Does peak shaving & storage integration green the grid?

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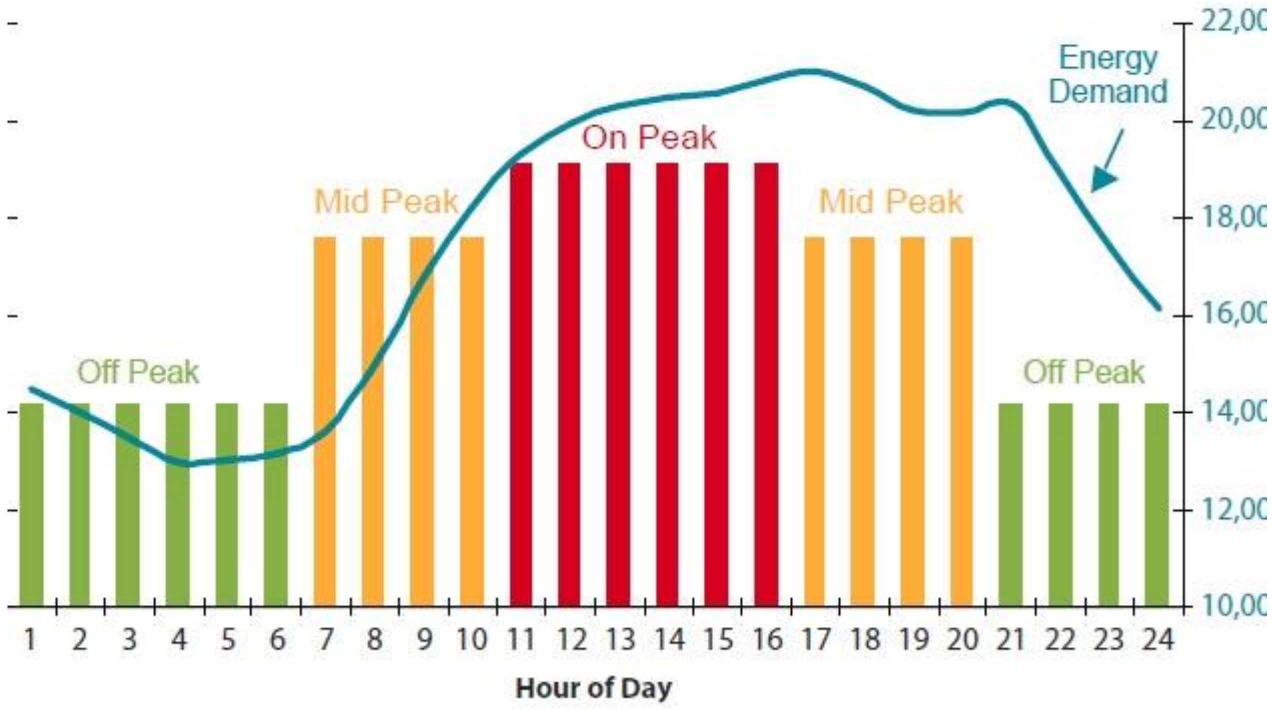
Motivation

- Earth's temperature is rising
  - 2020 tied the record for being the hottest year (with 2016)
- Temperature increase chiefly driven by human-caused greenhouse gas emissions
- Burning of fuel for electricity and heat is among the largest sources of CO2
  - Emissions proportionate to the energy generated and peak demands served
- Cutting peak demands could also save a utility's capital, operational costs

Peak-based variable electricity pricing



- Utilities offering pricing plans to incentivize peak shaving
- Seattle City Light (SCL) Downtown N/W rates:
  - Peak period (day times):
    - Energy: $0.1045/kWh
    - Peak surcharge: $8.38/kW
  - Off-peak period (night & holidays):
    - Energy: $0.0690/kWh
    - Peak surcharge: $0.27/kW

Commercial energy storage solutions

- To help industrial customers avoid peak pricing, several commercial battery systems now available
  - Tesla Powerpack, Megapack
  - LG ESS Battery
  - Voltpack from Northvolt


Problem statement

- Given today's peak-based variable pricing and commercial battery storage systems, determine:

1. Can batteries shave customer's peak demands?
2. Can batteries save enough on bills to result in a positive return-on-investment?
3. Can battery-based peak shaving solutions reduce the customer's CO_2 footprint?

MinBills optimization formulation

- Devised MinBills, an optimization formulation to minimize the customer's electricity bills using battery with peak-based variable pricing plans

$$b_1 = B \tag{1}$$

$$b_{T+1} = B \tag{2}$$

$$b_t = b_{t-1} + I * s_{t-1} - I * \frac{d_{t-1}}{e}, \forall t \in [2, T+1] \tag{3}$$

$$b_t \leq C, \forall t \in [1, T] \tag{4}$$

$$b_t \geq 0, \forall t \in [1, T] \tag{5}$$

$$s_i \geq 0, \forall i \in [1, T] \tag{6}$$

$$s_i \leq C/4, \forall i \in [1, T] \tag{7}$$

$$d_i \geq 0, \forall i \in [1, T] \tag{8}$$

$$d_t \leq b_t + s_t * e, \forall t \in [1, T] \tag{9}$$

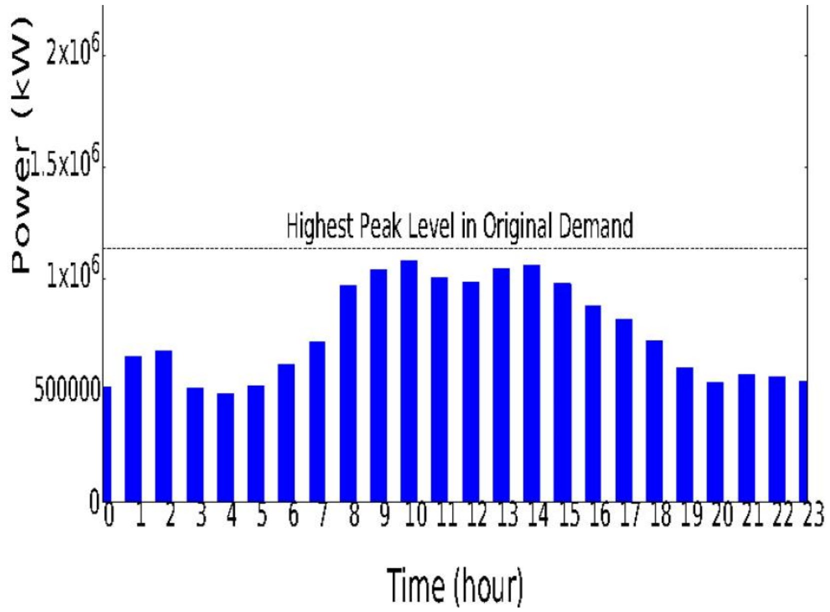
$$m_i = (p_i + s_i - d_i) * I * c_i, \forall i \in [1, T] \tag{10}$$

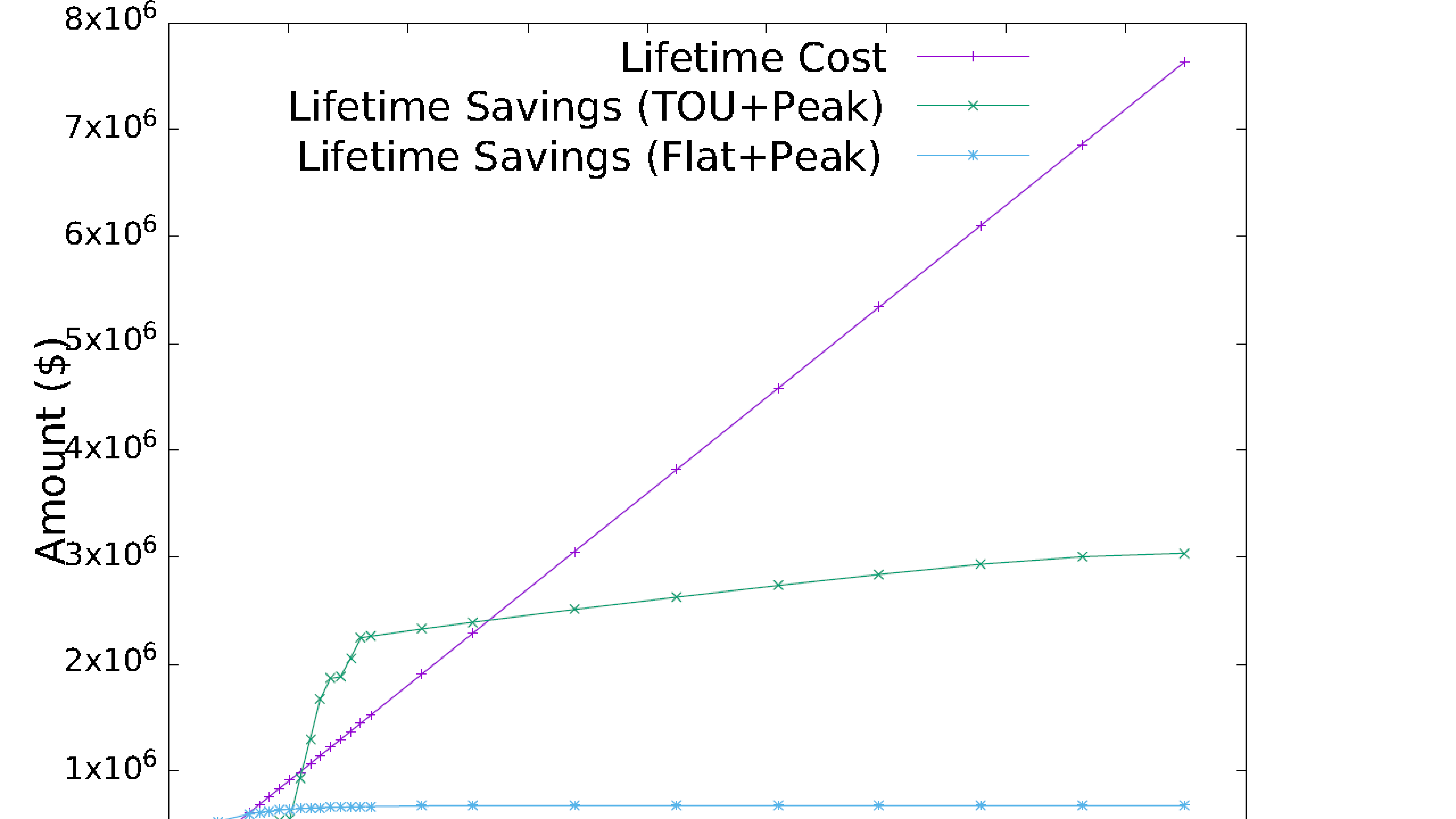
$$l_i = p_i + s_i - d_i, \forall i \in [1, T] \tag{11}$$

$$l_i \leq L, \forall i \in [1, T] \tag{12}$$

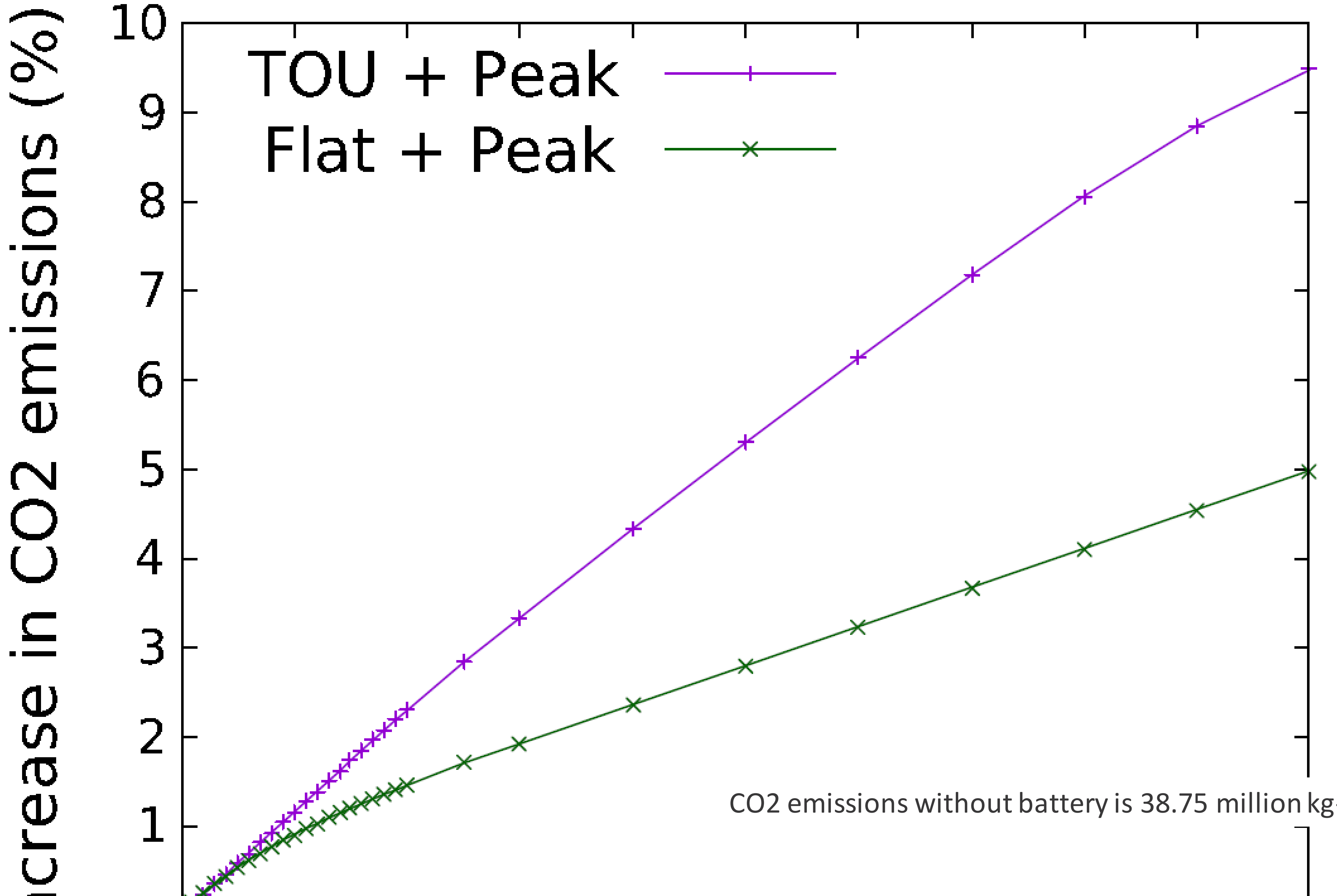
MinBills Evaluation using real-world data

- Real power traces from two industrial houses
  - Power data logged every 15 minutes for a year
  - Industry 1
    - Daily consumption 11.31 MWh
    - Tallest annual peak: 792 kW
  - Industry 2
    - Daily consumption 16.96 MWh
    - Tallest annual peak: 1.38 MW
- Existing commercial electricity pricing plans from
  - Seattle City Light
  - Holyoke Gas and Electric
- Commercial battery from Tesla





Lifetime Cost
Lifetime Savings (TOU+Peak)
Lifetime Savings (Flat+Peak)
Amount ($)
8x10^6
7x10^6
6x10^6
5x10^6
4x10^6
3x10^6
2x10^6
1x10^6



CO2 emissions without battery is 38.75 million kg-CO2eq.

Conclusion

- Energy storage with peak-based variable pricing
  - Can cut peak demands
  - Amount to significant cost savings over the system's lifetime
  - But increase the customer's CO_2 footprint

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