SOLUNA

WHITE PAPER

The Carbon Footprint of Project Dorothy:

An LME Analysis

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Table of Contents

1 Introduction
2 Project Dorothy
2 LME Analysis
3 Implications of Analysis
6 Next Steps
7 Future Significance

I. Introduction

Global renewable energy capacity is likely to continue soaring through 2024 and beyond, growing from current capacity of 440 GW to 500 GW or more by the end of next year. As more renewable energy comes online, grid flexibility is challenged by the inflexibility of these non-dispatchable resources (the inability to stockpile wind or solar for future use). The result is spilled, wasted energy. Because the grid cannot absorb abundant renewable energy, producers are unable to sell their unpredictable supply with timely and contiguous demand.

That's why Soluna exists. When production outpaces consumption, renewable suppliers often curtail operations, squandering revenue and electrons. Those who must offload generation onto the grid to achieve external subsidies will often pay the grid to take the energy they've produced (in effect, a negative price per kilowatt).

Either case undermines the profitability of renewable independent power producers (IPPs). Soluna estimates that 30% of renewable IPPs across the U.S. are experiencing curtailment issues, inhibiting their ability to scale.

This drag on efficiency and profitability is a significant impediment to bringing new renewables online. Renewable producers see a challenge to their business model, particularly when it comes to planning returns across a long time horizon. Without an effective way to monetize stranded and curtailed energy, the energy grid will be constrained to absorb additional fractions of renewable energy plants without significant investments in infrastructure.

II. Project Dorothy

Additionality refers to whether an intervention has an effect when compared to a baseline. In the context of renewable energy development, additionality refers to whether an intervention results in clean electrons being produced that would otherwise not be produced.

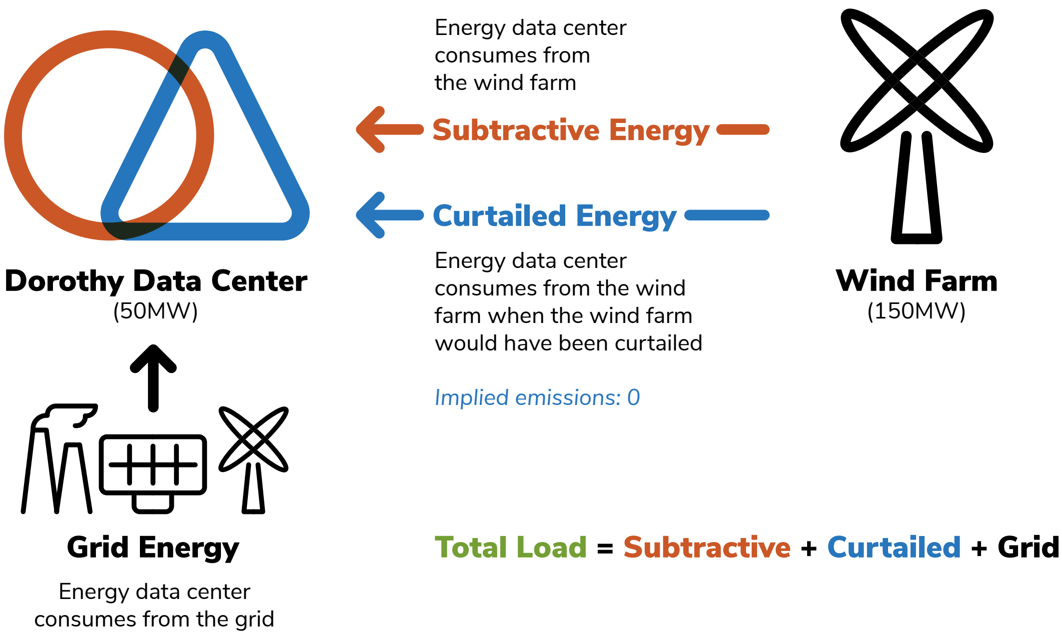
The key innovation that Soluna introduces is combining load and generation to create a more flexible resource on the grid. By co-locating with wind farms, the Soluna data center is able to draw directly off the wind farm in periods of high supply and curtailments, consuming energy that otherwise would have been lost.

Soluna's Project Dorothy is a 50 MW data center co-located behind the meter with a wind farm in the Electric Reliability Council of Texas (ERCOT) West territory. Project Dorothy is powered by a combination of three types of energy: curtailed energy, subtractive energy, and grid energy.

1. **Curtailed energy** is another name for stranded energy. It is energy that otherwise would not make it to the grid or would have to be sold at a deficit to the operator because of lack of demand. It is 100% clean energy, because it's pulled directly from the wind farm, and it has ***zero emissions impact***.

2. **Subtractive energy** is electrons directly from the wind farm that would otherwise be sold to the grid (and instead are sold to Soluna). It is also 100% clean, but it is factored differently because it is not adding additional renewable capacity to the grid.

3. **Grid energy** is a last resort option when neither stranded nor subtractive energy is available. It is a mix of clean and fossil fuel energy that depends on the makeup of the grid. A Soluna data center will consume grid energy only if the nodal or hub prices are below a certain threshold price ($150/MWh).



The result of this mix is incredibly low-carbon electricity. Sourcing energy from the grid means a consumer always gets some mix of clean and carbon sources. The Texas grid, similar to other U.S. power grids, is powered by 61% fossil fuels. By contrast, Soluna pulls the vast majority of its energy directly from the wind farm, and Soluna's data centers are powered by 75% clean energy on average.

III. LME Analysis

REsurety, a software and solutions provider dedicated to accelerating the world's transition to a zero-carbon future, analyzed Soluna's carbon footprint using the metric of locational marginal emissions (LME). An LME analysis measures the tons of carbon emissions displaced by 1 MWh of clean energy added to the grid at a specific location and point in time.

LME analysis is distinct from Scope 2 analysis in that it seeks to answer the question of how additional energy consumption results in total emissions from power generation across the grid. For example, if a new 50 MW load causes 50 MW of coal generation to come online, LME would assign 100% of that carbon footprint to the load.

REsurety did a hypothetical historical analysis based on data provided by the Soluna team, looking at the period from April 2022 to March 2023 and using the following assumptions:

Data

- The Soluna-provided data is aggregated from five minutes to an hour.
- Periods of missing data use a 0 MWh load for subtractive, grid, and curtailed energy.
- During missing time intervals, the site is assumed to be offline with 0 MWh load.
- Data that exceeded the nameplate of 50 MW were considered invalid and replaced with 0 MWh.
- Historic nodal LME calculations are based on REsurety's internal model.

Emissions Calculation

- Total energy consumption (total load) is defined as the sum of subtractive energy consumption, grid energy consumption, and curtailed energy consumption.
- There are no emissions associated with curtailed energy consumption.

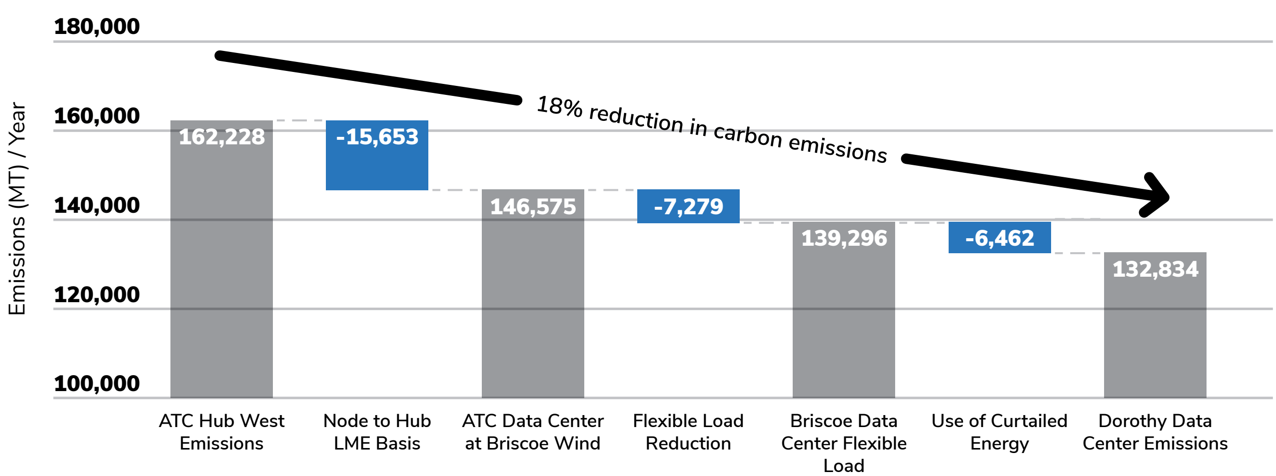
Benchmarking

- Hub and ISO compare the around-the-clock (ATC) LME across all existing solar and wind nodes within ERCOT and West Hub.
- The ATC data center is operating at 50 MWh 24/7.

IV. Implications of Analysis

The independent analysis found that **compared to data center counterparts in ERCOT West territory, Project Dorothy emits 18% less carbon annually.** It should be noted that ERCOT West, a renewable-heavy region, has a lower LME rate than ERCOT overall.

Relative Net Emissions: April 2022 – March 2023



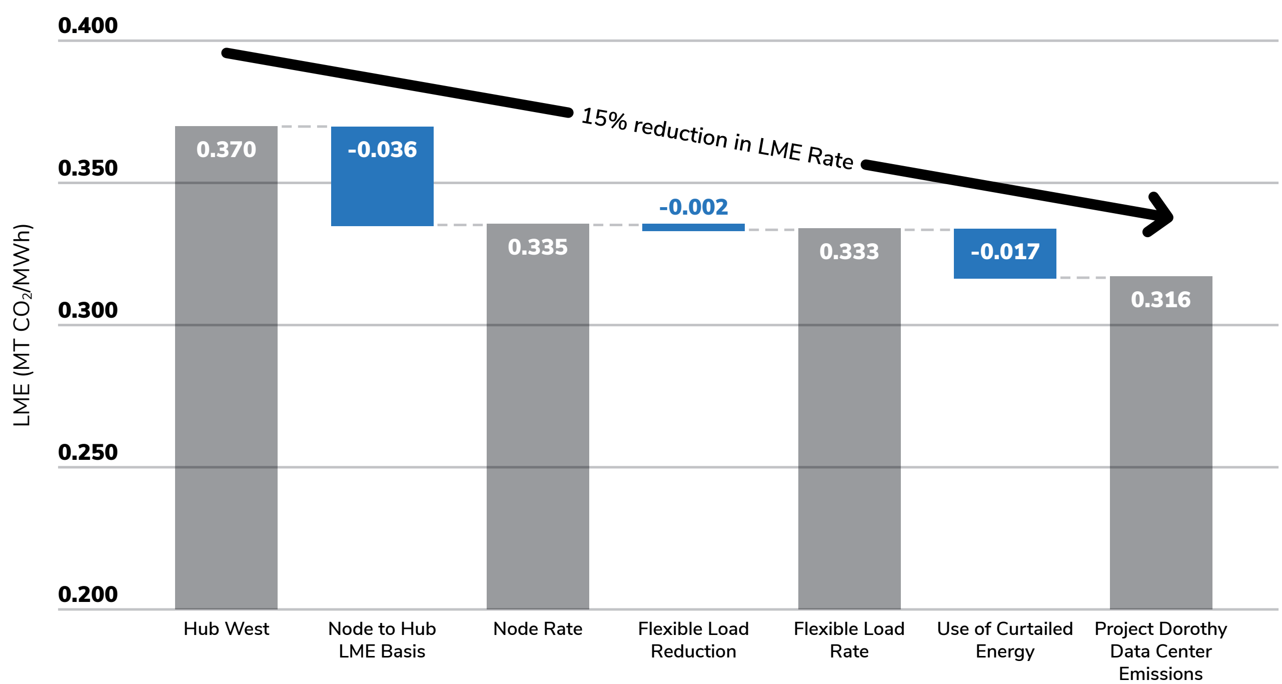
Missing Data is included into the flexible load reduction bracket

Soluna data centers achieve greater efficiency than their ERCOT counterparts thanks in part to their proprietary software MaestroOS™ and proprietary design, the latter of which utilizes advanced aerodynamics in lieu of traditional water cooling. The design enables the energy consumed by the facilities (which is, again, mostly green) to go almost entirely towards powering computers rather than operational needs.

The report found that the impact of flexible load alone on emissions reductions is minimal, accounting for a reduction of about 5% versus a regular MWh in ERCOT. In other words, adjusting consumption based on ebbs and flows of demand does not, by itself, result in significant emissions reductions. **Again, the key innovation is the use of curtailed clean energy that would otherwise not make it to the grid.**

This report on Soluna's performance contrasts the research provided by WattTime on data centers in Texas, as seen in the The New York Times earlier this year. The NYT / WattTime report found an average MW in their sample set induced emissions of 4,188 marginal CO2 tons per year. Using the WattTime methodology, we found that our data center, due to its location in renewable-rich West Texas and its ability to use otherwise curtailed wind energy, induced around 2,657 CO2 tons per year, almost 40% less.

Relative Emission Rate: April 2022 – March 2023



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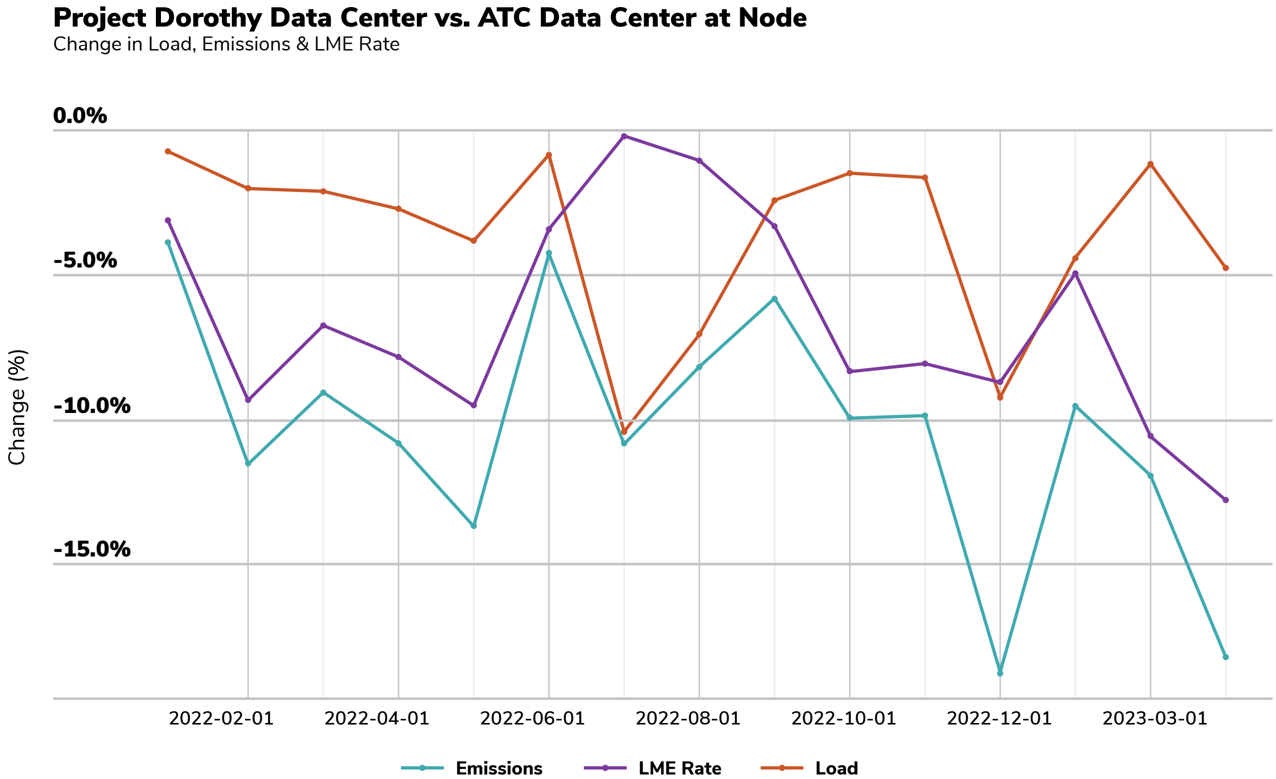


V. Next Steps

The Soluna team views this analysis as a starting point to build upon and plans to supplement it with a scope 2 analysis done by an independent provider.

Carbon emissions are broken down into three scopes:

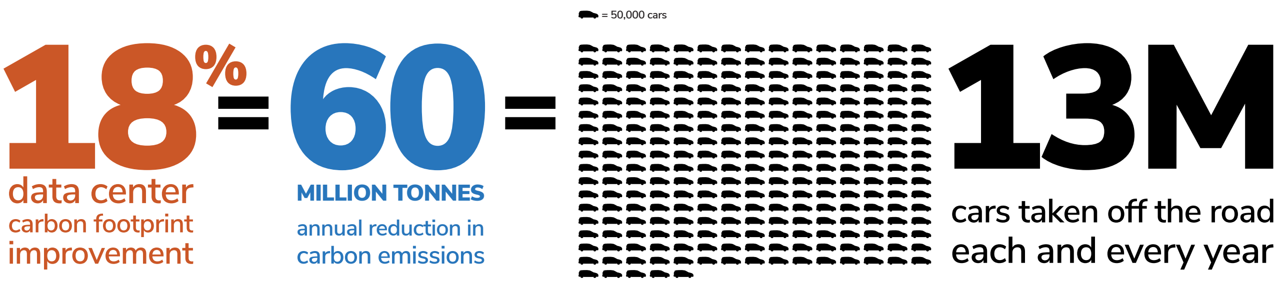
1. **Scope 1:** Direct and owned. Emissions from sources that an organization owns or controls directly.
2. **Scope 2:** Indirect and owned. Indirect emissions associated with energy used by an organization (purchased electricity is an example of scope 2 emissions).
3. **Scope 3:** Indirect and not owned. All other emissions caused by an organization's value chain. This includes both upstream and downstream sources, and is by far the hardest to monitor and measure.

In the meantime, Soluna performed a back-of-an-envelope estimate, assuming 75% of our energy used by Project Dorothy is coming from the co-located wind farm and RECs are eventually retired. We found that the computing in this facility produces 0.10 CO2E Mt per MWh, compared to an average of 0.39 Mt CO2E per MWh average of the U.S. grid in 2022 (a 75% reduction).

VI. Future Significance

As more AI applications come online and are distributed commercially, global computing demand will explode. Already, data centers account for 1% of global carbon emissions, or about 330 million tonnes of CO2. 50% of those emissions come from the United States.

A solution like Soluna's has broad implications for future computing workloads, particularly high-intensity ones that require more computing power and thus more energy. An 18% improvement in data center carbon footprint, if scaled in data centers across the board, could result in an annual reduction in carbon emissions of close to 60 million tonnes of CO2, the equivalent of 13 million cars taken off the road each year. Given the geographic distribution of data centers, nearly half of that reduction would have to happen in the U.S. alone.



Meanwhile, as the world races to electrify, renewable energy production will scale rapidly, but be impeded by the challenge of monetizing stranded energy. Soluna offers renewable IPPs the opportunity to bridge the intermittency gap, stay profitable during times of low demand, and unlock future growth. Scaling this solution could be transformative not only for individual producers but for aggregate production of renewable energy. Without such solutions, many fewer new wind and solar farms will be built.

Soluna's goal is to establish the building blocks for many similar and complementary solutions, helping build a greener and more resilient energy grid by ushering in a future of renewable computing.