Does Renewable and Energy Storage Integration Green the Electric Grid?

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Introduction

Peak demands dictate both the cost and carbon footprint of electricity generation. Peak-based pricing plans can help industrial consumers to flatten their demand but Behind-the-Meter battery storage solutions have not been able to provide good ROI in the past. In this research, we explored the true potential for cost reduction vs carbonization with various pricing models and formulated the storage-driven electricity bill reduction as an optimization problem (Min Bills). The results show that for a typical industrial house's electric bill can be reduced upto 25%. However at the it increases customer's lifetime CO2 footprint by upto 9% with current mass storage battery technologies .

Background and Methodology

Electricity utility rate profiles impose sharp demand charges on the peaks to overcome the cost for peaking generators and costlier imports. With the objective to minimize the customer's electricity bills using energy storage in the presence of peak-based hybrid pricing plans and TOU pricing plans, we consider the following sources in our analysis

- Electricity pricing profiles
  - TOU + Peak : Seattle City Light which implies demand charges according to TOU (Time of Use) and Peaks,
  - TOU + Flat Rate : HG&E (Holyoke Gas & Electric Department which implies charges according to Flat pricing on Energy and demand charges on highest Peaks.
- Industrial Consumption - Medium to Large Commercial Datasets from two sources logging consumption every 15 minute interval annually.
- Battery - Commercial mass Storage Battery as Tesla Megpack
- Fuel Mix - Granular 15 minute spaced fuel mix from EIA and respective ISO.

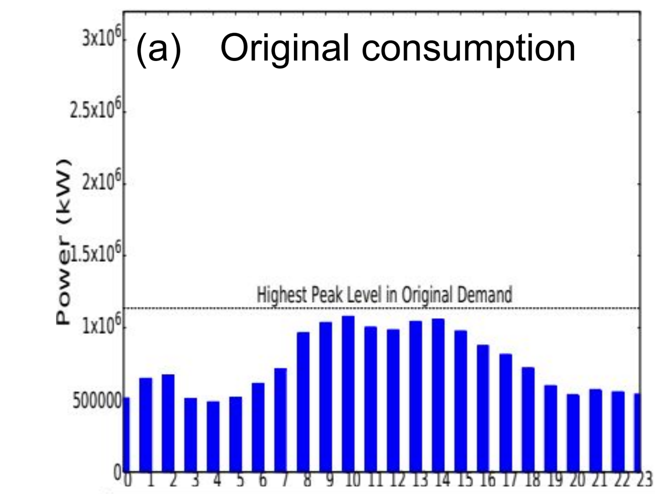
Problem Statement and Formulation

We address the problem of deploying energy storage at a customer's premise to cut their electricity bill. We define the problem of estimating net cost savings using energy storage as follows, *given the customer's power consumption traces, electricity pricing plan, and size and attributes of the battery, the problem is to find an optimal battery charging-discharging pattern that minimizes the customer's electricity bill in the presence of TOU or peak-based hybrid pricing plans.*

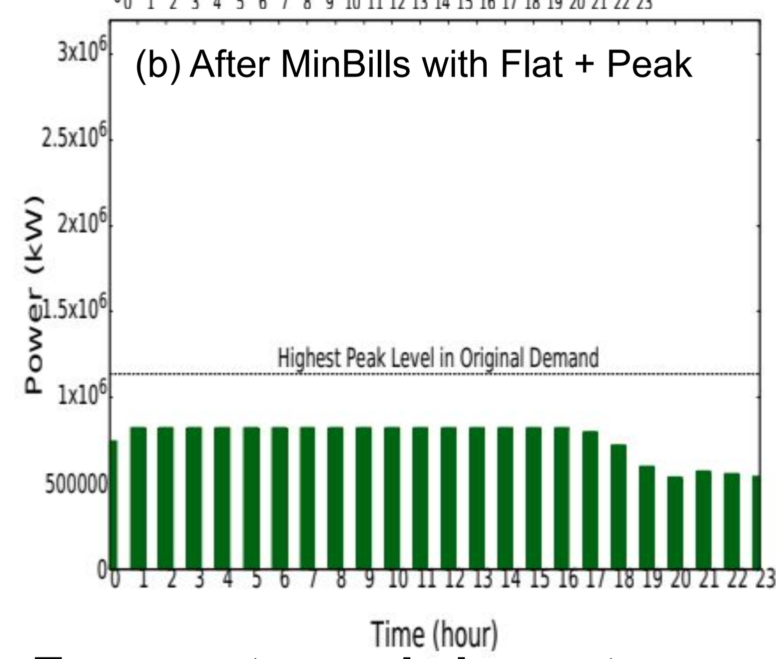
MinBills Optimization framework

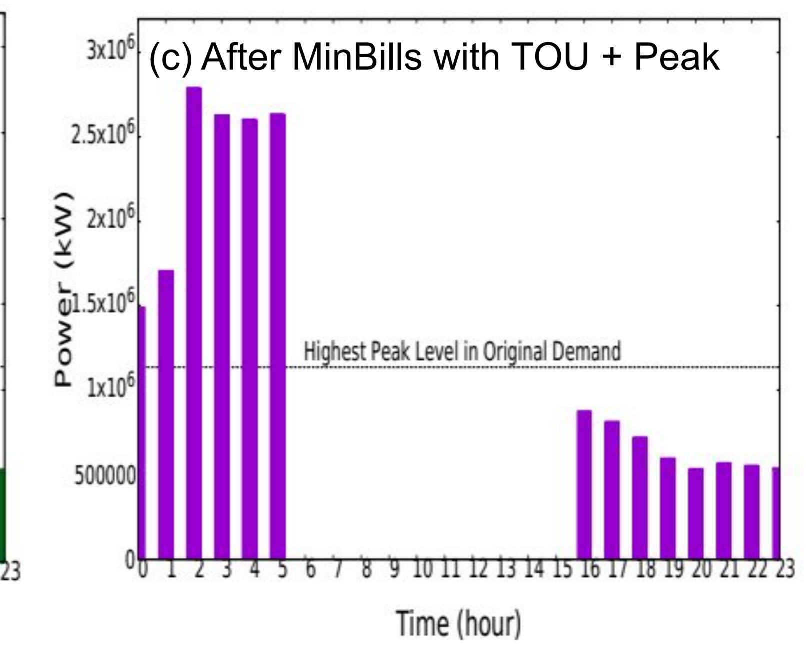
Minimize $\sum_{i=1}^{T} m_i + L * c^0$ the peak-based cost in $/kW is presented by C^0

Experimental Evaluation



In our experiments we vary battery capacity to understand how it affects the savings, peak demands, energy consumption, CO2 footprint, and lifetime return-on investment (ROI).



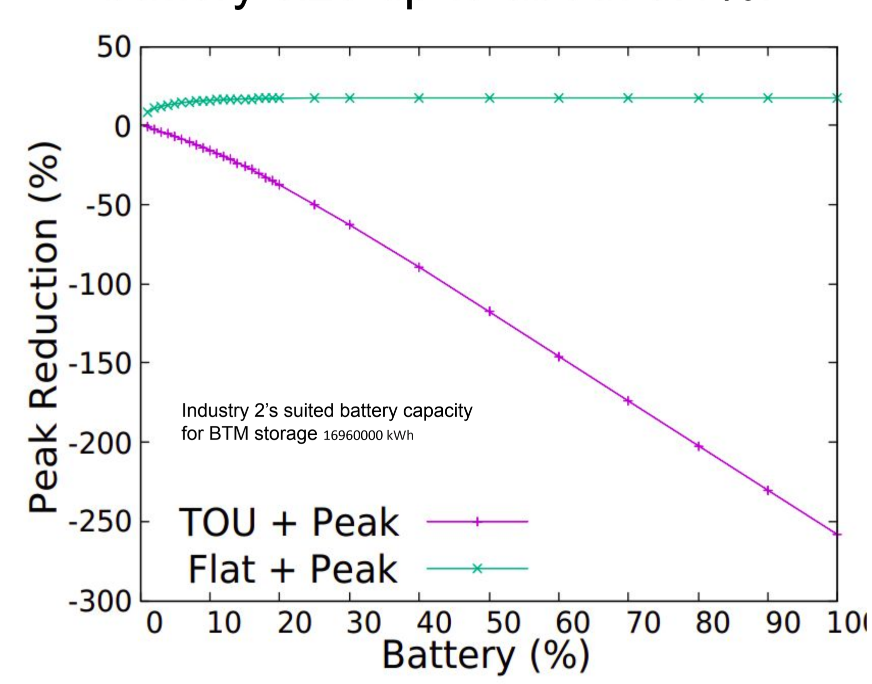


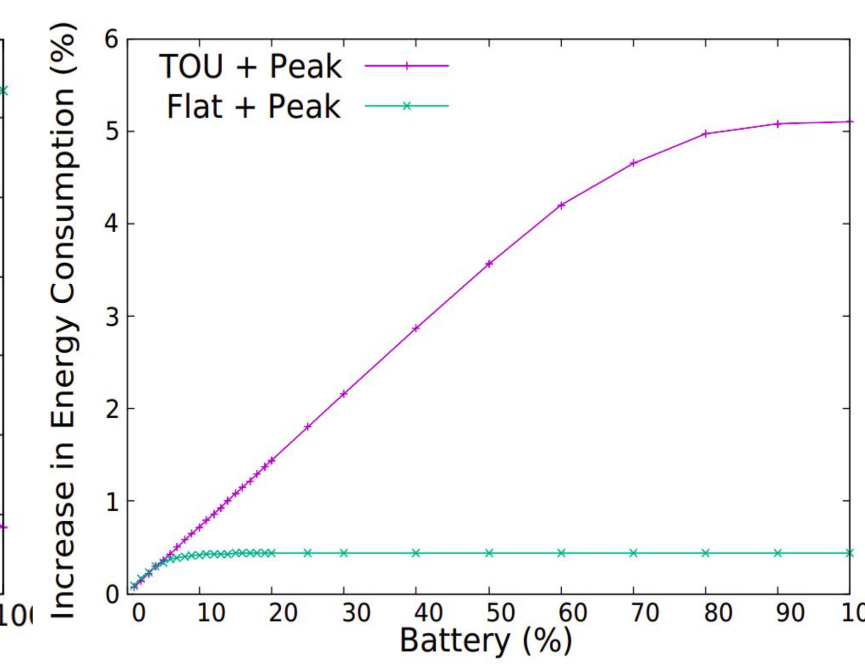
Energy storage's impact on peak demand

- Flat+Peak pricing, reduces peak demand up to 17.5%.
- TOU+Peak pricing, peak reductions can be negative.

Increase in overall energy consumption

- Flat+Peak, average energy consumption can increase up to 0.6%. The increase flattens out after battery capacity is at 25% of daily consumption
- TOU+Peak pricing, energy consumption steadily increases with battery size up to about 5.1%.





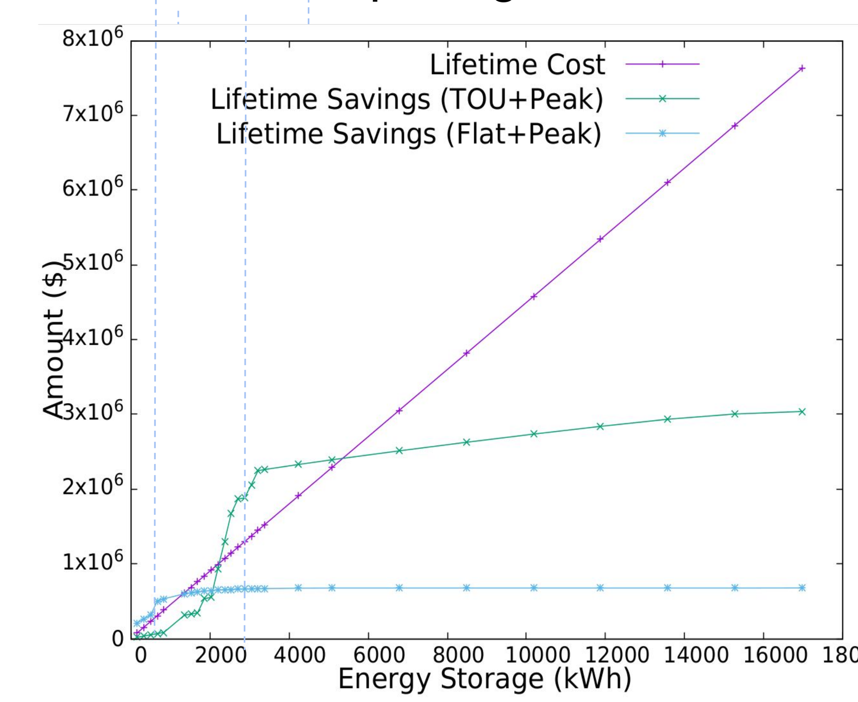
References

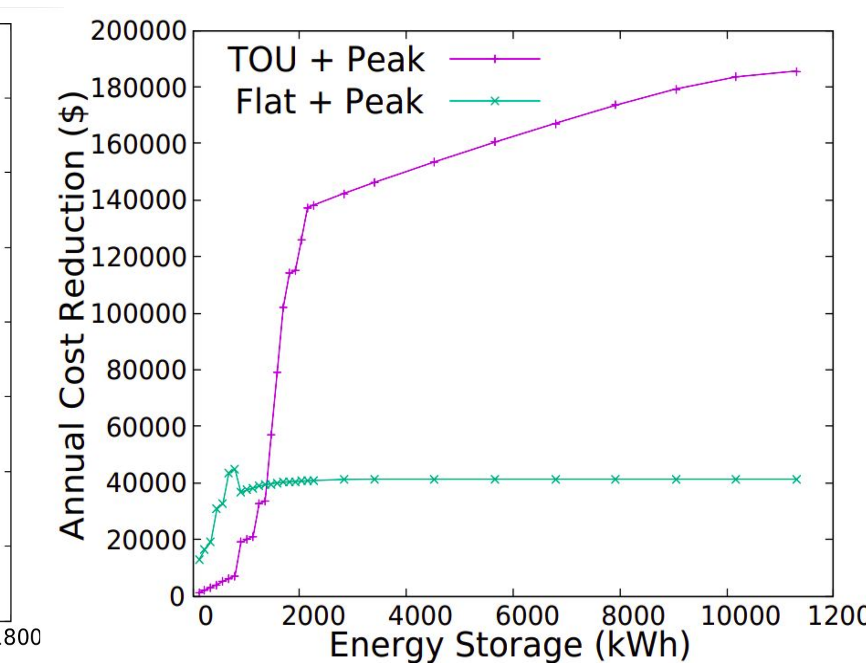
1. M. Arbabzadeh, R. Sioshansi, J. X. Johnson, and G. A. Keoleian. The role of energy storage in deep decarbonization of electricity production. Nature communications, 10(1):1–11, 2019.
2. Y. Chandio, A. Mishra, and A. Seetharam. Grid peaks: Employing distributed energy storage for grid peak reduction. In 2019 Tenth International Green and Sustainable Computing Conference (IGSC), pages 1–8. IEEE, 2019.
3. E. S. Hittinger and I. M. Azevedo. Bulk energy storage increases United states electricity system emissions. Environmental science & technology, 49(5):3203–3210, 2015.

Economic Analysis

High Potential Savings from Storage

- TOU+Peak pricing can cut the bills up to 28%
- Flat+Peak pricing can cut the bills up to 6.25%



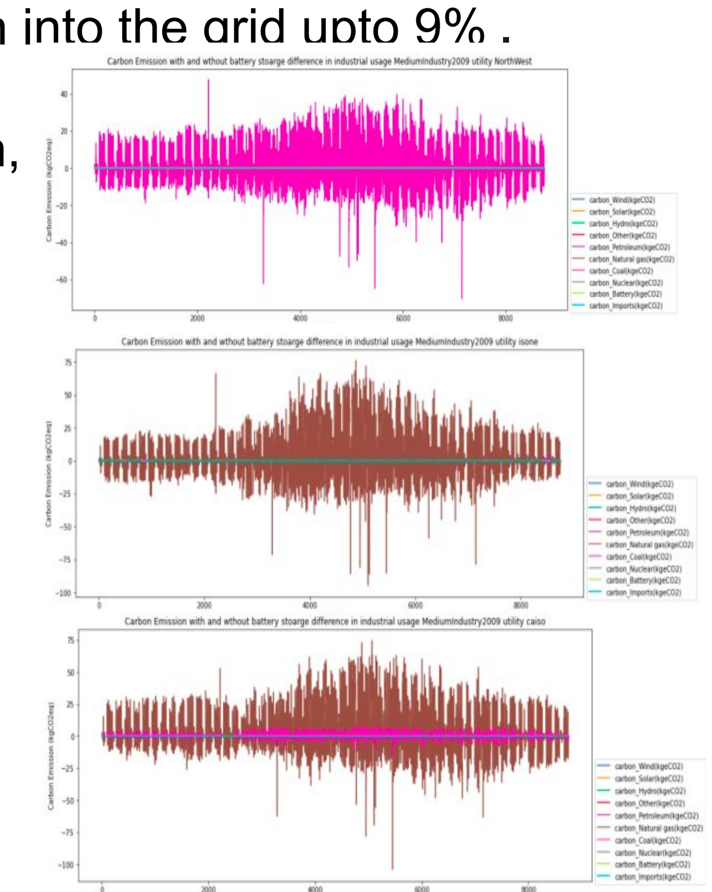


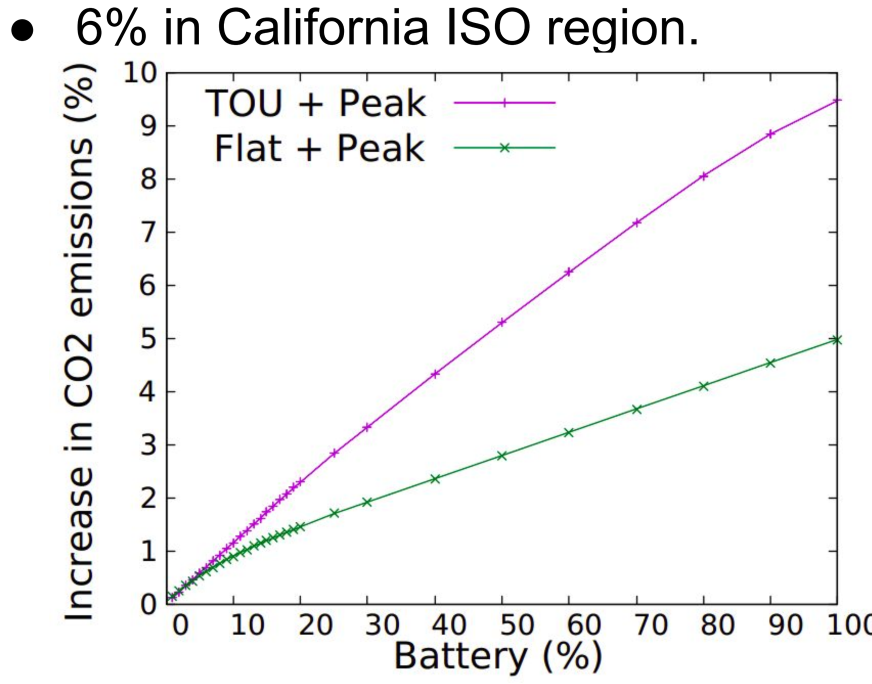
ROI (Return on Investment) maximizes upto 55-56% of storage system cost

Environmental Analysis

BTM storage increases Carbon emission into the grid upto 9% .
The findings for some of the regions are

- 1-3% in the NorthWestern ISO region,
- 7% in New England ISO region and
- 6% in California ISO region.





Conclusion

Our evaluations using raw power consumption data from two industrial customers and real electricity pricing plans from two utilities showed that energy storage solutions could save up to 25% in electricity bills and result in a positive ROI. However, given greedy battery charging-discharging, energy lost in battery inefficiencies, and the high lifetime carbon footprint of the batteries, current storage-based solutions can potentially increase the customer's lifetime CO2 footprint by millions of kg CO2eq.

Acknowledgements

I thank EIA (U.S. Energy Information Administration) for detailed reports and utilities to provide granular energy generated datasets for my work. I also thank Seattle City Lights for their support in assisting me with the breakdown of the industrial billing structure.