SAND2021-13029C

Sandia National Laboratories

Exceptional service in the national interest

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

Andrew G. Benson

Org. 8811

DOE-OE Energy Storage Program Peer Review

Oct. 26-28, 2021

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

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.

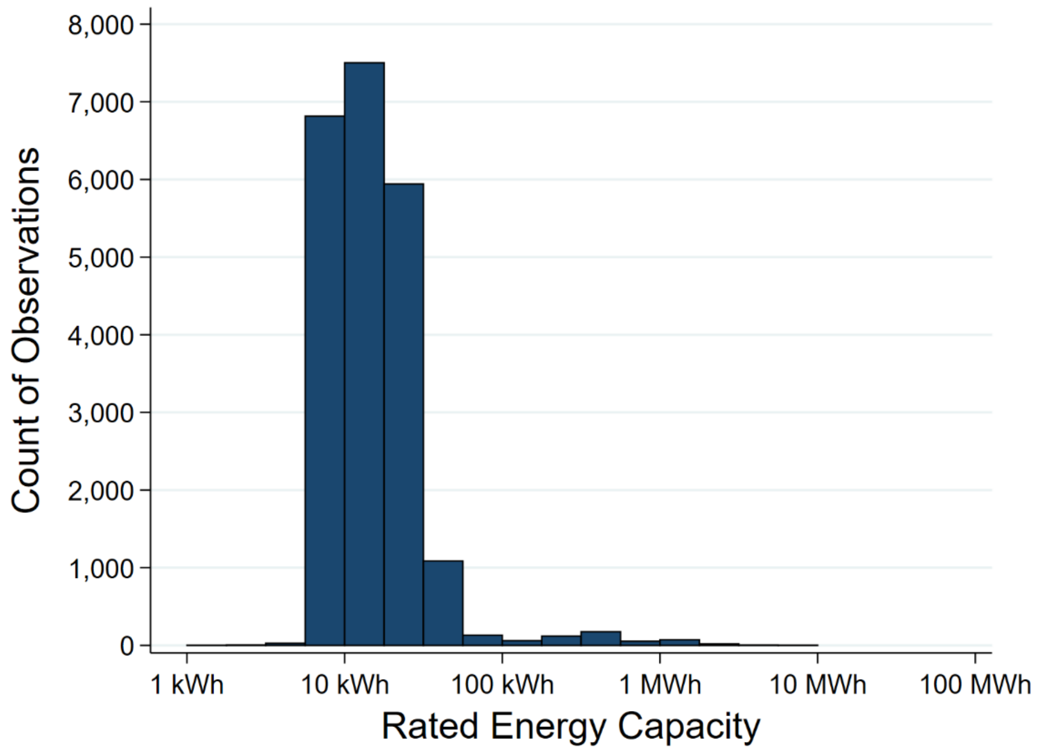
Objective: *Use real-world data of BESS installations to estimate a statistical model that predicts:*

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*

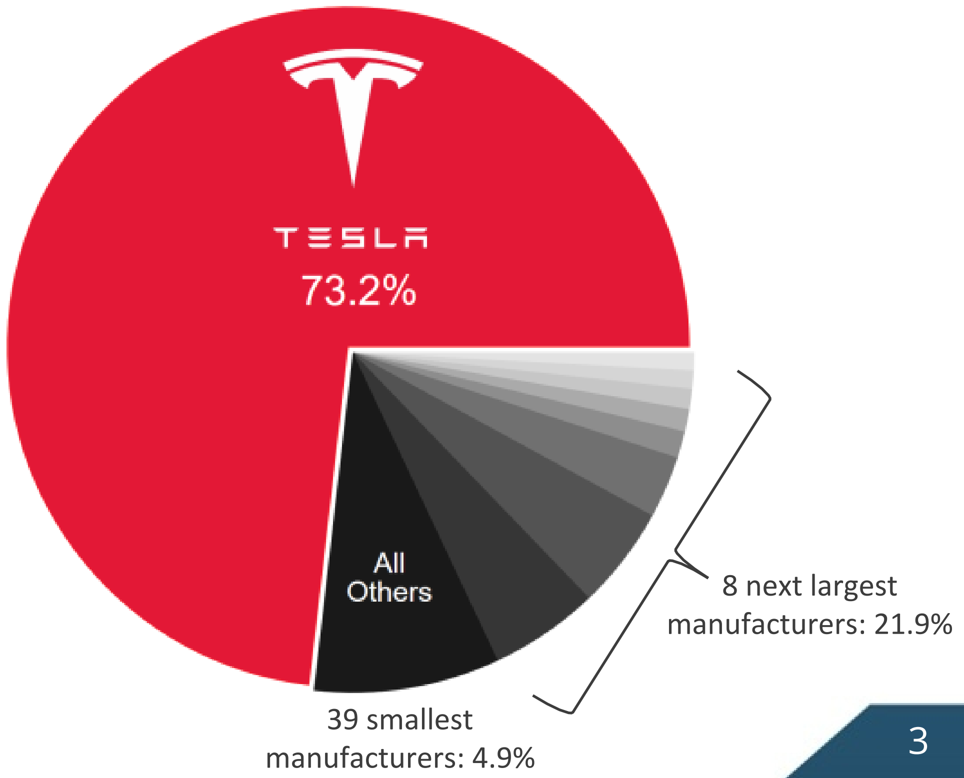
Data Source & Summary Statistics

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



Methods

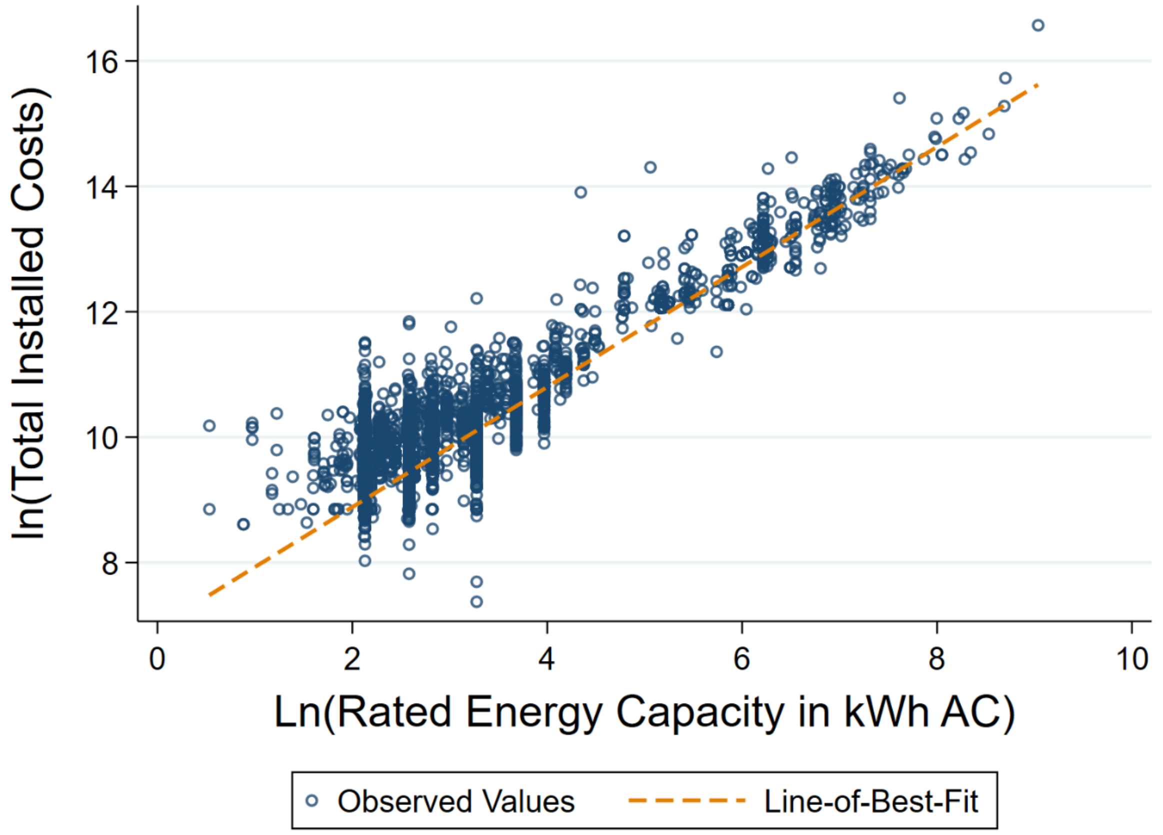
Several statistical models were tested against the data using cross-validation.

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"

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

error (ε); year fixed effect (α_t); vector of additional co-variates ($\boldsymbol{X}$)

Preliminary Results

Estimated Equation for the Residential Sector

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

$\beta < 1$: economies of scale

Interpretation: "A 1% increase in energy rating increases costs by 0.83%."

= 1 if the BESS is not paired with distributed generation
= 0 otherwise

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

Cumulative Experience of the Installer (kWh installed)

Year	$\hat{\alpha}_t$
2015	8.01
2016	8.20
2017	7.50
2018	7.68
2019	7.84
2020	7.99
2021	8.12

- 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)*
- Learning-by-Doing among installers
  - Estimated Learning Rate: 4.3% lower cost for each doubling of cumulative experience
- 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.