Optimizing Direct Air Capture (DAC) for Profitability and Climate Impact: A Comparative Study in New York and California

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Introduction: Direct Air Capture (DAC) technology, essential for combating climate change, needs profitable and low carbon footprint strategies for commercial adoption. This work compares two approaches for optimizing DAC system operations exposed to time-varying electricity price fluctuations, focusing on low-cost electricity periods and increasing net CO_2 reduction. Our study compares DAC deployments in New York (NY) and California (CA), highlighting the "duck curve" in California due to solar energy integration. Optimizing the DAC system with real-time electricity prices is crucial because operators can submit hourly bids based on the electricity price they are willing to accept for its operation.

Methods: The main difficulty in optimizing DAC operation is modeling the nonlinear absorption and desorption rate. To this end, we compare two optimization approaches: a mixed-integer linear programming (MILP) model provided by Zhiyuan Fan based on piecewise linearization of the nonlinear process, which requires commercial-grade solvers and is implemented in Julia, and a new custom in-house algorithm that directly deals with the nonlinear process implemented in MATLAB.

Results: When comparing simulations with similar pricing data (adjusted or unadjusted), the MILP model consistently makes more profit, but our in-house model is up to 745 times faster with a <5% difference in profit from the benchmark, making it useful for generating electricity demand bids. Incorporating CO_2 emission adjustments to the electricity price changes the DAC's profit and overall behavior, emphasizing the importance of considering climate factors in economic simulations. Seasonal variations also affected outcomes; the CA case excelled in summer due to solar power, while the NY case thrived in spring and fall.

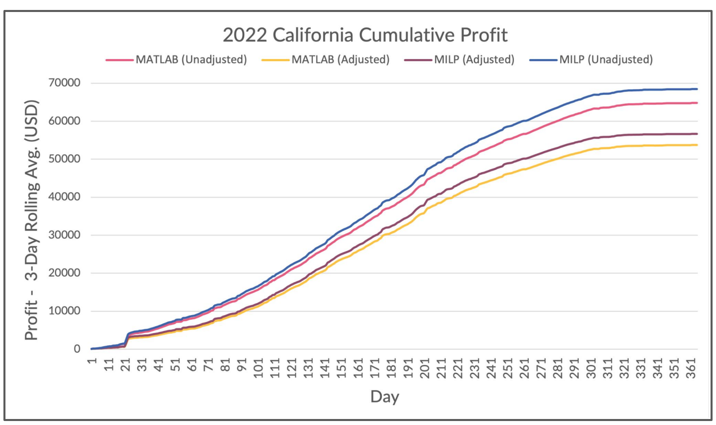

Figure 1. 2022 California Cumulative Profit

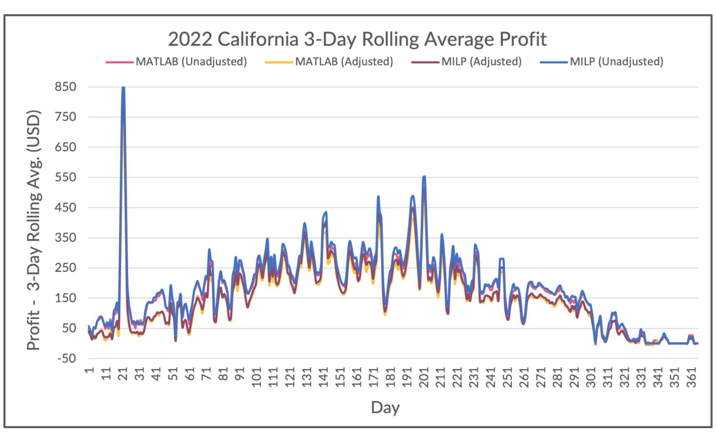

Figure 2. 2022 California 3-Day Rolling Average Profit

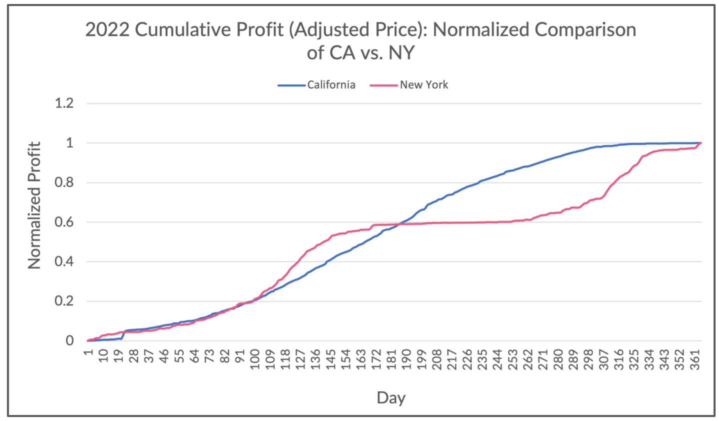

Figure 3. 2022 Cumulative Profit (Adjusted Price): Normalized Comparison of CA vs. NY

Conclusion: The study concludes that maximizing DAC profitability and climate benefits require strategic optimization and real-time pricing alignment.

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