

# Operations and Maintenance Considerations for PV+Storage

Jal Desai<sup>1</sup>, Nicole D. Jackson<sup>2\*</sup>, Natalie Gayoso<sup>2</sup>, Thushara Gunda<sup>2</sup>, and Andy Walker<sup>1</sup>

<sup>1</sup>National Renewable Energy Laboratory, <sup>2</sup>Sandia National Laboratories

\*jal.desai@nrel.gov



## Motivation

- Photovoltaic (PV) technology is a rapidly developing technology in response to supply-demand balancing needs.
- Although there is some understanding of costs associated with PV O&M, costs associated with emerging technologies such as PV plus storage lack details about the specific systems and/or activities that contribute to the cost values.

## Study Objectives

### Study Focus:

Establish a baseline understanding of utility-scale photovoltaic (UPVS) operations and maintenance (O&M) cost drivers

- This study aims to:
  - Identify specific factors and drivers contributing to utility-scale PV plus storage (UPVS) systems O&M costs,
  - Understand how particular storage technologies were selected
  - Learn how O&M data is being collected and used by owners and operations
  - Catalog ongoing challenges and needs in this space from field.

## Methods

- Obtain insights from industry experts
  - Online questionnaire
  - Semi-structured interviews
  - Snowball sampling
    - Word of mouth
    - Advertising in industry publications

### Questionnaire

- Contact Information
- Site Details
- Selection and Purpose of Energy Storage
- O&M Activities
- Data collection & Analysis
- Challenges and Needs

### Data Processing

- Multiple selection cleaning
- Qualitative coding
- O&M Log Reviews

### Data Analysis

- Statistical analysis
- Visualizations

**Figure 1.** Overview of questionnaire, data processing, and data analysis used in this study.

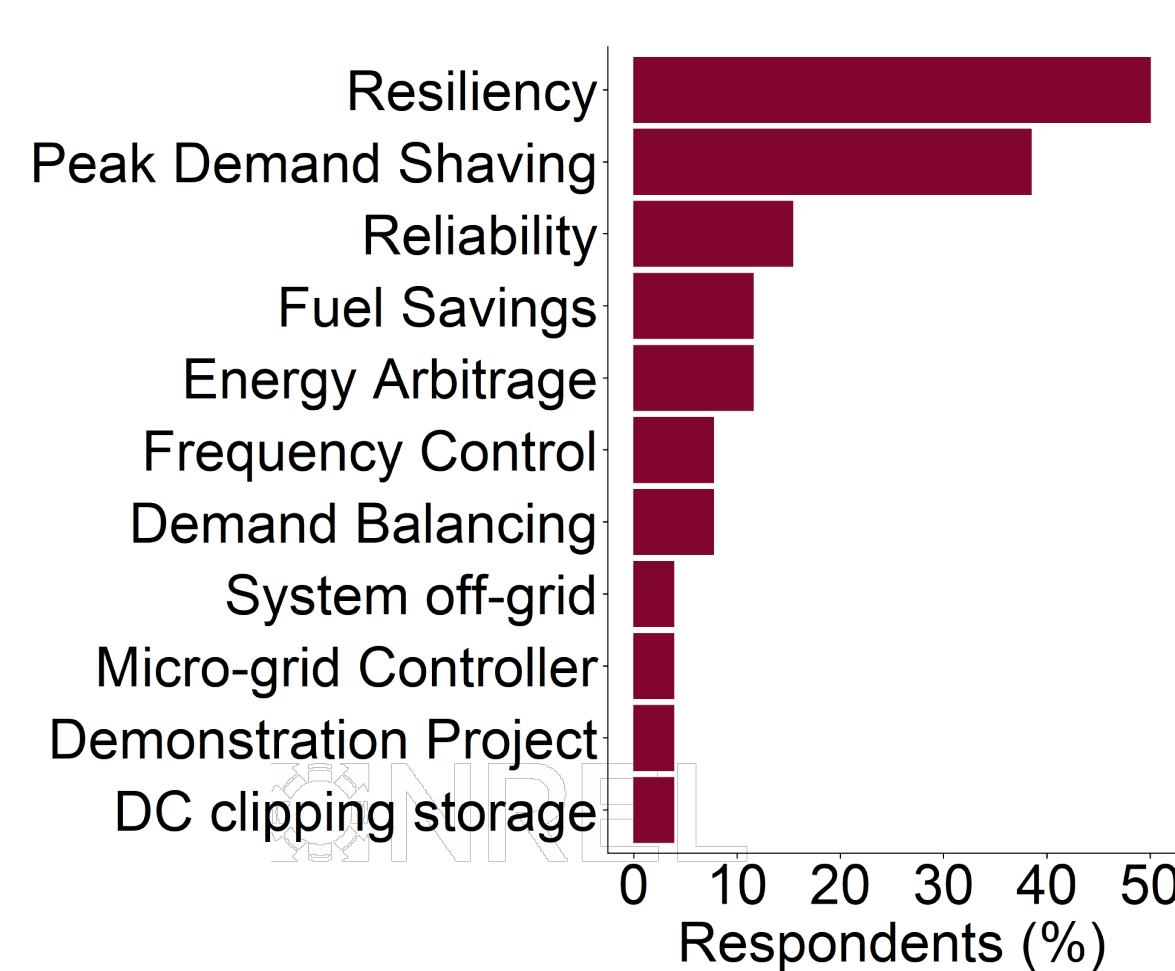
- Insights from 81 sites (14 partners) with co-located PV+Storage captured Geographic distribution spans 13 states
- Total PV system size: 51.1 MW
- Total Battery Storage size: 64.1 MWh
- Site age: Mean = 5.2 years, Range = 0-11 years
- Storage technologies: Li-ion (77%), Lead Acid (23%)
- Metering location: Back (69%), Front (19%)
- Percentage of storage technology's energy source coming from PV at the site: Mean = 51.6%

## Selection and Purpose of Energy Storage

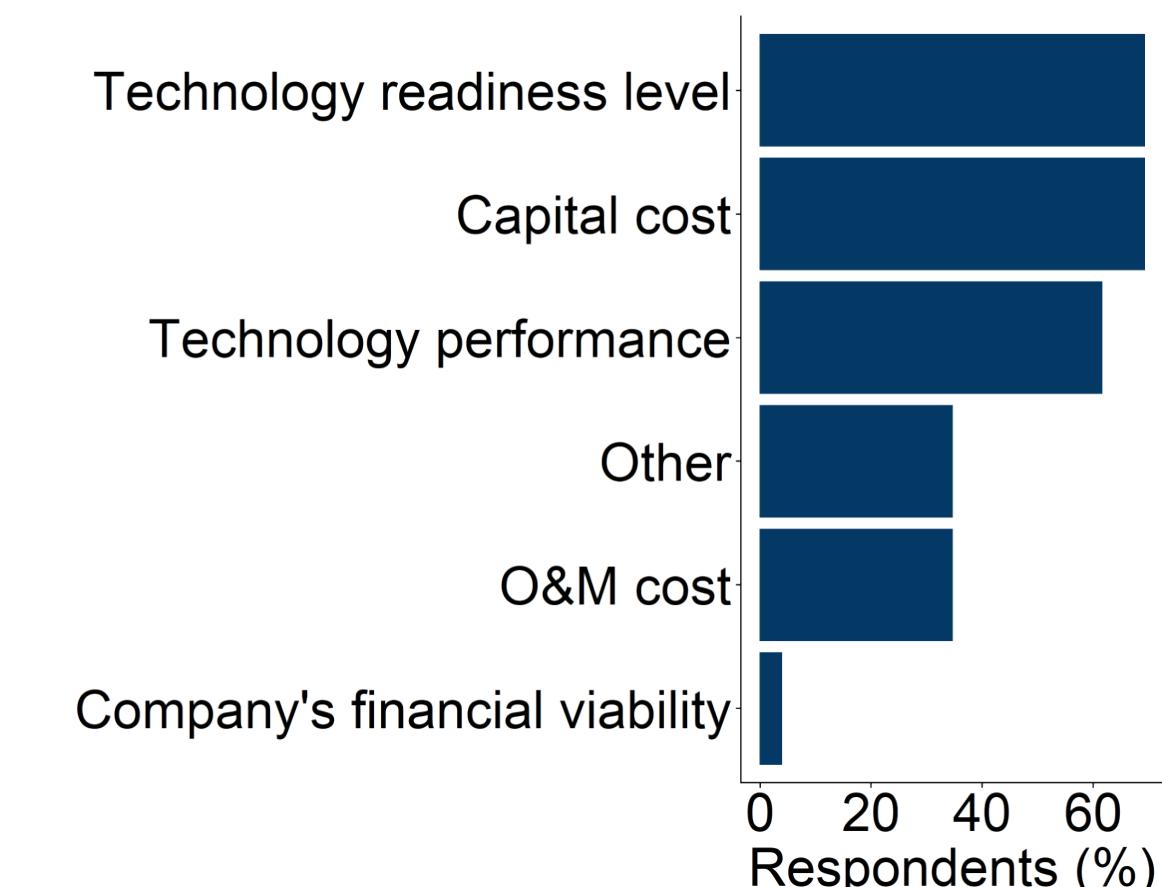
- Storage is most often cycled daily

**Table 1.** Mean reported values for storage system parameters by storage technology

Parameter	Storage Technology	
	Li-ion	Lead Acid
Capital cost (\$ per kWh)	487-594	500-667
Expected Lifetime (years)	13.6±1.3	15.4±3.6
Degradation rate (%/year)	1.4±0.2	1.57±0.4



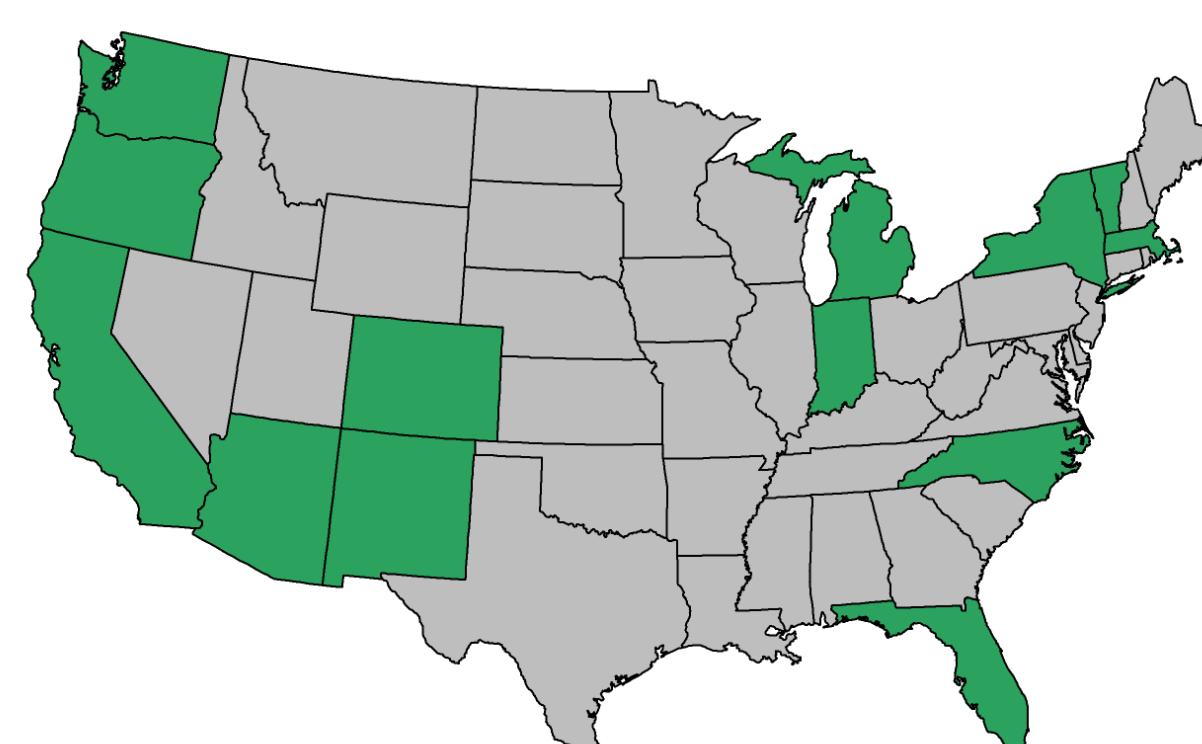
**Figure 4.** Primary storage system functions.



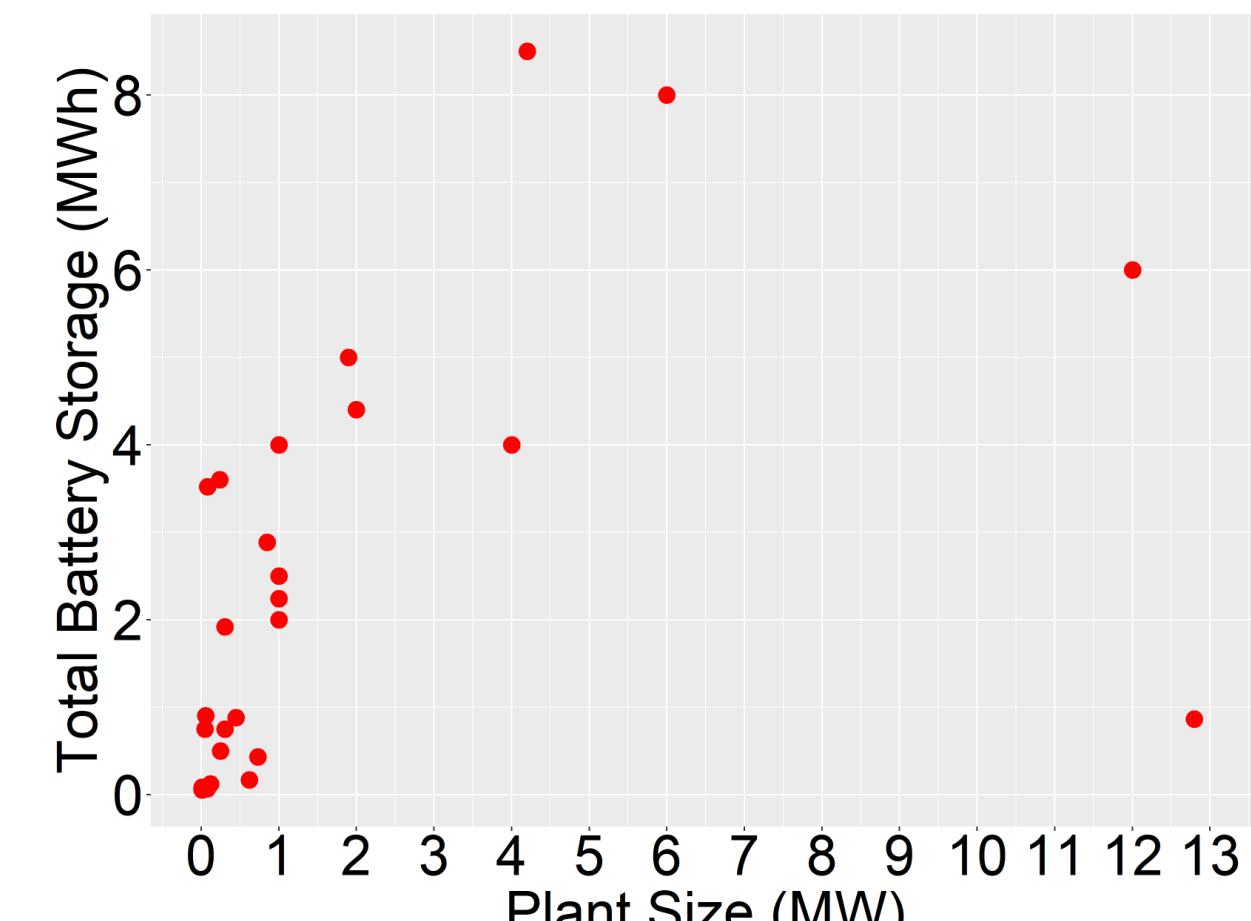
**Figure 5.** Technology selection factors.

## Questionnaire Demographics and Site Details

PV+Storage: Yes No Data



**Figure 2.** Geographic distribution of states with PV+Storage sites in this study.

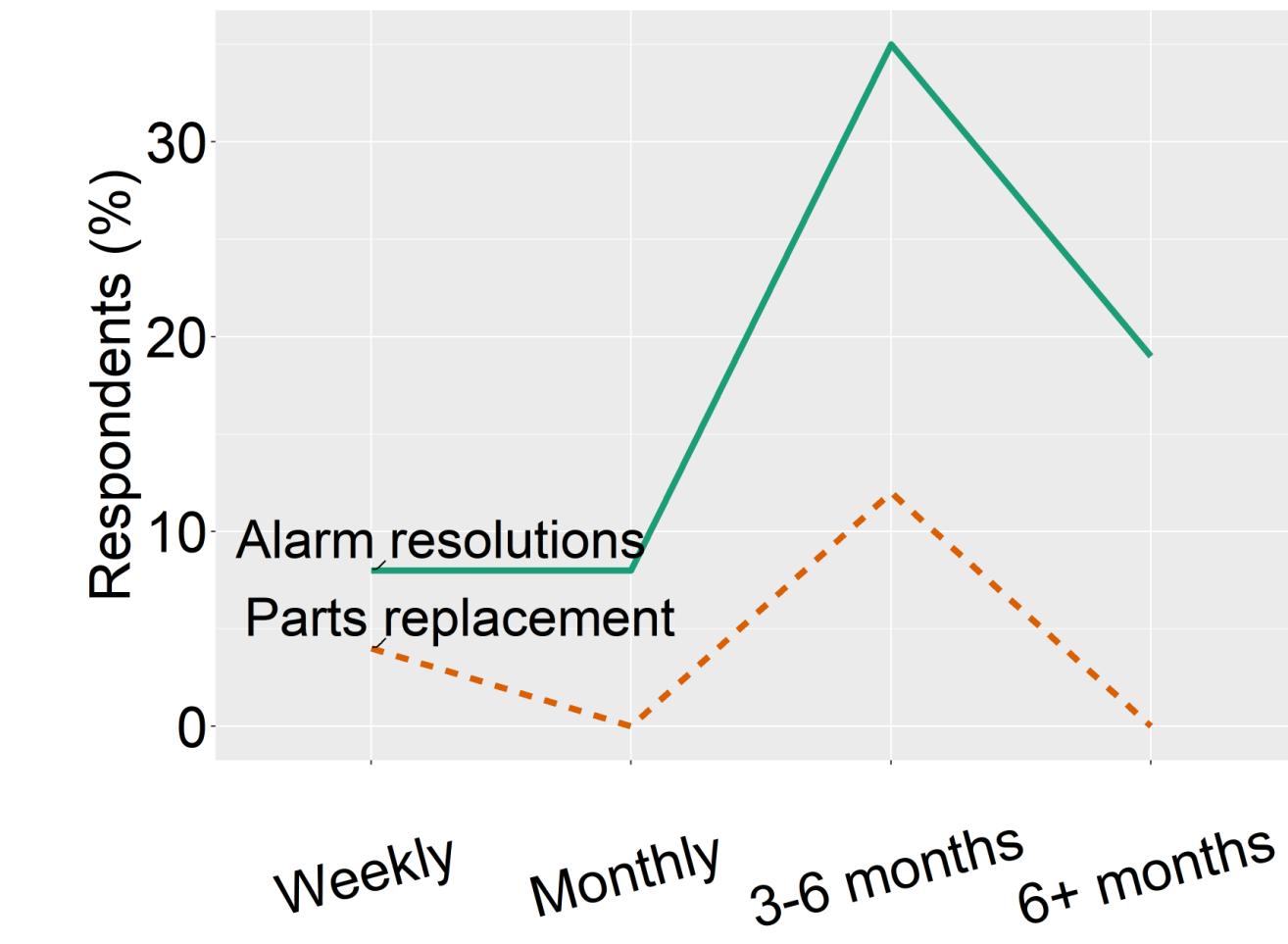


**Figure 3.** Nameplate PV plant size versus total battery storage.

## Study Findings

### O&M Activities

- Storage system's maintenance is primarily performed by system vendor or in-house
- 61% respondents have observed no change in O&M costs over time
- 50% respondents have a warranty period of at least 5 years
- 35.8% of sites have already filed a warranty

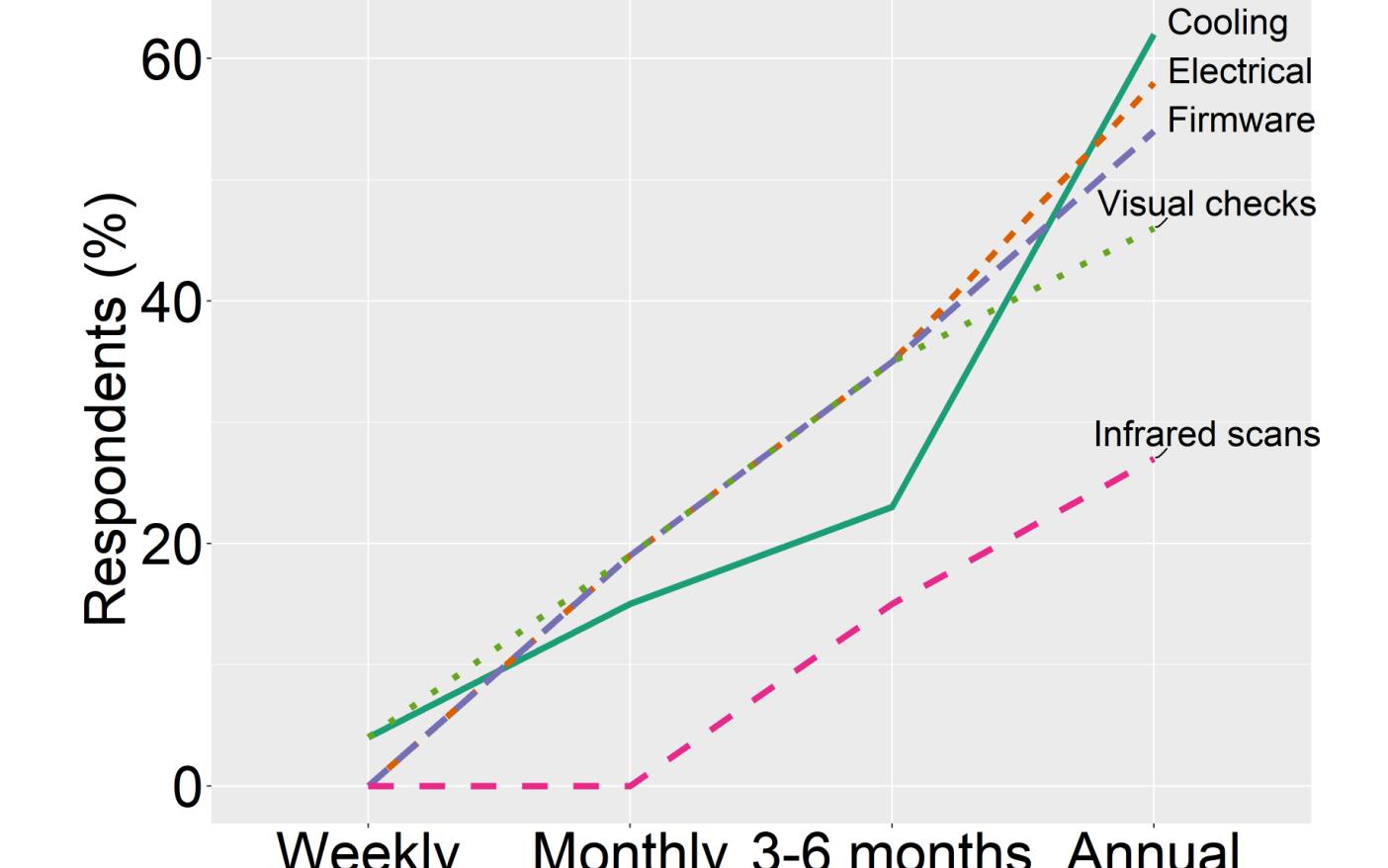


**Figure 6.** Frequency of corrective O&M. Alarm resolutions and parts replacement most often occur ~3-6 months.

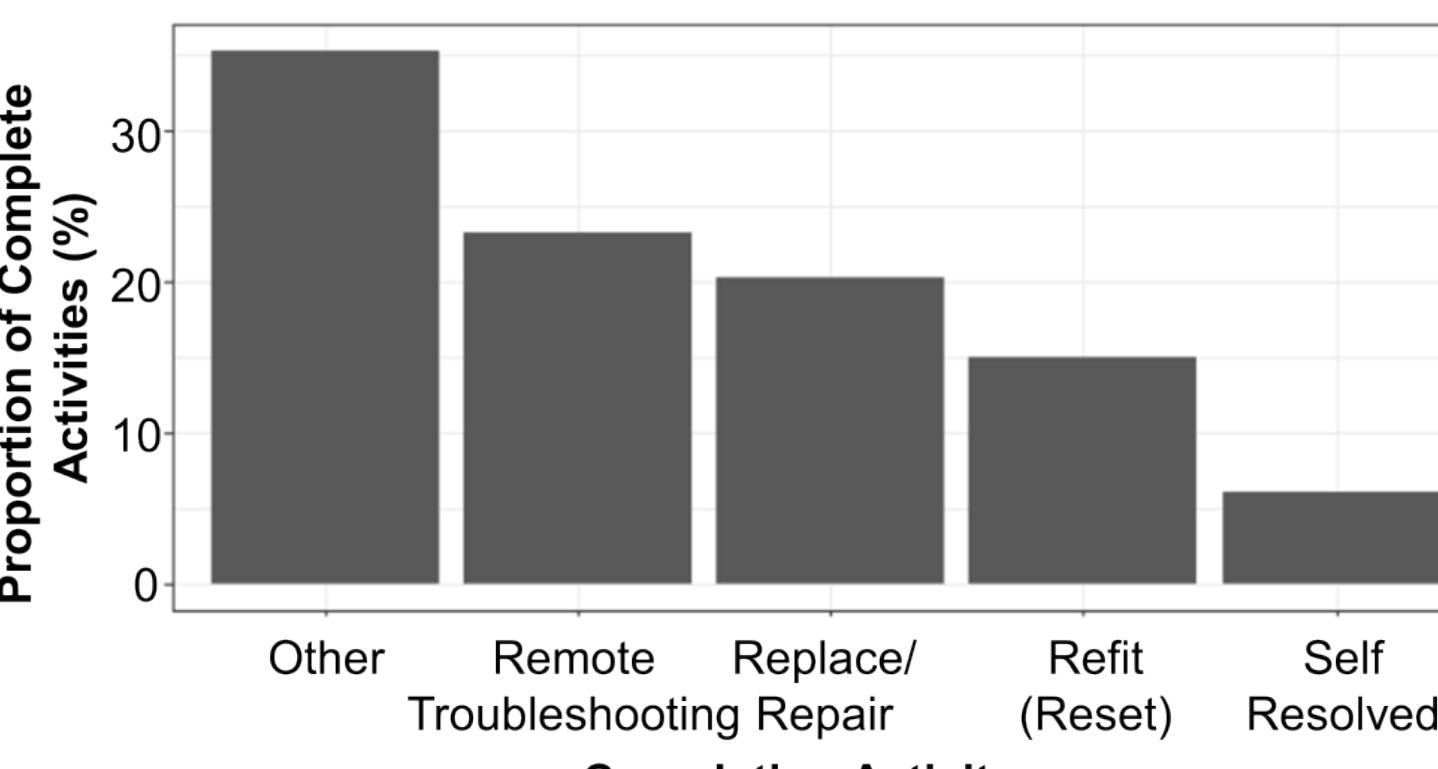
- Summary of Storage-Related Entries in PVROM
  - 14 sites (out of ~800) contain storage-related O&M tickets
  - Typical storage capacity: < 1 MW<sub>DC</sub>
  - 152 tickets were labeled under "Energy Storage/Battery" or "Battery (Solar + storage facilities)"
- Common PVROM O&M ticket themes
  - Underperformance (64%)
  - Production outages (19%)
  - Communications-related outages (16%)

**Table 2.** Median operations and maintenance ticket duration by completion activity from PVROM.

Completion Activity	Ticket Duration (minutes)
Refit (Reset)	114,240
Remote	567
Troubleshooting	
Replace/Repair	3,487
Self-Resolved	1,200



**Figure 7.** Frequency of preventative O&M. All activities most often occur annually.



**Figure 8.** Distribution of completion activities by type based on PVROM O&M tickets.

## Challenges and Needs

- New processes needed to set up PV+storage contracts
- Missing PV+storage performance metrics
- Prior experience of individual technologies but no experience combining technologies
- Long-term vendor availability and reliability
- Data management and handling
- Expected versus actual storage lifetimes, field performance
- Storage technology obsolescence
- Locally available technicians and parts for servicing O&M needs
- Changing standards and codes affect equipment availability

- Collect more data to update the database
  - Participating site performance data
  - Operations and maintenance logs
- Expand PV cost model to include battery storage and more public information
- Industry suggested opportunities
  - Validation of name plate battery life
  - Predictive maintenance and alarm tools
- Refinement of analysis tools and metrics