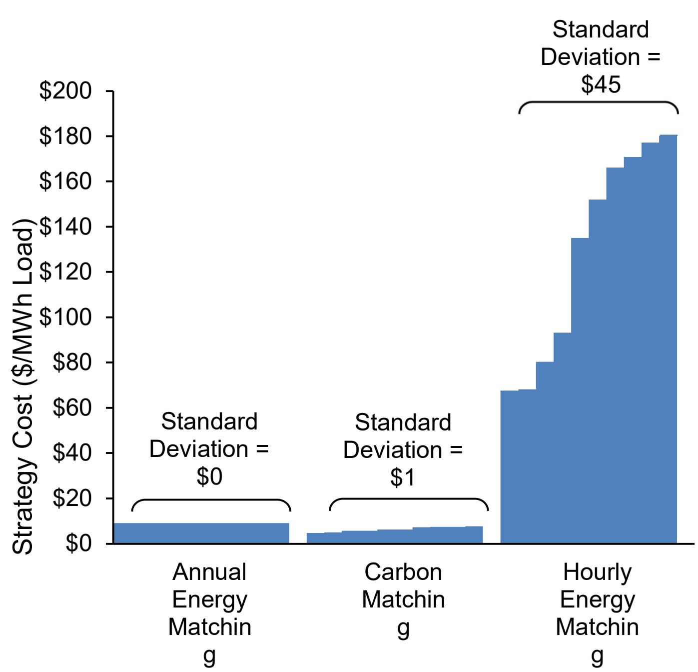

Figure ES-4: Strategy cost by strategy, load BA, and load shape. Hourly energy matching strategy shown with 100% CFE score.

Pursuing **localized energy matching strategies** may not be practical and can **deter participation**.

The cost metrics alone fail to capture other potential hurdles for localized energy matching (*i.e.,* procuring energy in the balancing authority where the load is located). Within some balancing authorities, especially smaller metropolitan ones like LADWP and PGE, clean energy projects may not be readily available for procurement.

For our analysis, we allowed LADWP and PGE customers to procure energy from nearby regions with a firm transmission contract. But transmission contracts add cost, and this distorts the concept of energy matching within a single balancing authority. Technology options may be restricted by other factors. For example, in DUKE there are legal, geographic, and regulatory obstacles that effectively rule out consideration of onshore wind projects.

With hourly energy matching, a small geographic region and restricted technology choices limit diversity in renewable energy generation profiles. Such customers are forced to procure additional battery storage as backup power for periods of low renewable generation. Finally, building a project in a regulated utility territory may demand lengthy, costly negotiations — a steep barrier for customers without the necessary time or resources.

While larger corporations may be able to leverage those circumstances as an opportunity to increase market access, such challenges can discourage participation by the wider corporate world.