REsurety

Locational Marginal Emissions Introduction

Prepared for PJM Emerging Technologies Forum

June 14, 2022

REsurety Introduction

REsurety Overview

Company Overview

- Founded in 2012 with focus on hedging tools to support project finance for renewables
- Expertise in analysis of value ($/MWh and tons/MWh) and variability in clean energy
- In-house atmospheric science and power markets modeling teams
- 7,000+ MW transactions supported in US and Australian wholesale electricity markets
- Today, offer software and data solutions in addition to hedging and advisory services

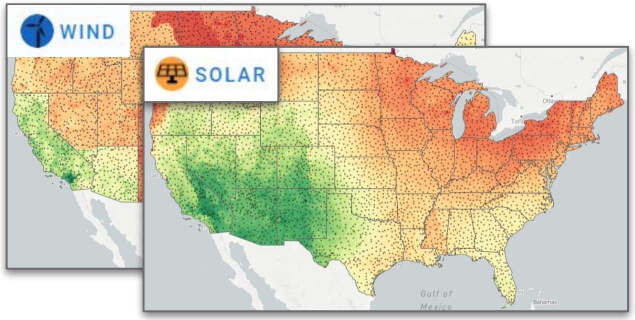
REsurety Overview and Product Suite

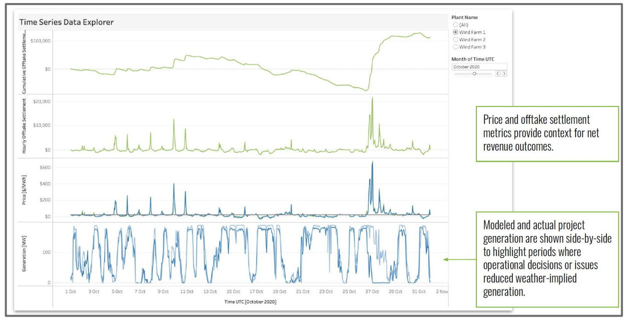
Power Markets and Atmospheric Science Modeling

Software Solutions
REmap, LMEs, REview

Analytics Services
Risk Transfer, Advisory

- **REmap SaaS Platform**
  - Modeled and actual hourly renewable plant generation performance and captured prices at 15,000 locations nationwide
- **Locational Marginal Emissions Data (LMEs)**
  - Measure nodal, hourly marginal impact of generation and load on grid-wide emissions
- **REview SaaS Platform**
  - Track project and portfolio operational, financial, and CO_2 performance given onsite weather conditions and power market dynamics





Locational Marginal Emissions

Background and case studies

Background: The Need for Better Emissions Data

The Challenge

Renewable energy is a means to an end: **decarbonization.**

To achieve that end, we must optimize in the relevant units: **tons of carbon, not MWh of electricity.**

Access to accurate, high-resolution consequential carbon emissions data **has been a barrier** to carbon-based decision making.

Google

"To measure the impact of our projects, we need to be able to evaluate which source of electricity production this new asset would replace. ***'Marginal emissions' is often viewed as the best metric to do this… However, as of today, this information is generally unavailable"*** *Feb '21*

salesforce

"…not all renewable energy is created equal. Two projects with identical transactional details can have enormously different impacts. ***Some renewable energy projects displace more fossil fuels than others****."* – Oct '20

CATF CLEAN AIR TASK FORCE

*"The REC from an additional megawatt-hour of wind generation in wind-saturated West Texas has the same "value" as a megawatt-hour of new solar in fossil-intensive Alabama****, even though the amount of carbon emissions avoided by each are radically different****."* - Feb '21

Background: The Need for Better Emissions Data

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The Solution: Locational Marginal Emissions

Akamai

"LMEs are creating a market-leading opportunity for Akamai to be more accurate regarding our emissions reduction claims." *- Akamai Technologies*

BROAD REACH POWER

"Granular carbon emissions data is mission critical in assisting Broad Reach Power more efficiently reduce carbon emissions while increasing grid reliability; REsurety provides that data." *- Broad Reach Power*

Note: REsurety and our customers were excited to see PJM's release of nodal emissions data (LMEs) last year. We encourage other ISOs to release this data as well.

Approach: Locational Marginal Emissions Methodology

Locational Marginal Emissions
Hourly, nodal emissions rates at each node in the grid

LMEs

Used to:

- Measure the project-specific emissions impact of renewable, storage, and load
- Maximize emissions reductions per dollar invested

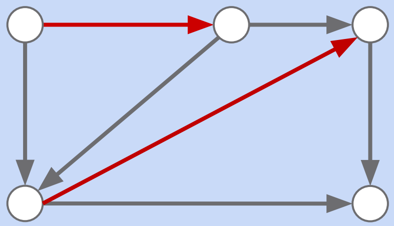
Azure Compute Infrastructure

Patent Pending Calculation

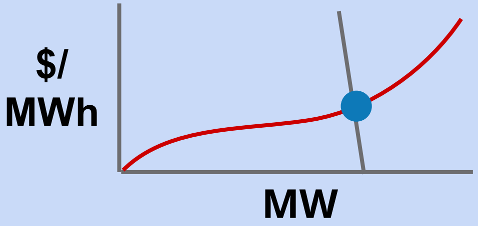
Robust Methodology

Granular Data

Transmission Network



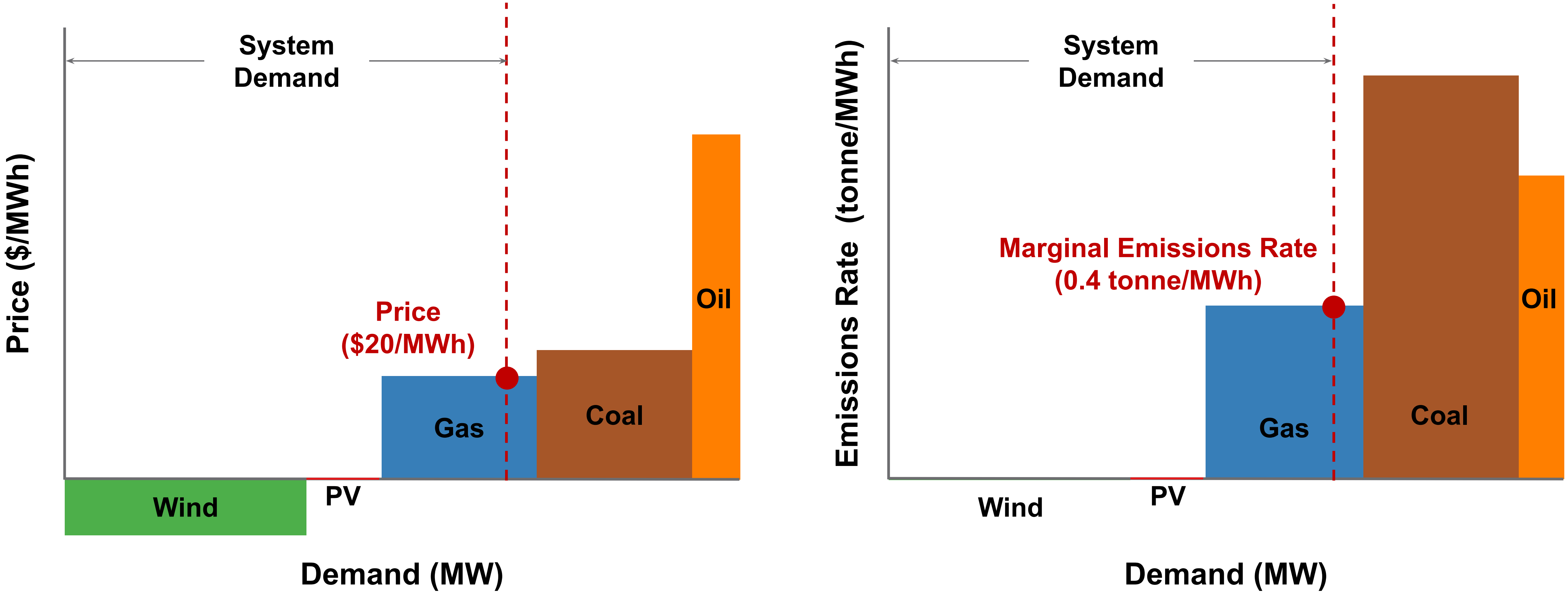
Offers and LMPs



Fossil Emissions Rates

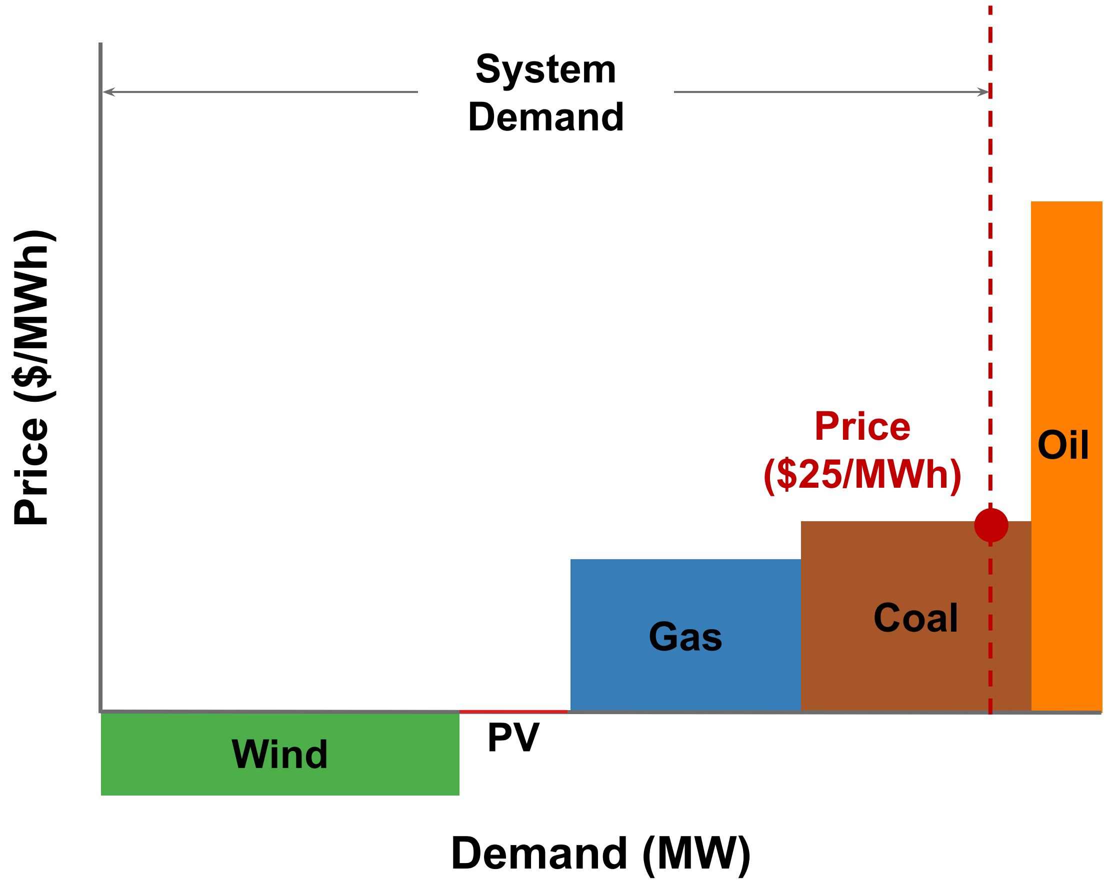
Marginal Emissions Background: The Importance of Timing

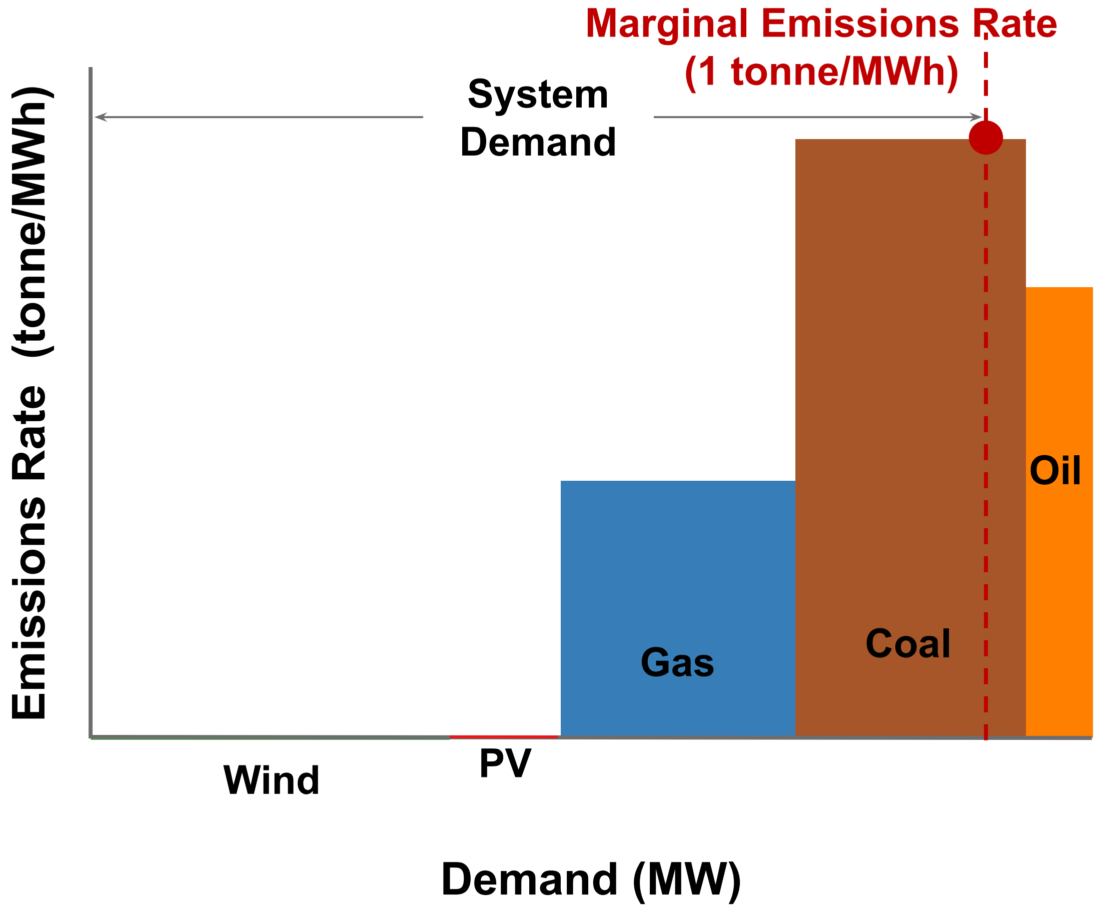
During an example hour, gas is on the margin. Incremental renewables or storage dispatch displaces gas, abating 0.4 tonnes of CO_2 per MWh.



Marginal Emissions Background: The Importance of Timing

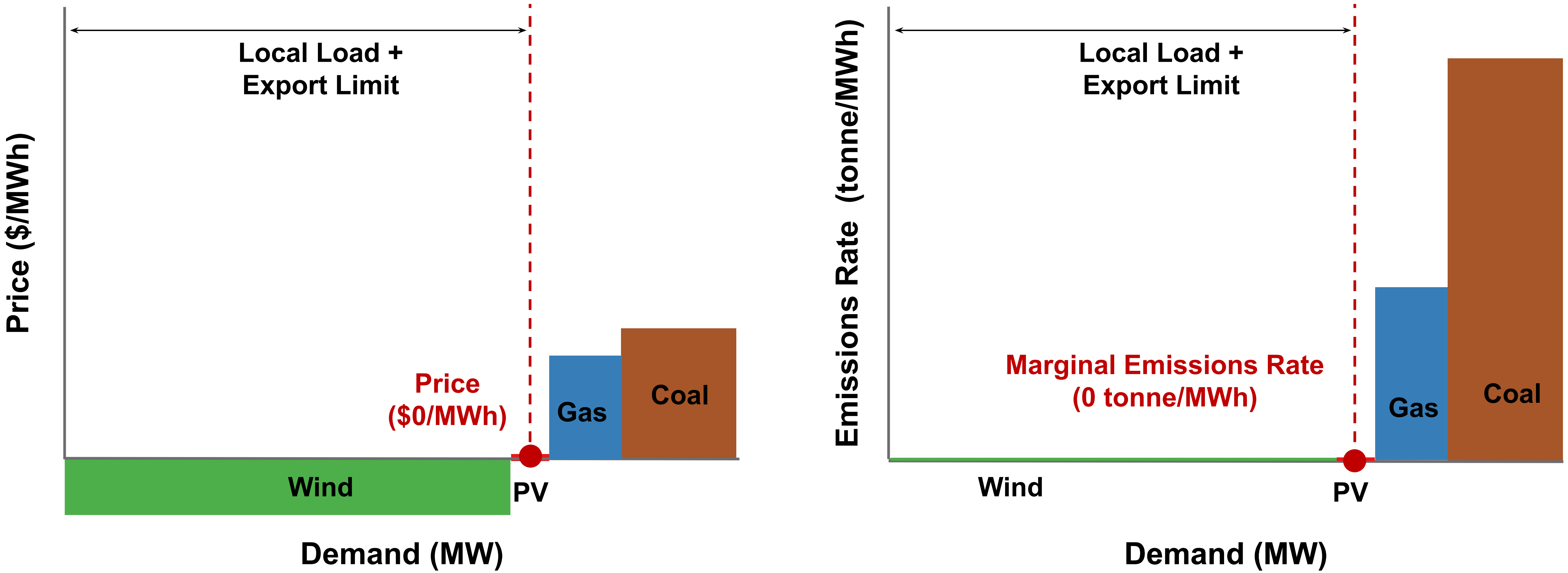
During a different hour, coal is on the margin. During this hour, incremental renewables or storage dispatch displaces coal, abating more than double the CO_2 per MWh.





Marginal Emissions Background: The Importance of Transmission

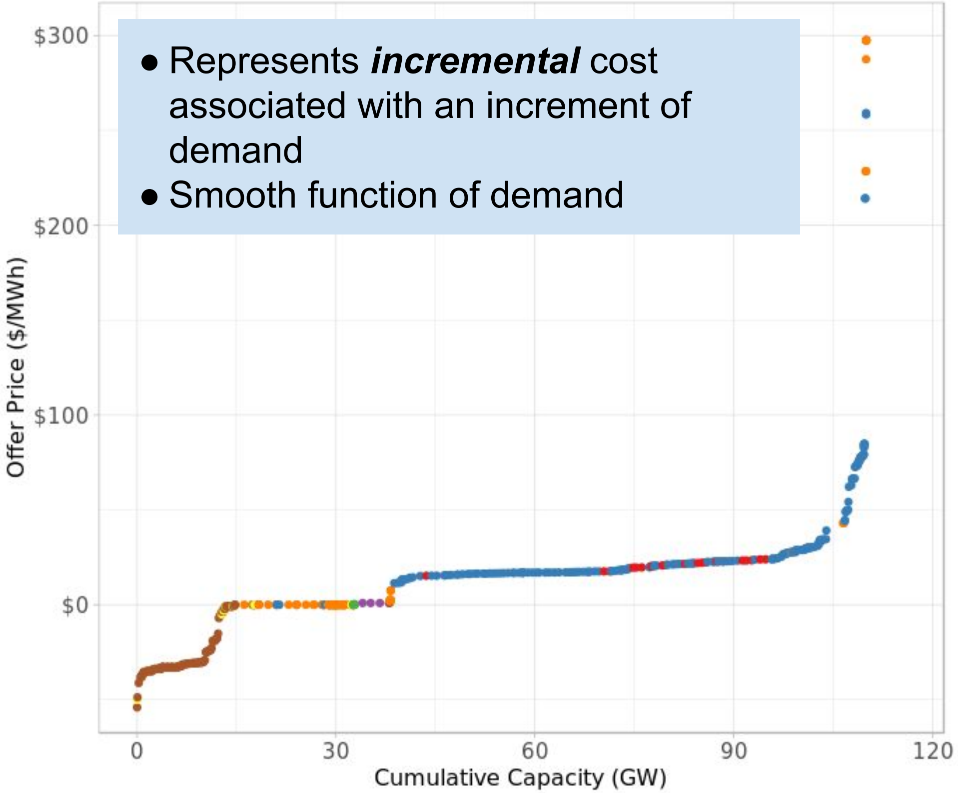
Transmission also matters. In a **wind**-heavy **export**-constrained region, marginal emissions can fall to 0, even when system demand is relatively high.



Supply curve and marginal emissions scatter

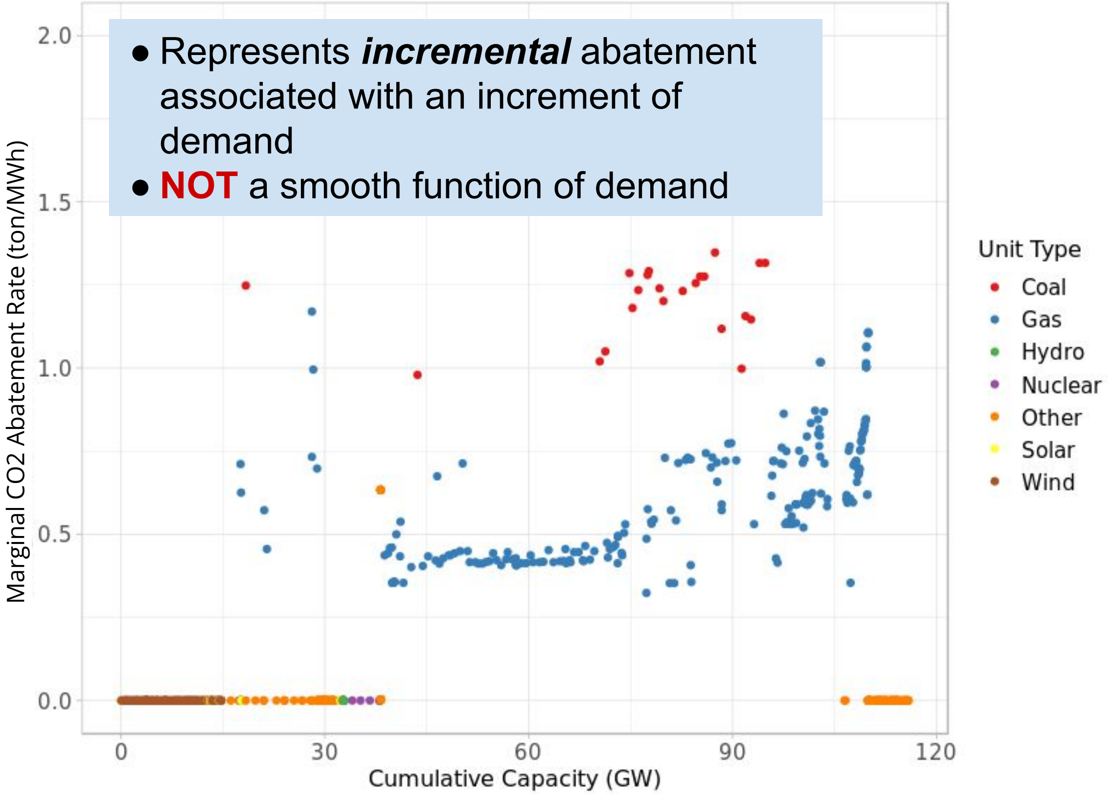
In the absence of a centralized carbon tax, marginal emissions rates don't always correlate with price.

ERCOT Supply Curve: 2020-01-01, Hour Beginning 11



Emissions rates of units in merit order

ERCOT Marginal CO2 Abatement Rate "Curve": 2020-01-01, Hour Beginning 11



Note: Prices and emissions are based on estimates from eGRID for a single timestamp and are somewhat indicative.

Before and After LME

Status Quo:
Limited differentiation, high bias

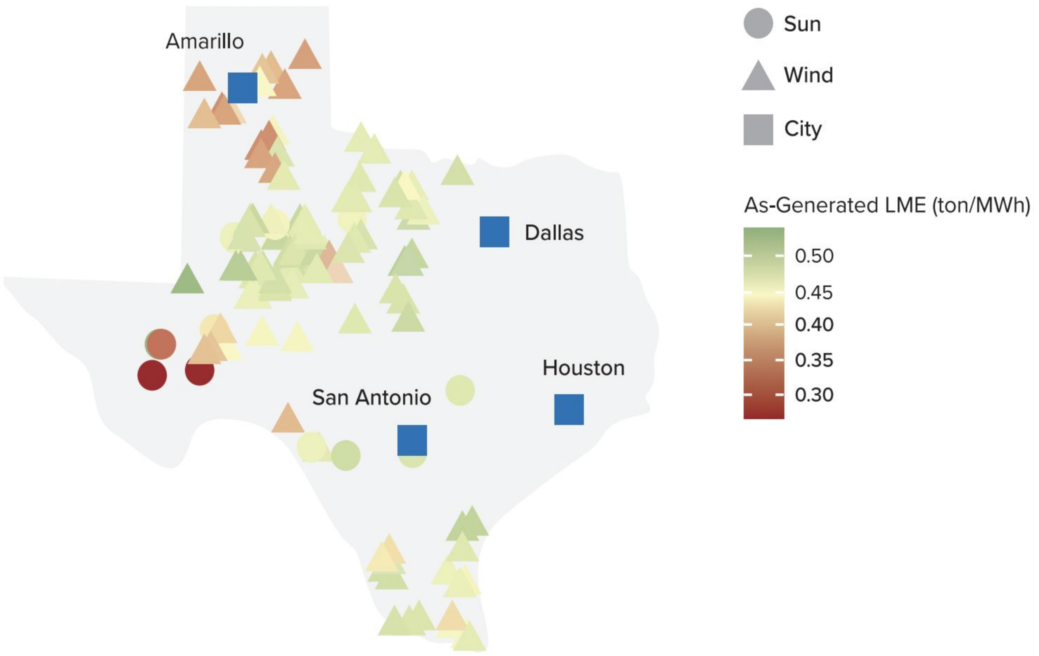
AVERT
AVoided Emissions and geneRation Tool
www.epa.gov/avert

Any and all wind farms in Texas displace:
0.602 Tons per MWh

Any and all solar projects in Texas displace:
0.620 Tons per MWh

Reality powered by LMEs:
Dramatic project differentiation

Average 2018-19 LME of Renewables Across ERCOT

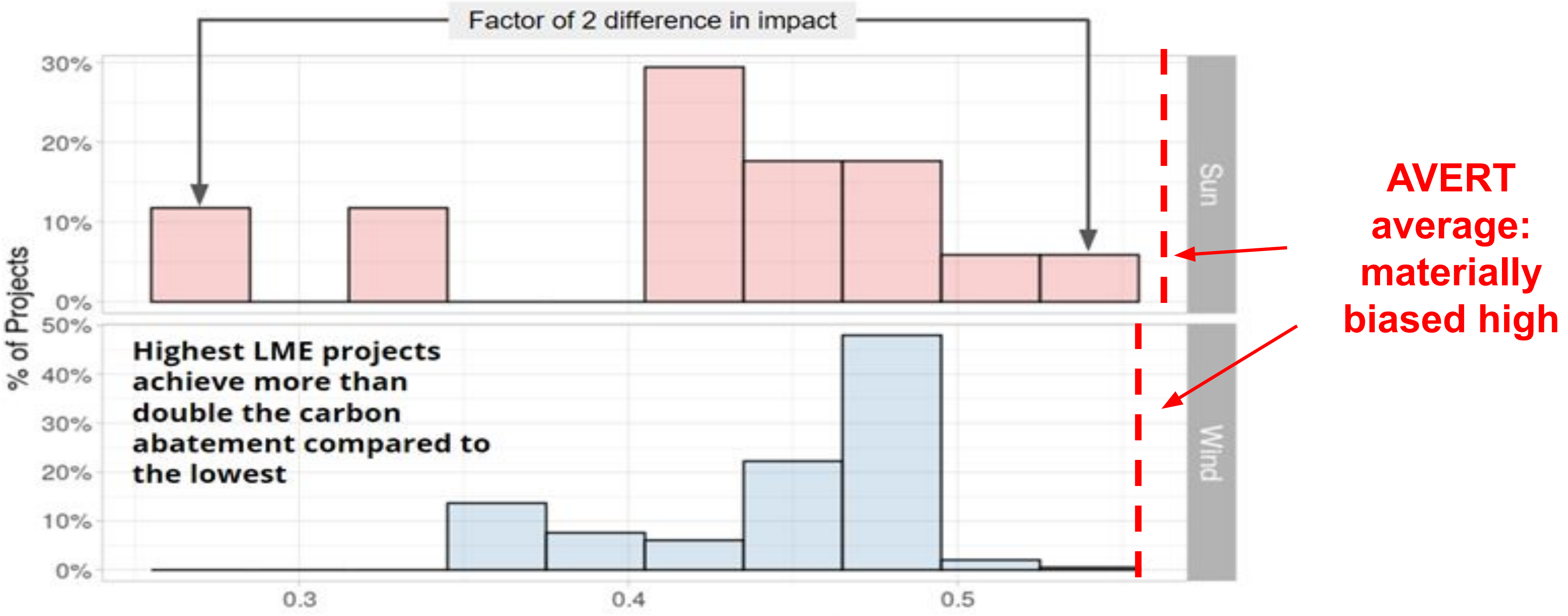


Previously existing tools are biased high and miss project-specific variability

Case Study: Nodal abatement in ERCOT

We calculated the avoided carbon from every wind and solar project operating in ERCOT in 2018 and 2019, and found a wide range of impact.

Average 2018-19 LME of Renewables Across ERCOT

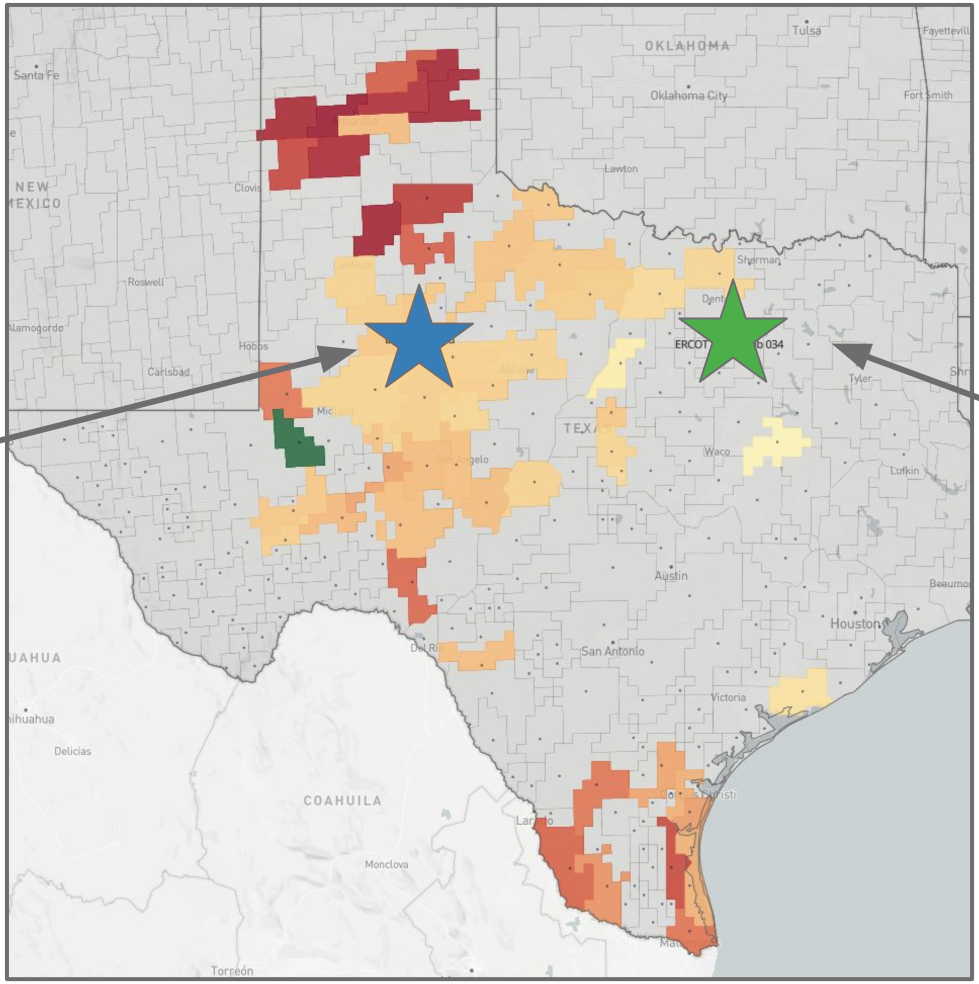


Average Avoided Emissions per MWh

Case Study #1: Corporate Wind Farm and Data Center

As a case study for a large corporate, REsurety used LME data to measure the avoided emissions from a particular wind farm in west Texas. We then compared that to the incremental emissions caused by a hypothetical data center near Dallas that consumed exactly the same total amount of electricity.

Wind farm producing 900 GWh annually

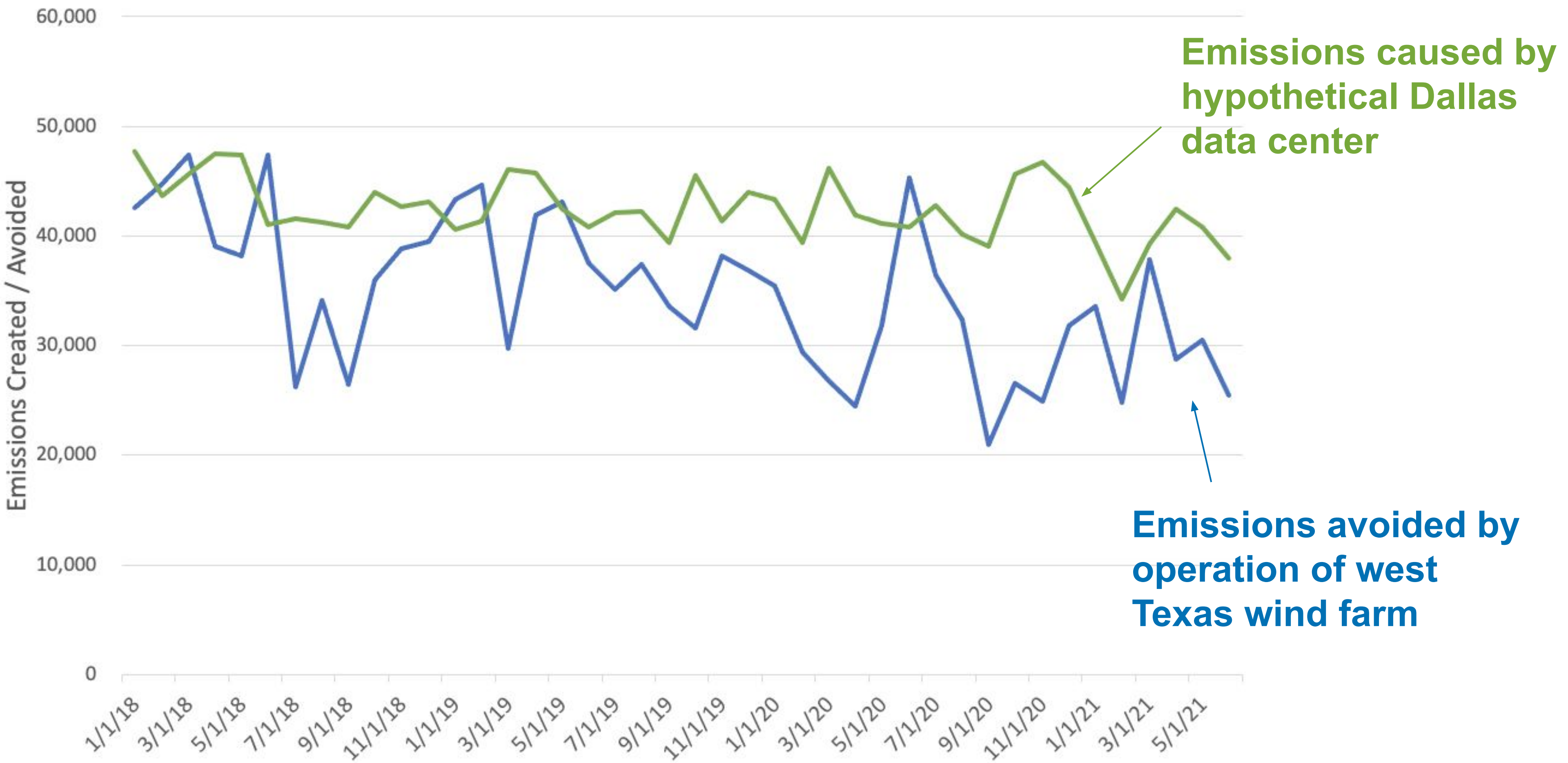


Data center consuming 900 GWh annually

Map coloring shows generation-weighted node-hub congestion over prior 4 years. Source: REmap.

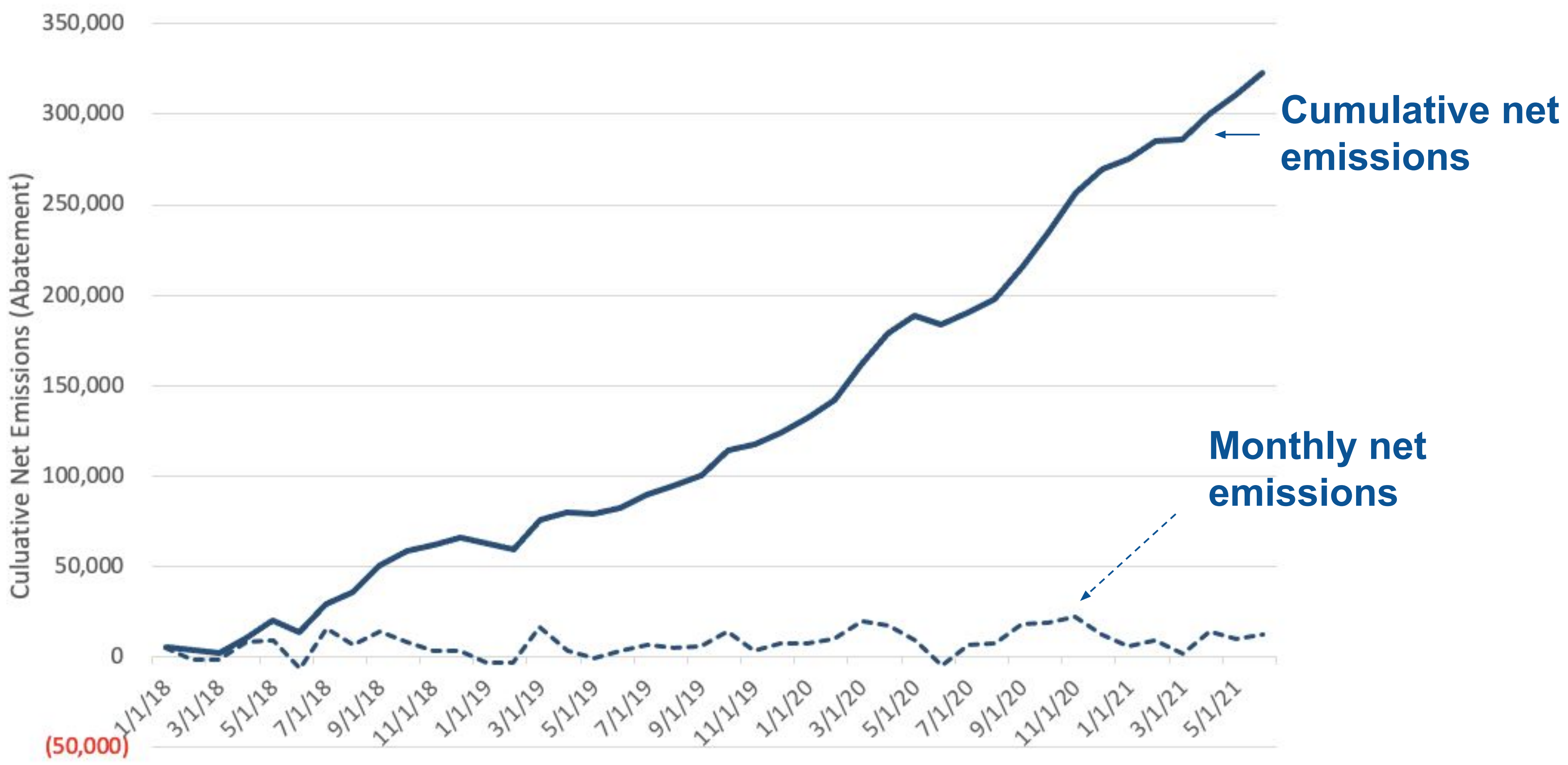
Case Study #1: Corporate Wind Farm and Data Center

We found that the wind farm avoids far fewer tons of carbon than are emitted by the data center, even though they match in annual MWhs. This is due to both timing of production and location on the grid.



Case Study #1: Corporate Wind Farm and Data Center

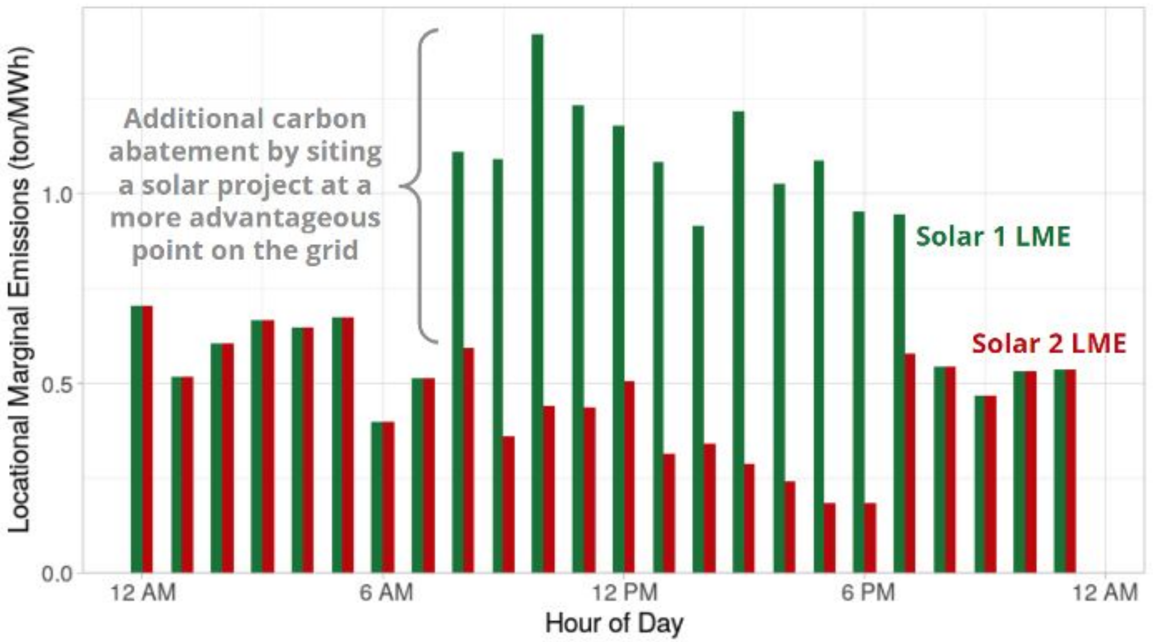
Over the 3.5 year period, the cumulative gap between the emissions caused by the data center and emissions abated by the wind farm was ~325,000 tons. REsurety is now working with this corporate to procure energy from new projects and technologies that will have the biggest carbon impact.

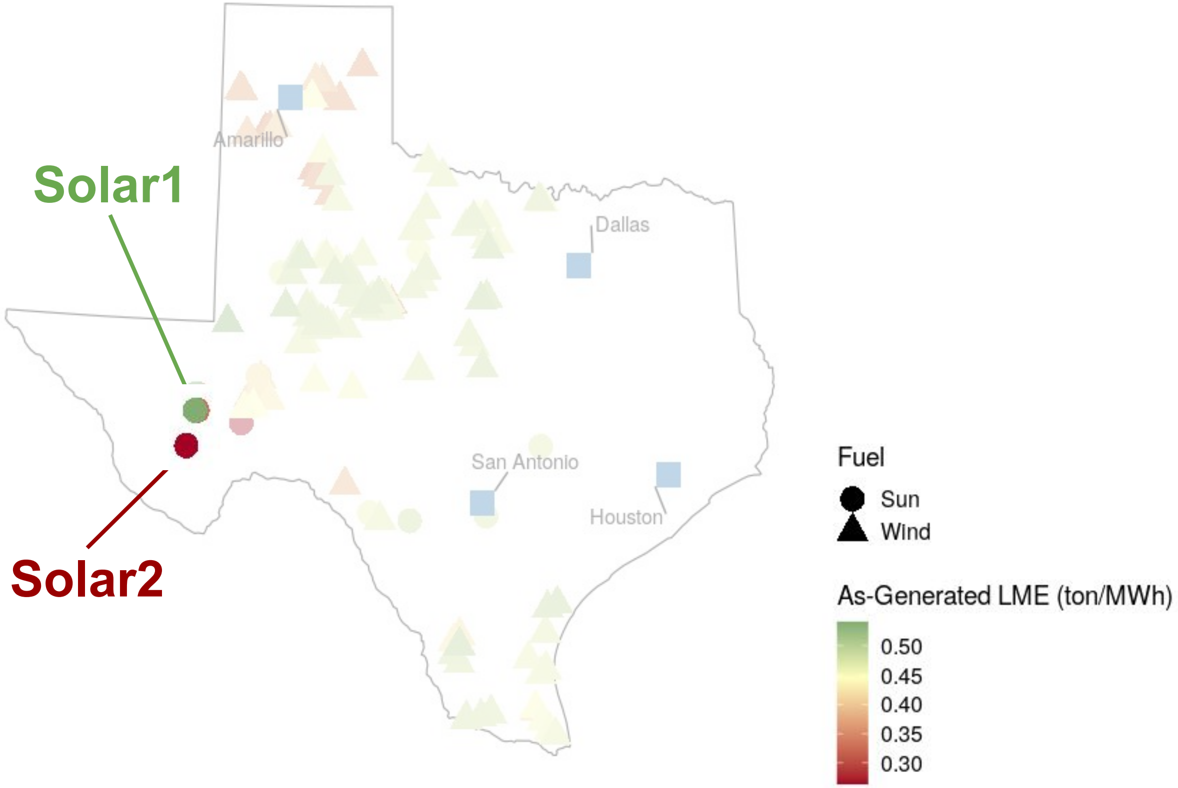


Case Study #2: Comparison Between Two Solar Projects

Differences in carbon abatement between two far-west solar facilities highlight the role of transmission in carbon value

LME of Two Solar Projects in Texas for an Actual Day



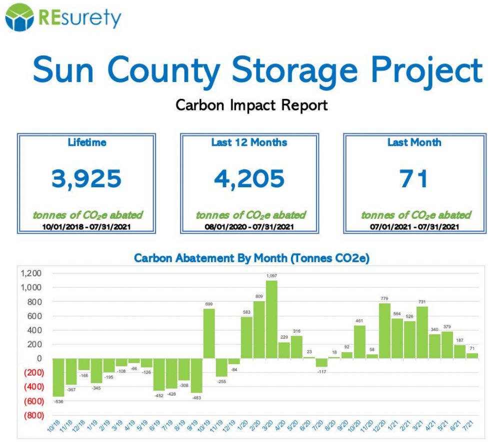


The Solar 2 project is abating half the amount of carbon as the Solar 1 project

REsurety Offering: Tools and Interface

Project-Specific Historical Analyses:

LME Report: providing detailed diligence of impact, trends and drivers for a given project.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Sun County Storage Project

Carbon Impact Report

Lifetime	Last 12 Months	Last Month
3,925	4,205	71
tonnes of CO_2e abated	tonnes of CO_2e abated	tonnes of CO_2e abated
10/01/2018 - 07/31/2021	08/01/2020 - 07/31/2021	07/01/2021 - 07/31/2021

Carbon Abatement By Month (Tonnes CO2e)

Granular Historical Data at Scale:

LME API: providing programmatic access to hourly LME rates at any node

/lme_node_availability

Returns a list of all available nodes, their ISO, and min and max dates available.

Code examples:

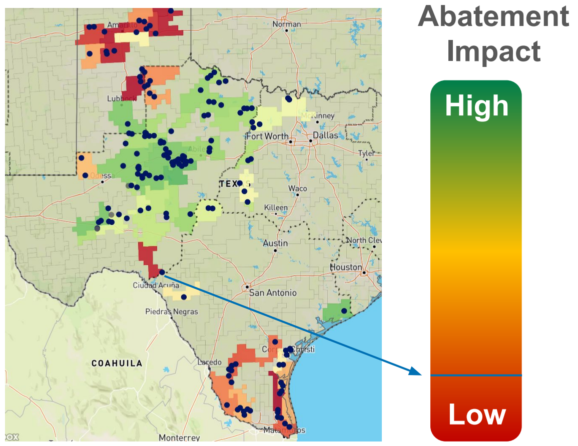
Python Shell

```
endpoint_url = "https://api.resurety.com/v0/lme_node_availability"
headers = {"Authorization": "Bearer " + token}

requests.get(endpoint_url, headers=headers)
```

Forecasting and Map-Based Visibility:

LME Scores: transparency into low and high-emission impact strategies

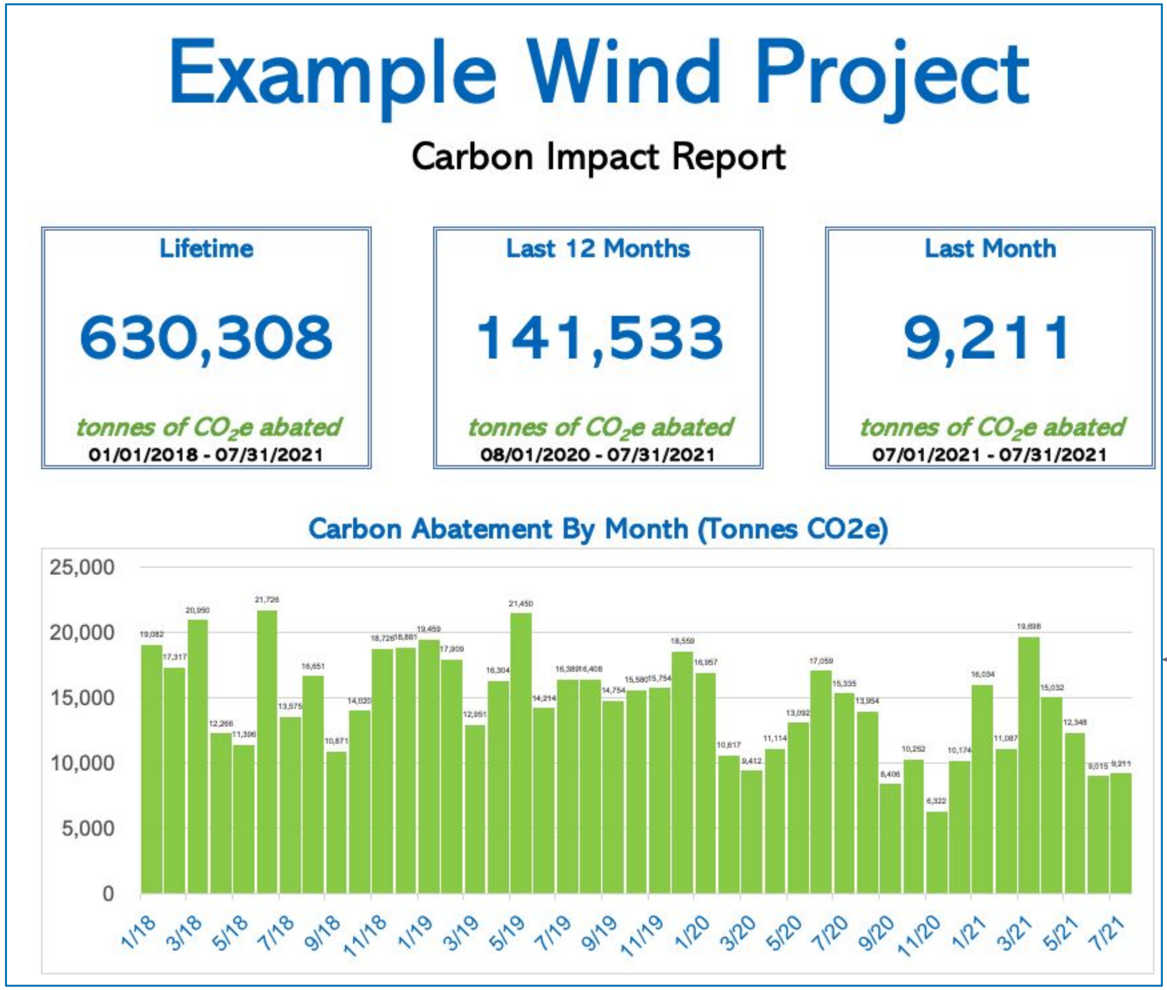


A la carte for project evaluation Ongoing tracking for reporting	Strategic development, M&A Policy-related research	General market trends PPA Decision-making

Sample Emissions Report

Project-specific reports include detailed project abatement information for wind, solar, or storage projects.

Headline avoided emissions metrics for clear reporting



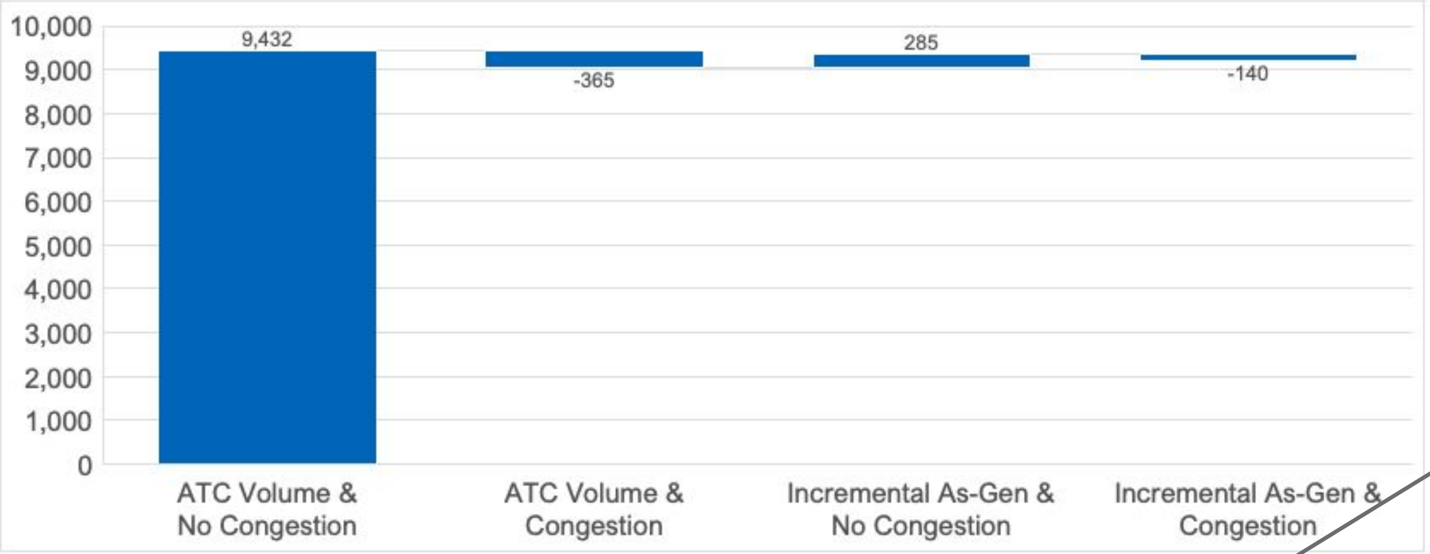
Monthly time series of avoided emissions, with hourly details available for download.

Sample Emissions Report Details

Project-specific reports include detailed project abatement information for wind, solar, or storage projects.

Analysis of congestion and shape impact

Drivers of Carbon Abatement (Tonnes CO2e) - Last Month



Ranking of project relative to all other renewable projects

Identifying project information

Project Details

Capacity	110 MW
Activity	Wind Generation
ISO	ERCOT
Price Node Name	EXAMPLE_RN
Generation Source	ERCOT
Contracted Fraction	100%
Location	33.000, -98.000
Interconnection Voltage	138 kV

Detail of avoided energy and emissions by fuel source

Last Month Carbon Impact - 64%*

	Energy Displaced		Carbon Displaced	
Fuel	MWh	%	tonnes CO_2e	% of tonnes
Coal	2,212	10%	2,291	25%
Gas	16,058	75%	6,860	74%
Wind	936	4%	0	0%
Solar	188	1%	0	0%
Other	1,986	9%	60	1%

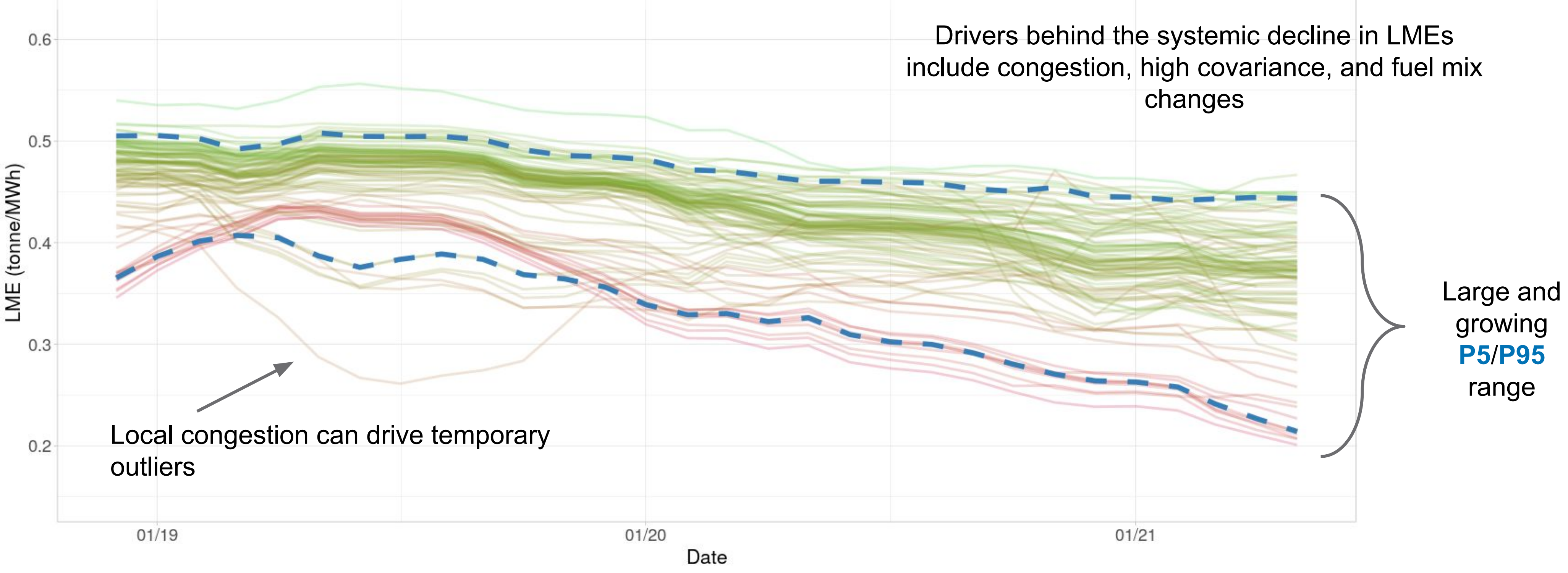
*Percentile among all solar and wind projects

Locational Marginal Emissions

Use Cases

Use case #1: corporates and investors measuring the carbon emissions value of their projects on the grid.

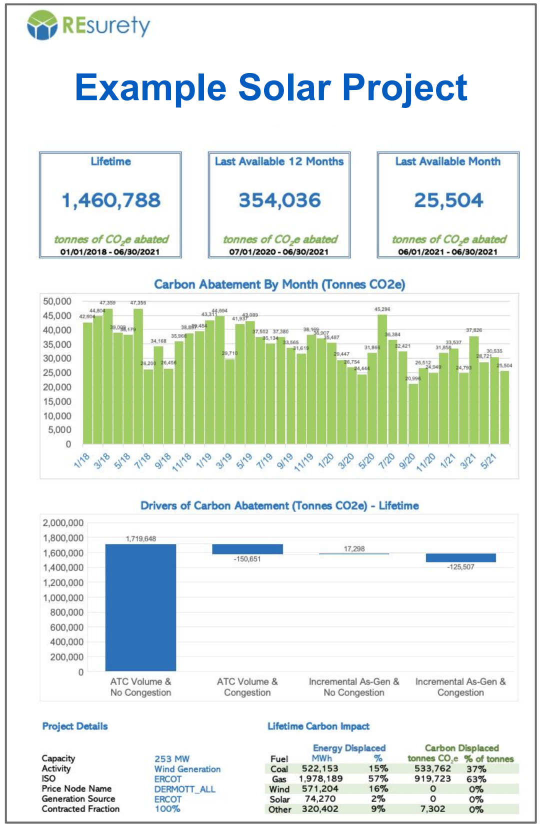
12-Month Rolling average LME by Wind Project



Lines colored by project performance in 2018 (green = highest-abating, red = lowest-abating). High-abating projects in one year tend to be among the best performers in following years, indicating year-to-year stability in relative abatement value among projects.

Use case #2: help developers, investors, corporates identify the most impactful technologies and locations.

Sell Side: Market the carbon impact of the project as a differentiating feature.



Buy Side: Identify the projects with both high returns and high impact, and set up clients well for future disclosure requirements (ex. SEC, GHG revisions)

Identify Solar Plant A as having the largest carbon impact for each dollar invested

Project Name	IRR	Carbon Score (Rank)
Solar Plant A	X.X%	97th percentile
Storage Plant B	X.X%	23th percentile
Wind Project C	X.X%	51st percentile
Wind Project D	X.X%	34th percntile

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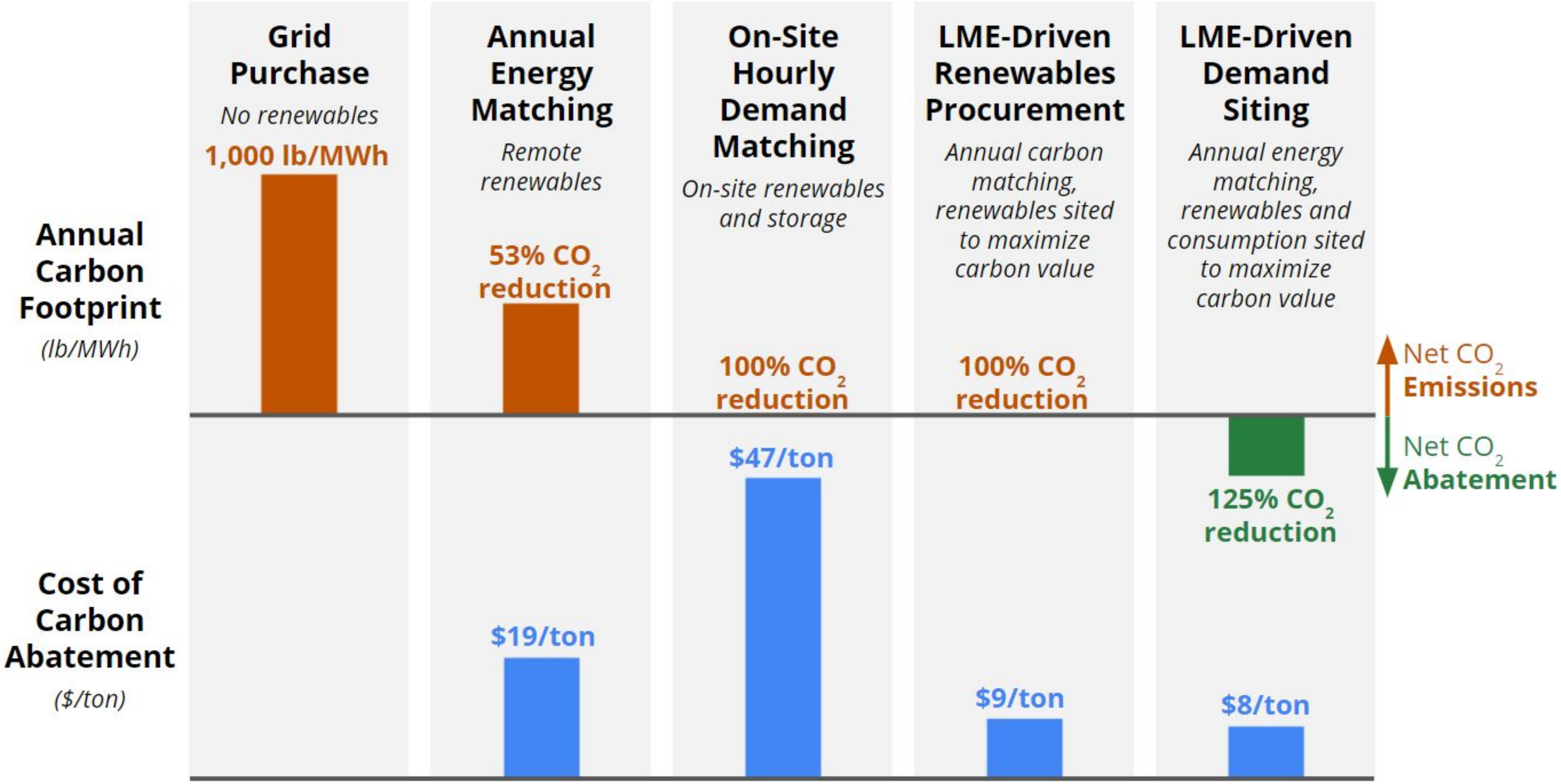

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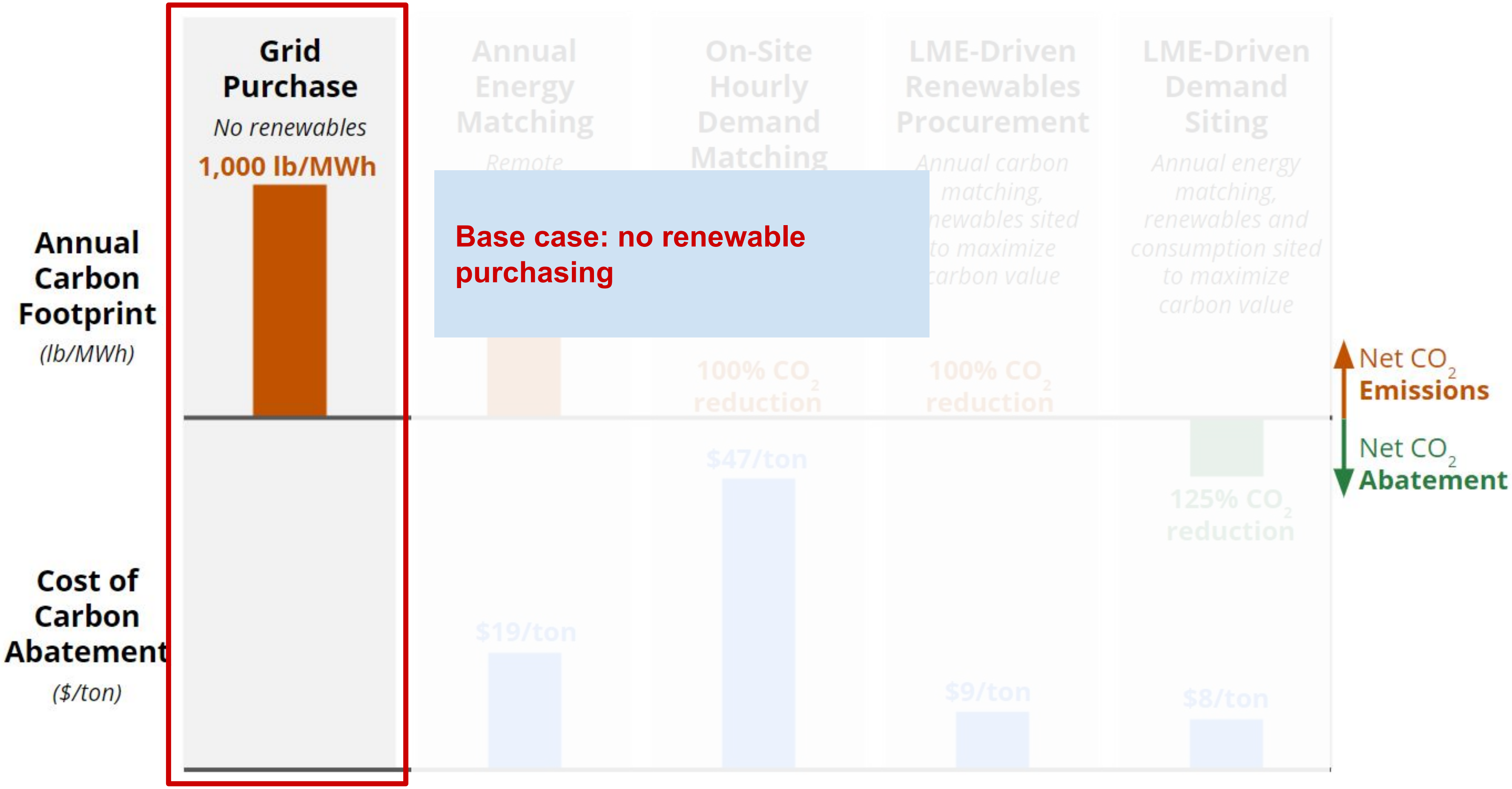

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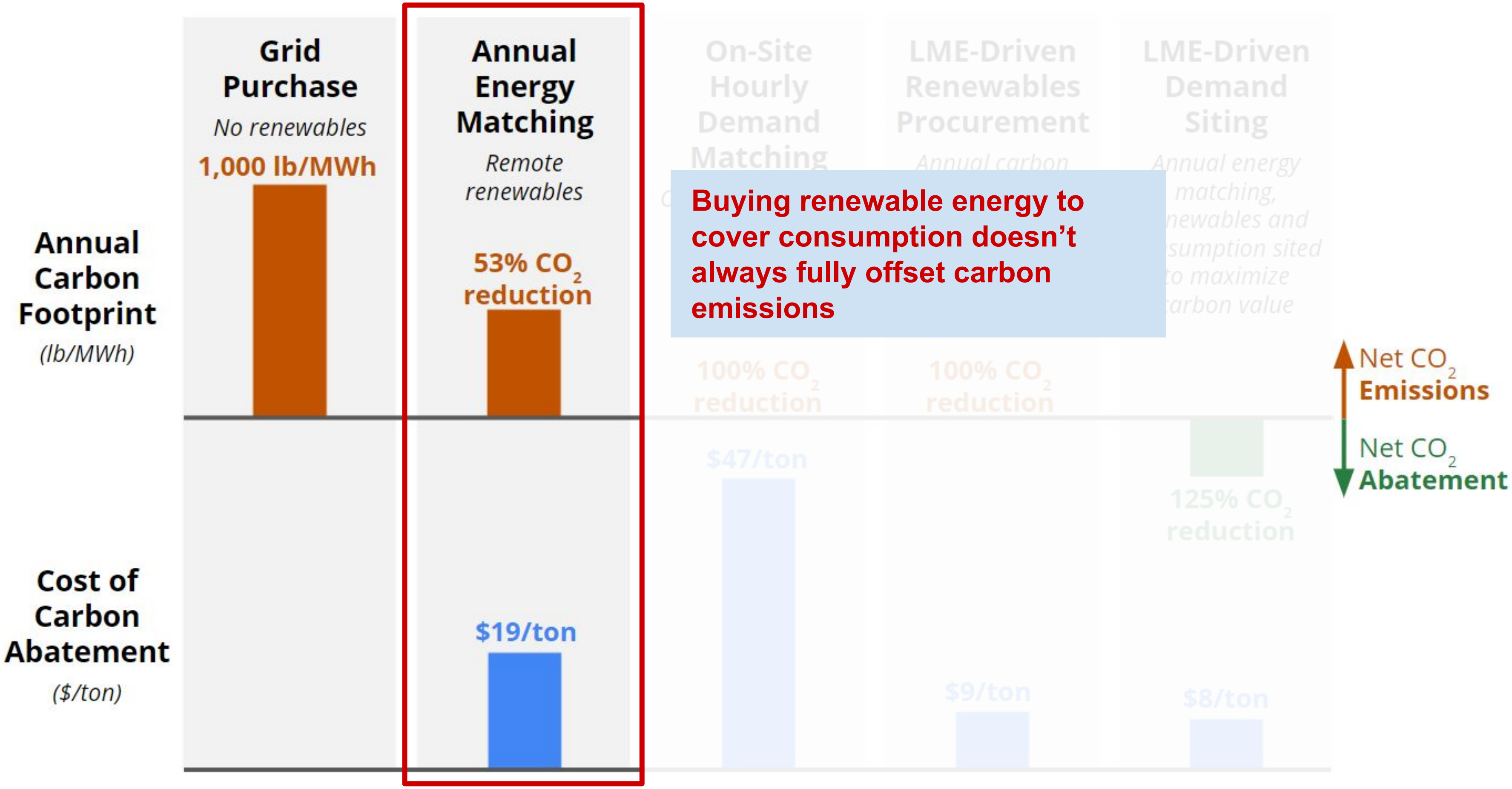

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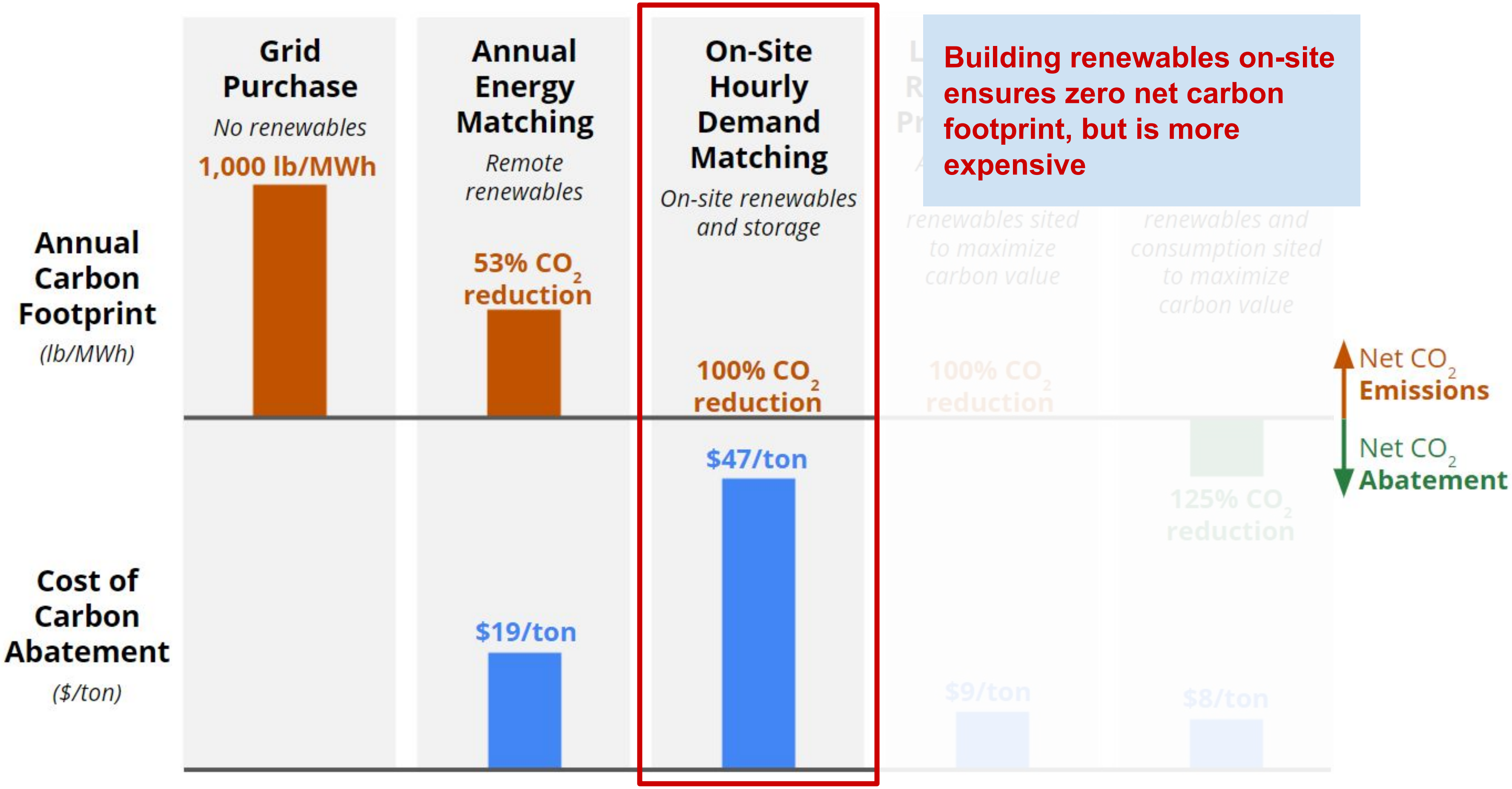
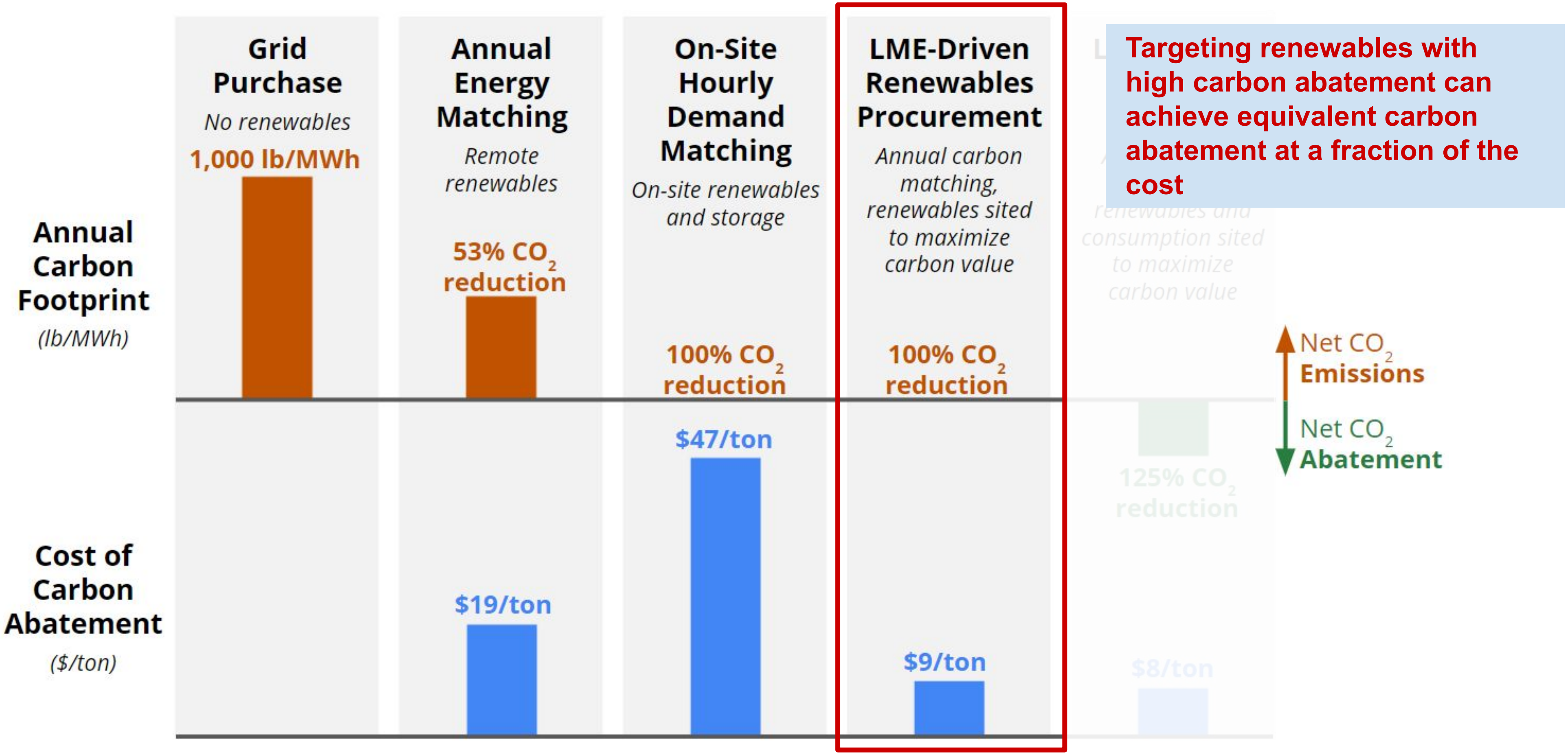


Building renewables on-site ensures zero net carbon footprint, but is more expensive

Use case #2: help developers, investors, corporates identify the most impactful technologies and locations.



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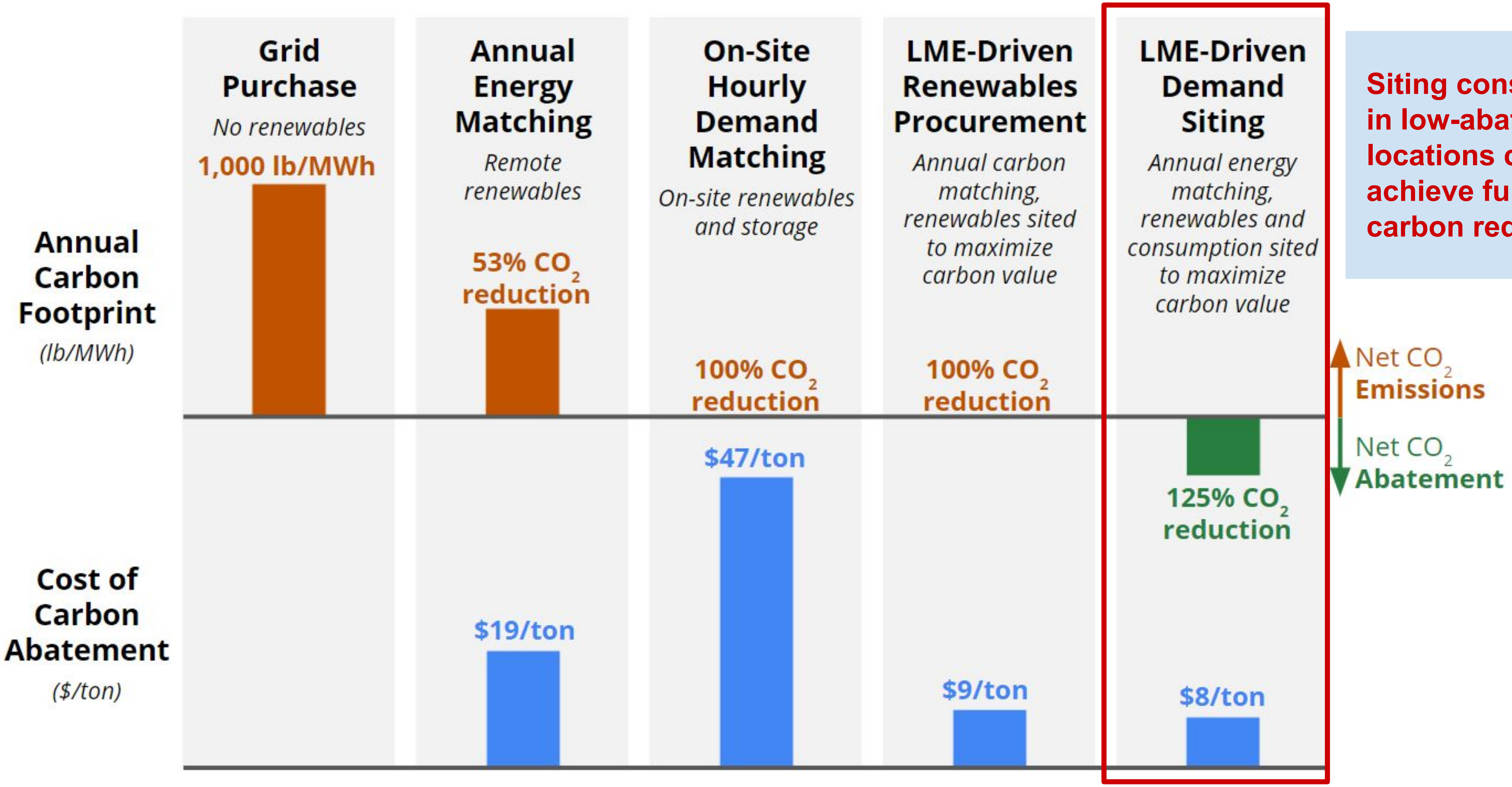
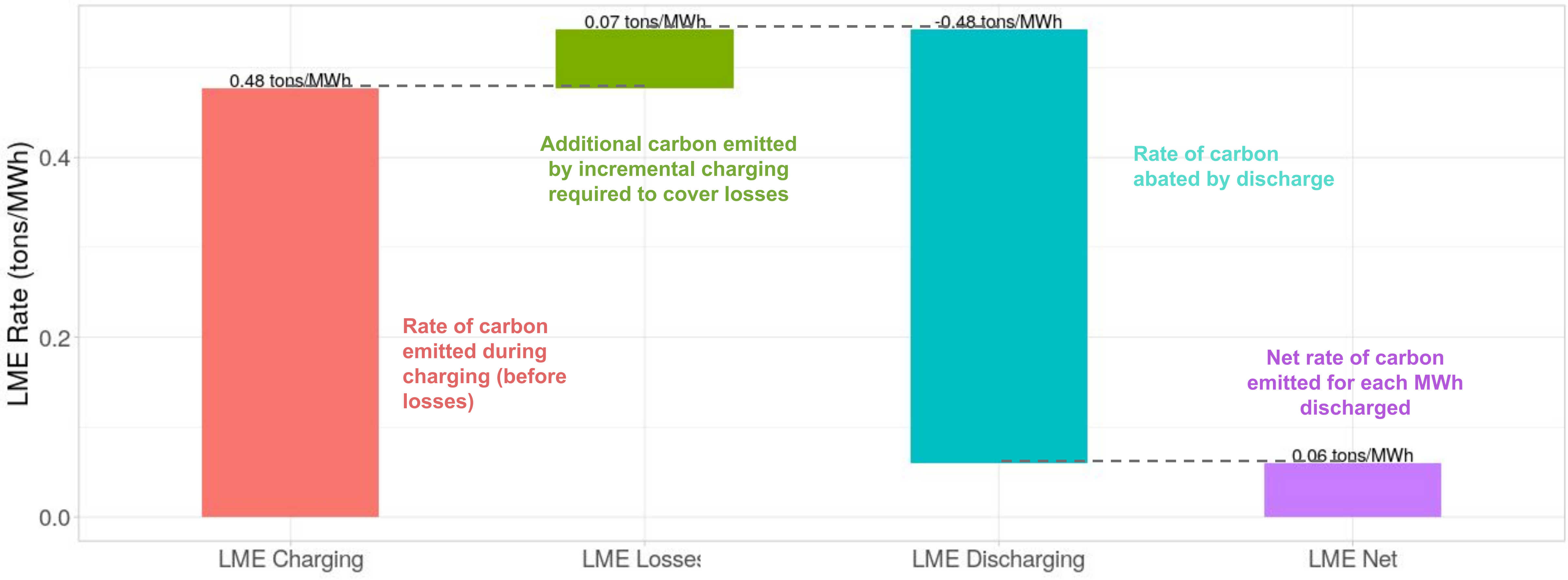


Siting consumption in low-abatement locations can achieve further carbon reductions

Use case #3: measure the carbon impact of storage through hourly, nodal emissions impact data.

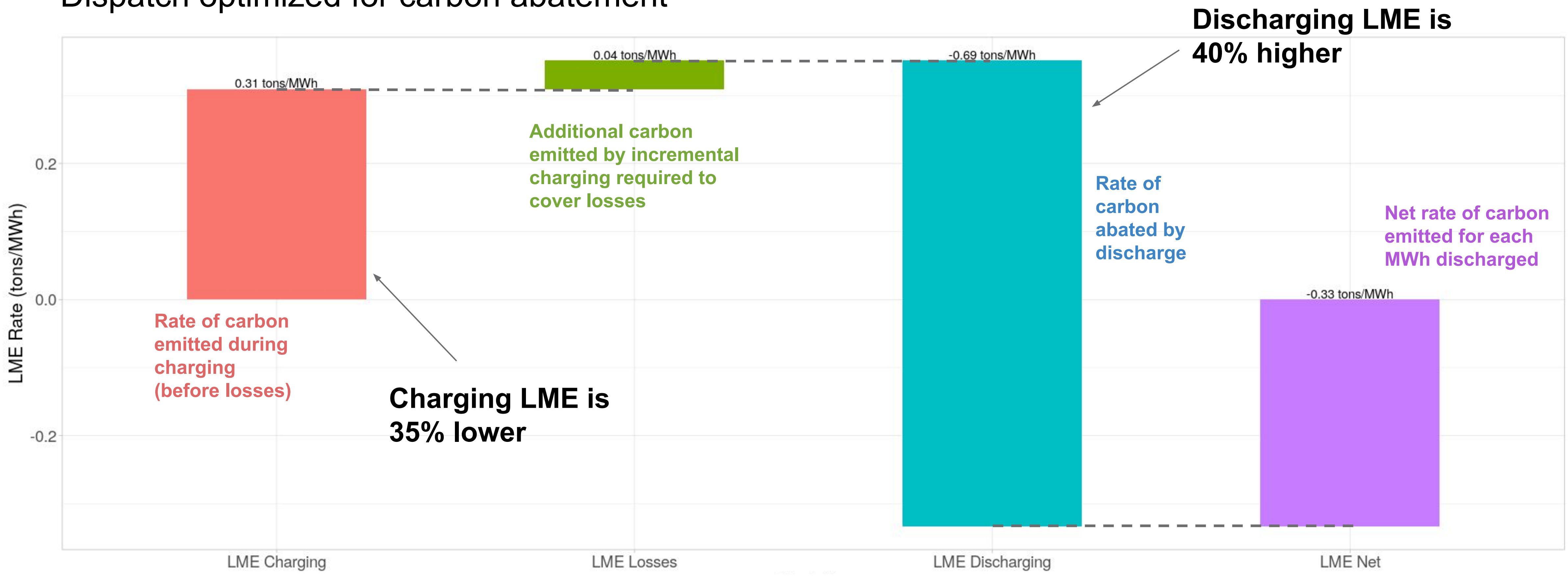
Example analysis for actual ERCOT storage project



Notes: For all components, carbon emitted / abated is normalized by total *discharge* MWh. Loss LME calculated as: LME Charging * Loss MWh / Discharge MWh

Use case #4: Optimize dispatchable resources (like storage) to maximize carbon abatement.

Dispatch optimized for carbon abatement



Notes:
For all components, carbon emitted / abated is normalized by total *discharge* MWh. Loss LME calculated as: LME Charging * Loss MWh / Discharge MWh
Discharge pattern determined by TB1 (“Top / Bottom 1”) algorithm with perfect foresight, in which the battery charges in the single hour with the lowest LME and discharges in the hour with highest LME.

Locational Marginal Emissions

Carbon Accounting Questions

Carbon Accounting: Consolidating Standards

Voluntary carbon accounting, disclosure, and target-setting are increasingly consolidating around three anchor standards. This includes the GHG Protocol for accounting. The SEC's recent proposed rule incorporates large portions (though not all) of these anchor standards.

SEC

SCIENCE BASED TARGETS — DRIVING AMBITIOUS CORPORATE CLIMATE ACTION	**Targets**	
TCFD — TASK FORCE ON CLIMATE-RELATED FINANCIAL DISCLOSURES	**Disclosure**	ISO 14064, CDP, CDSB, GRI, IR, SASB, IFRS, IOSCO, PCAF,...
GREENHOUSE GAS PROTOCOL	**Accounting**	ISO 14064, PCAF,...

Adapted from: https://watershed.com/blog/tcfd-standards-what-companies-need-to-know

Carbon Accounting: Challenges with GHG Protocol

While the GHG Protocol Scope 2 Guidance provides a common framework for corporate GHG accounting, it fails to achieve two key objectives we would expect from such a framework:

- **Allocate total emissions:** The GHG Protocol allows corporates to reduce their footprint to account for purchased RECs. To avoid double-counting, *all* entities must apply an adjusted “residual mix” emissions rate to their non-REC consumption. Since residual mix rates aren’t available in practice, total inventories don’t match total emissions and there is systemic over-counting.

- **Incentivize emissions-reducing decisions:** Since corporate GHG footprints are based on *average* emissions rates, and all RECs are treated equally, interventions designed to reduce maximize emissions reductions are often not accurately reflected in footprints.

Carbon Accounting: LMEs and the GHG Protocol

A carbon accounting mechanism based on LMEs could both allocate total emissions and provide better incentives for decarbonization. However, the GHG Protocol only allows LMEs to be used in limited ways:

- **Location-Based Scope 2:** The GHG protocol expressly forbids use of marginal emissions rates with the **location-based** method for Scope 2 accounting
- **Market-Based Scope 2:** While marginal emissions rates aren't expressly prohibited for the **market-based** method for Scope 2 accounting, they aren't included in the data hierarchy for acceptable emissions rates.
- **Optional Avoided Emissions Reporting:** we believe LMEs are consistent with optional avoided emissions reporting as defined by the GHG Protocol.

Note: the GHG Protocol is silent on *timing* of generation / procurement. It provides no incentive for other initiatives, such as 24/7 matching.

Contact us carbon@resurety.com

or visit resurety.com to learn more

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