Customized Predictions of the Installed Cost of Behind-the-Meter Battery Energy Storage Systems

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Problem Statement & Objective

Existing literature on the costs of battery energy storage systems (BESS) tends to...
1. report measures of central tendency (mean or median)
2. report costs in terms of $/kW or $/kWh

Hence, existing literature is not adequate for individualized predictions:
1. A measure of dispersion is necessary to generate a margin of error around the best estimate. In real-world deployment, costs associated with balance-of-system design, integration, & installation can vary widely.
2. Existing studies do not estimate costs at every possible scale.

**Objective:** Use real-world data of BESS installations to estimate a statistical model that predicts:
1. installed cost given kW, kWh, year of installation, and other project-specific factors
2. an appropriate margin of error that reflects real-world variability in installed costs
Data Source & Summary Statistics

Data Source: Self-Generation Incentive Program (SGIP)
- provides incentives for behind-the-meter energy storage
- available to ratepayers of investor-owned utilities in California
- program data publicly available at www.selfgenca.com

Market Share by Manufacturer

- Tesla: 73.2%
- 8 next largest manufacturers: 21.9%
- 39 smallest manufacturers: 4.9%
Methods

Several statistical models were tested against the data using cross-validation.

The models were evaluated with standard measures of goodness-of-fit & precision:
- adjusted $R^2$
- root mean squared error

Power rating was dropped (for now):
- kW makes negligible improvement to prediction when kWh is already accounted for.
- The SGIP sample contains relatively little variation in the energy-to-power ratios. (“multicollinearity of kWh and kW”)
- The estimation procedure can’t reliably distinguish between power-related and energy-related cost scaling within the SGIP sample.

**Chosen Model:** quasi-“Cobb-Douglas”

$$\ln(\text{Installed Cost}) = \alpha_t + \beta \ln(kWh) + \gamma X + \epsilon$$

- $\alpha_t$: year fixed effect
- $X$: vector of additional co-variates
- $\epsilon$: error
Preliminary Results

Estimated Equation for the Residential Sector

\[
\ln(\text{Installed Cost}) = 0.83 \ln(\text{kWh}) - 0.05 \mathbb{1}\{\text{StandAlone}\} + 0.06 \text{HHI} - 0.07 \ln(\text{Exp.}) + \hat{\alpha}_t
\]

- **Higher installed costs in counties with less competition among installers**
  - Auxiliary analysis finds that, when Tesla is the installer, it does not exercise market power.
  - Effect is stronger among 3rd-party installers.
  - Effect is absent in non-residential sector.

- **Learning-by-Doing among installers**
  - estimated learning rate: 4.3% lower cost for each doubling of cumulative experience

- **Trends over time:**
  - large drop in cost from 2016 to 2017
  - increasing costs from 2017 to 2021
  - Trends likely reflect module price of Tesla Powerwall, which dominates the market.

- **SGIP incentives modestly inflate costs**
  - causality established in separate analysis that relies on the quasi-random step-down in generosity of SGIP incentives
  - $1 of subsidy = 5 cents higher installed cost (i.e. 95 cents lower cost, on net, for consumer)

### Herfindahl-Hirschman Index
ranges from 1 (monopoly) to 0 (perfect competition)

- Cumulative Experience of the Installer (kWh installed)

<table>
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<th>Year</th>
<th>(\hat{\alpha}_t)</th>
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