Energy Storage, DER, and Microgrid Project Valuation

EPRI DER-VET™ Analysis in Action

www.der-vet.com
DER-VET Developer Team | EPRI

September 2022
The Challenges of Storage, DER*, & Microgrid Modeling

- Today’s storage, DER, and microgrid deployments demand robust analysis for strategic planning
- Valuation of storage requires project-level analyses for specific applications and locations
- Complex co-optimization and decision-making process

*DER: Distributed Energy Resources

EPRI’s DER-VET™ addresses these challenges
The Solution: EPRI’s DER-VET™

Bridges industry gaps in project-level energy storage, DER, and microgrid analysis

Creates a common communication tool among all stakeholders

Evaluates various perspectives from customers values to grid values in any market

DER-VET™ provides an open-source platform for calculating, understanding, and optimizing the value of DER based on their technical merits and constraints: www.der-vet.com
DER-VET’s Past, Present, and Future

2016
EPRI StorageVET®
www.storagevet.com

2013
EPRI ESVT
Cost-Effectiveness of Energy Storage in California
https://www.epri.com/research/products/000000003002001164

2020
EPRI DER-VET Beta

2022
EPRI DER-VET™ V1.2
1,000+ Users
www.der-vet.com

202X
DER-VET User Group and Open-Source Developer Community
Input and Output Examples in DER-VET

DER-VET Project Configuration Example

DER-VET Dispatch Results Example
Technologies in DER-VET

Transmission Level (System)

System Load

Deferral Load

POI

Site Load

Controllable Load

EV

DC-Coupled Solar + Storage

CAES

Battery

Inverter Constraint

POI Constraint

Inverter Constraint

Battery

PV

Generator

CT

GHP

Heat Source

Thermal Electric Storage

Steam Thermal Load

Hot Water Thermal Load

Chiller

Cooling Load
Services in DER-VET

Bulk Market Services
- Energy Time Shift
- Load Following
- Frequency Regulation
- Spinning Reserves
- Non-spinning Reserves
- Resource Adequacy Capacity

T&D Services
- Upgrade Deferral
- Reliability/Resilience

Customer Services
- Retail Energy Time Shift
- Demand Charge Reduction
- Demand Response
- Reliability/Resilience
Long Duration Energy Storage Case Study
Long Duration Energy Storage (LDES) DER-VET Analysis

<table>
<thead>
<tr>
<th>Type</th>
<th>Technology</th>
<th>Acronym</th>
<th>TRL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Concrete Thermal Energy Storage</td>
<td>CTES</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Electro-Thermal Energy Storage</td>
<td>ETES</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Gravitational Energy Storage</td>
<td>GES</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Liquid Air Energy Storage</td>
<td>LAES</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Lithium-Ion Battery Storage</td>
<td>Li-Ion</td>
<td>9</td>
</tr>
</tbody>
</table>

Base
- All technologies were run using the original pricing curves in each region 6, 8, and 10h (+4h for Li-Ion Benchmark)

Sensitivities
- Capital costs were adjusted +10% / -30%
- Energy prices were modified (mod) from their original (orig)
- RTE was adjusted +/- 5% points

18 Cases per Technology per Hours of Duration

<table>
<thead>
<tr>
<th>Pricing</th>
<th>Orig</th>
<th>Orig</th>
<th>Orig</th>
<th>Orig</th>
<th>Orig</th>
<th>Orig</th>
<th>Orig</th>
<th>Orig</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTE</td>
<td>Base</td>
<td>Base</td>
<td>Base</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Costs</td>
<td>Base</td>
<td>High</td>
<td>Low</td>
<td>Base</td>
<td>High</td>
<td>Low</td>
<td>Base</td>
<td>High</td>
</tr>
</tbody>
</table>

Significant number of DER-VET cases: 1728 total
DER-VET Results: Tech Duration vs. Revenue Requirements

Technology cost forecast is a key driver for LDES analysis.
Transmission Solar + Energy Storage Case Study
# LADWP Energy Storage + Solar Project

- Los Angeles Department of Water and Power (LADWP) required to study and procure energy storage
- 100 MW, 4-hour battery energy storage system
- 200 MW solar PV
- Power Purchase Agreement (PPA) able to claim Federal Investment Tax Credit (FITC) incentive

## LADWP Full Report:

<table>
<thead>
<tr>
<th></th>
<th>Provide Energy Time Shift and Spinning Reserve</th>
<th>Restrict Charging from Grid</th>
<th>Restrict Charging from Grid and Discharge Min</th>
<th>Provide Frequency Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case #1</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Case #2</td>
<td>✓</td>
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<tr>
<td>Case #3</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case #4</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>
LADWP Case Results - Dispatch

- Impact of grid charging constraints:

**Unrestricted Storage Dispatch (Jan 11)**

**Restricted Storage Charging from Grid (Jan 11)**

- Storage charging profile follows the PV profile

**DER-VET Optimized Dispatch Outputs**
LADWP Case Results - CBA

- Several cases resulted in benefit-cost ratios greater than one for project starts years after 2022 as illustrated in the graph below.
Microgrid Design for PSPS Events
Microgrid Design - DER-VET Modeling Assumptions

- Identify potential Public Safety Power Shutoff (PSPS) planned events and duration in California
- Solar PV plus battery energy storage microgrid technologies
- Initial storage state of charge at the start of outage event is 100% with advanced PSPS notifications
Load and PV Profile

LA – Sec School
Peak load – 0.9 MW
24hr load requirement – 13MWh
36hr load requirement – 18MWh
48hr load requirement – 25MWh

LA - Hospital
Peak load – 1.4 MW
24hr load requirement – 28MWh
36hr load requirement – 43MWh
48hr load requirement – 55MWh

SCE Feeder
Peak load – 2.16 MW
24hr load requirement – 35MWh
36hr load requirement – 48MWh
48hr load requirement – 76MWh
Microgrid Sizing Results

LA – Sec School

2.5MW PV + 0.735MW/4.9MWh ES

LA - Hospital

24h – 3.5MW PV+1.4MW/17MWh ES
36h – 5MW PV+1.6MW/15MWh ES
48h – 7.5MW PV+3MW/15MWh ES

SCE Feeder

24h – 5.5MW PV+1.9MW/9.2MWh ES
36h – 5.5MW PV+1.9MW/17.2MWh ES
48h – 5.5MW PV +2 MW/17.2MWh ES

The energy storage and PV size corresponding to the knee point. Knee-point is a point where adding more PV does not affect the size of energy storage significantly.
Microgrid Cost Summary

LA – Sec School

Min Cost of covering 24, 36, and 48hr outage – $5M, $7M, and $8M

LA - Hospital

Min Cost of covering 24, 36, and 48hr outage – $10M, $14M, and $18M

SCE Feeder

Min Cost of covering 24, 36, and 48hr outage – $12M, $16M, and $22M
DER-VET Engagement

- Visit **www.der-vet.com**:  
  - Download the tool for free  
  - Reference case examples  
  - Help and documentation  
  - Engage with monthly Public ESIC Task Force Web Meetings

- Additional Case Studies in Appendix:  
  - More details from case studies presented  
  - T&D Upgrade Deferral  
  - Military Installation Microgrid  
  - Utility-Sited PSPS Microgrid
Together...Shaping the Future of Energy®
Additional DER-VET Background
DER-VET™ User Group

OBJECTIVES:
- Demonstrate application and economic decision-making opportunities to promote the applicability of microgrids and DER deployments
- Provide a forum to support tool usability, applicability, and user supported feature improvements
- Create a user community to learn and share experience and hare in training on DER-VET through meetings and webcasts

APPROACH:
- Access to advanced DER-VET modules, features, and datasets that promote tool usability and user experience
- Annual Meeting to provide updates on tool functionality, facilitate user experience sharing, and solicit inputs for tool development direction, new features, and updates
- Quarterly Webinars to share feedback of new feature development and case studies
- Personalized user training to facilitate for tool development and promote questions and answers

Personalized DER-VET User Training to Promote Applicability
DER-VET Optimization Framework

**Inputs**
- Electrical & Thermal Loads
- Electricity & Gas Tariff Data
- DER data
- Site Weather Data

**External Databases**
- OASIS, OpenEI, PVWatts, etc.

**Outputs**
- Optimal DER Mix & Capacity
- DER Dispatch
- Incentives, Taxes & Financing
- Quantitative Cost/Benefit

**Optimization Engine**
- Objectives
  - Minimize Operating Cost
  - Improve Reliability/Resiliency
  - Defer Asset Upgrade
  - Participate in Wholesale Market
- Constraints
  - Power Import/Export Cap
  - Battery Grid Charging Cap
  - Battery Cycling Limit
  - DER related constraints

*DER-VET is an open-source software tool available at [https://www.der-vet.com/](https://www.der-vet.com/)*
User-Defined Reliability Targets in DER-VET

- **Planned Outages:**
  100% or <100% load coverage for target hours of **planned** outages

- **Un-planned Outages:**
  100% or <100% load coverage for target hours (ex. 4 hours) of any possible un-planned outages

- **Relational Definition:**
  Reliability target for every outage length

![Graph showing reliability targets](image)

- **Microgrid is designed to have probabilistic reliability equal to or greater than the target**
### Energy Storage Implementation Strategies in DER-VET

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Augmentation</strong></td>
<td><img src="image1" alt="Augmentation Chart" /></td>
</tr>
<tr>
<td><strong>Replacement</strong></td>
<td><img src="image2" alt="Replacement Chart" /></td>
</tr>
<tr>
<td><strong>Oversizing</strong></td>
<td><img src="image3" alt="Oversizing Chart" /></td>
</tr>
<tr>
<td><strong>Modular Implementation</strong></td>
<td><img src="image4" alt="Modular Implementation Chart" /></td>
</tr>
</tbody>
</table>
Degradation in DER-VET

- Only consider calendar and cycling degradation of energy capacity with no compounding stress factors
- Cycle life curve input and %/yr calendar degradation input
- Images from NREL’s SAM tool (very similar degradation model)
CBA in DER-VET: Time Horizon Solution

- Analysis end time
  - Shortest lifetime of all assets
  - Longest lifetime of all assets
  - Something else user-defined
- Replacement
  - User can turn automated replacement on or off
- Remaining value/cost at end of analysis
  - Sunk cost (0$, do not consider)
  - Salvage value (linear decline over life or customized)
  - Decommissioning cost
- Annualize everything (ECC)

Beginning of Y1

Where to end??

- Storage, LT = 10 years
- PV, LT = 15 years
- Genset, LT = 17 years
OpenDSS + DER-VET Tool Interaction

- Inputs to DER-VET:
  - From User
    - Customer load profile (8760)
    - Customer tariff
  - From OpenDSS*
    - Operational envelope (min/max power at POI OR min/max battery power, depending on if load is already included in OpenDSS model)

- Outputs from DER-VET
  - Optimal battery size
  - Customer electric bill savings

* https://www.epri.com/pages/sa/opendss
## Validation through Case Studies

<table>
<thead>
<tr>
<th>Case Study</th>
<th>Goals (WHY)</th>
<th>Objectives (WHAT)</th>
<th>DER Options &amp; Features (WHICH)</th>
<th>Outcome (HOW)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Case Study #1</strong></td>
<td>Customer DER portfolio sized for Bill Reduction and customer resilience</td>
<td>Primary objective: Customer bill reduction. DER sized for this service</td>
<td>Blue sky day: ES+PV (retail services) Outage days: ES+PV+DG (optional) User-defined critical load percentages to calculate reliability metrics</td>
<td>Metrics: 1. NPV comparisons (CBA), Payback period, Cost Normalization (e.g.: $/kW of DER installed capacity), Avoided costs per service 2. Critical load coverage comparisons ($/kW-yr) 3. Reliability performance and load coverage</td>
</tr>
<tr>
<td></td>
<td>Check if the DER portfolio sized for bill reduction can also provide backup and improve customer resilience</td>
<td>Secondary objective: Evaluate reliability in terms of load coverage</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Case Study #2</strong></td>
<td>Energy storage-enabled microgrid designed with the similar or better reliability than the conventional diesel generator-based microgrid</td>
<td>Primary objective: Reliability/Resilience</td>
<td>Blue sky day: ES+PV (retail services) Outage days: ES+PV+DG User-defined Load coverage probability User-defined critical load percentages to calculate reliability metrics</td>
<td>Metrics: 1. Critical load coverage comparisons ($/kW-yr) 2. Reliability Performance based on targets and load coverage curve comparison 3. NPV comparisons (CBA), Payback period, Cost Normalization (e.g.: $/kW of DER installed capacity), Avoided costs per service</td>
</tr>
<tr>
<td></td>
<td>Check if net cost of operation is same/lesser than the conventional diesel generator-based microgrid</td>
<td>Secondary objective: Customer bill reduction</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Case Study #3</strong></td>
<td>Improve community resilience during crisis (hurricanes, wildfire, PSPS events) with community &amp; customer PV and Storage assets</td>
<td>Primary objective: Community Resilience, Improve grid reliability</td>
<td>Blue sky day: ES+PV (market services) Outage days: ES+PV User-defined outage durations User-defined critical load percentages to calculate reliability metrics</td>
<td>Metrics: 1. Critical load coverage comparisons ($/kW-yr) 2. Reliability Performance based on targets and load coverage curve comparison 3. NPV comparisons (CBA), Payback period, Cost Normalization (e.g.: $/kW of DER installed capacity), Avoided costs per service</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Secondary objective: Market Participation</td>
<td></td>
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</tbody>
</table>
### Validation through Case Studies (cont.)

<table>
<thead>
<tr>
<th>Case List</th>
<th>Goals (WHY)</th>
<th>Objectives (WHAT)</th>
<th>DER Options &amp; Features (WHICH)</th>
<th>Outcome (HOW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case Study #4</td>
<td>Customer DER + CHP portfolio sized for customer resilience + bill reduction</td>
<td>Primary objective: Customer bill reduction</td>
<td>Blue sky day: Electric + Heating + Cooling CHP/CHP + other DER Outage days: CHP/CHP + other DER</td>
<td>Metrics: 1. NPV comparisons (CBA), Payback period, Cost Normalization (e.g.: $/kW of DER installed capacity), Avoided costs per service</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Secondary objective: Customer resilience</td>
<td>User-defined outage durations</td>
<td>2. Critical load coverage comparisons ($/kW-yr)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>User-defined critical load percentages to calculate reliability metrics</td>
<td>3. Reliability performance and load coverage</td>
</tr>
<tr>
<td>Case Study #5</td>
<td>Leverage EVs as a grid resource to maintain mobility and reliability</td>
<td>Primary objective: Customer Bill reduction. Secondary objective: Customer resilience</td>
<td>Blue sky day: ES+PV+EV (retail services) Outage days: ES+PV+EV</td>
<td>Metrics: 1. NPV comparisons (CBA), Payback period, Cost Normalization (e.g.: $/kW of DER installed capacity), Avoided costs per service</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>User-defined outage durations</td>
<td>2. Critical load coverage comparisons ($/kW-yr)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>User-defined critical load percentages to calculate reliability metrics</td>
<td>3. Reliability performance and load coverage</td>
</tr>
<tr>
<td>Case Study #6</td>
<td>External Tool Integration: Assessing Non-Wires Solutions (NWS) impact on community feeder reliability. DER-VET integration with power flow tools (e.g. EPRI’s OpenDSS)</td>
<td>Primary objective: Community feeder reliability improvements + capacity deferral (NWS) Secondary objective: Customer resilience</td>
<td>Blue sky day: ES+PV (grid services) Outage days: ES + PV</td>
<td>Metrics: 1. Critical load coverage comparisons ($/kW-yr)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>User-defined feeder reliability improvement targets</td>
<td>2. Reliability Performance based on targets and load coverage curve comparison</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>User-defined customer outage durations</td>
<td>3. NPV comparisons (CBA), Payback period, Cost Normalization (e.g.: $/kW of DER installed capacity), Avoided costs per service</td>
</tr>
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<td></td>
<td></td>
<td>User-defined critical load percentages to calculate reliability metrics</td>
<td></td>
</tr>
</tbody>
</table>
Transmission Solar + Energy Storage Case Study
Site-Specific Energy Storage Analysis Framework

**Dx and Tx Assessment**
- Develop enhanced Dx and Tx planning criteria, methods, and tools
- Characterize Dx and Tx needs and solutions
- Apply energy storage non-wires solutions (NWS) screening criteria and methods

**Alternative Evaluation**
- Design energy storage NWS solution including sizing, siting, controls, etc.
- Assess energy storage Dx impacts
- Evaluate stacked benefits, state of charge management, degradation, etc.

**Economic Evaluation**
- How do energy storage costs & value compare to conventional solutions?
- What are the operating costs of the system?
- What revenues might the added energy storage provide?
Example: LADWP Transmission Project

<table>
<thead>
<tr>
<th>Application</th>
<th>Description</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market Service Participation</td>
<td>Buy low, sell high</td>
<td>Project has been Contracted and in Execution</td>
</tr>
<tr>
<td>Energy Arbitrage</td>
<td>Rapidly inject and remove power</td>
<td></td>
</tr>
<tr>
<td>Frequency Regulation</td>
<td>Dispatch power</td>
<td></td>
</tr>
<tr>
<td>Spinning Reserves</td>
<td>Real power reserve</td>
<td></td>
</tr>
<tr>
<td>Resource Adequacy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long-term resource planning and</td>
<td>Meet long-term reliability needs with both high renewables and storage</td>
<td>In-Progress</td>
</tr>
<tr>
<td>operational reliability</td>
<td>penetration in and out of LA Basin</td>
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# LADWP Transmission Projects

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<td>Real power reserve</td>
<td></td>
</tr>
<tr>
<td><strong>Long-term resource planning and operational reliability</strong></td>
<td>Meet long-term reliability needs with both high renewables and storage penetration in and out of LA Basin</td>
<td>Concept Stage</td>
</tr>
</tbody>
</table>
LADWP Energy Storage Project #1

- Los Angeles Department of Water and Power (LADWP) was required to meet its California Senate Bill SB801 requirements

- The study considers a 100 MW, 4-hour battery energy storage system paired with a 200 MW solar PV facility to be procured through a Power Purchase Agreement (PPA) with a third-party developer who would be able to claim 30% Federal Investment Tax Credit incentive

LADWP Case Results - Dispatch

- Impact of grid charging constraints

DER-VET (and StorageVET) Optimized Dispatch Outputs
Several cases resulted in benefit-cost ratios greater than one for project starts years after 2022 as illustrated in the graph below.
Microgrid Design for PSPS Events
Microgrid Design - DER-VET Modeling Assumptions

- Identify potential Public Safety Power Shutoff (PSPS) planned events and duration in California
  - A load profile is chosen from Aug-Dec time period with the highest net energy demand
  - Load cannot be shed

- Solar PV assumptions and limitations
  - Corresponding Solar irradiance profile
  - PV profile from TMY profile
  - PV can be curtailed

- Battery ES assumptions:
  - Initial SOC at the start of outage event is 100%
  - Battery round trip efficiency – 91%
  - Hybrid solar plus storage installation – co-located at the dc side
## Candidate Critical Load Facilities

<table>
<thead>
<tr>
<th>Critical Load Facility</th>
<th>Peak Load</th>
<th>Energy Requirement for 48h Outage (Without PV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCE – Feeder with 137 customers (98% commercial)</td>
<td>2.2 MW</td>
<td>68.6 MWh</td>
</tr>
<tr>
<td>LA – Hospital</td>
<td>1.4 MW</td>
<td>55.3 MWh</td>
</tr>
<tr>
<td>LA – Sec School</td>
<td>0.9 MW</td>
<td>24.97 MWh</td>
</tr>
</tbody>
</table>
Load and PV Profile

LA – Sec School

Peak load – 0.9 MW
24hr load requirement – 13MWh
36hr load requirement – 18MWh
48hr load requirement – 25MWh

LA - Hospital

Peak load – 1.4 MW
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SCE Feeder

Peak load – 2.16 MW
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Microgrid Sizing Results

LA – Sec School

- 2.5MW PV + 0.735MW/4.9MWh ES

24h – 3.5MW PV+1.4MW/17MWh ES
36h – 5MW PV+1.6MW/15MWh ES
48h – 7.5MW PV+3MW/15MWh ES

24h – 5.5MW PV+1.9MW/9.2MWh ES
36h – 5.5MW PV+1.9MW/17.2MWh ES
48h – 5.5MWPV +2 MW/17.2MWh ES

The energy storage and PV size corresponding to the knee point. Knee-point is a point where adding more PV does not affect the size of energy storage significantly.
Outage Length Variation – SCE case-study

- Microgrid designs results for 24, 36 and 48h outage lengths

There is a linear relationship for low levels of installed PV capacity.

In this case-study, the knee point happens for PV size of 5.5 MW in all three cases.

It is non-linear for high PV generation. The microgrid size depends on the load shape and PV generation coincidence.
Microgrid Cost Summary

LA – Sec School

Min Cost of covering 24, 36 and 48hr outage – 5M$, 7M$ and 8M$

LA - Hospital

Min Cost of covering 24, 36 and 48hr outage – 10M$, 14M$ and 17.5M$

SCE Feeder

Min Cost of covering 24, 36 and 48hr outage – 12M$, 16M$ and 21.5M$
T&D Upgrade Deferral Case Study
### Screening of Three Energy Storage Sites*

<table>
<thead>
<tr>
<th></th>
<th>Feeder 1</th>
<th>Feeder 2</th>
<th>Substation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overloaded Asset</strong></td>
<td>379A underground cable limit 8% Overloaded few hours/year</td>
<td>379A underground cable limit 6% Overloaded few hours/year</td>
<td>Feeder 3</td>
</tr>
<tr>
<td><strong>Necessitating Action</strong></td>
<td></td>
<td></td>
<td>Feeder 4</td>
</tr>
<tr>
<td><strong>Traditional Upgrade Option and Cost</strong></td>
<td>Reconfigure some load to adjacent feeder, also reconductoring underground portion of feeder head cables to double ampacity. $1.1 Million</td>
<td>Extend adjacent feeder and transfer some loads off of feeder $0.1 Million</td>
<td>Build a new substation $5.9 Million</td>
</tr>
<tr>
<td><strong>Projected Load Growth Rate</strong></td>
<td>0.5 %/year</td>
<td>0.5 %/year</td>
<td>1 %/year</td>
</tr>
<tr>
<td><strong>Additional Data Provided by For Screening</strong></td>
<td>• 2017 hourly feeder head currents (for each phase), total MW, and total MVAR • 2008-2029 recorded/predicted yearly feeder head peak load values</td>
<td>• 2017 hourly feeder head currents (for each phase), total MW, and total MVAR • 2008-2029 recorded/predicted yearly feeder head peak load values</td>
<td>• 2017 hourly feeder head currents (for each phase) • 2004-2029 recorded/predicted yearly feeder head peak load values</td>
</tr>
</tbody>
</table>

* The three sites were identified by distribution planners.
Screening Analysis Results - Choosing a Feeder for Detailed Analysis

<table>
<thead>
<tr>
<th></th>
<th>Feeder 1</th>
<th>Feeder 2</th>
<th>Substation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Feeder 3</td>
<td>Feeder 4</td>
<td>Transformer</td>
</tr>
<tr>
<td>(Feeding 3 &amp; 4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Energy Storage Requirements in Year 10 to Defer Capacity Investment</strong></td>
<td>2 MW</td>
<td>1.47 MW</td>
<td>0.17 MW</td>
</tr>
<tr>
<td></td>
<td>4.72 MWh</td>
<td>9.07 MWh</td>
<td>0.17 MWh</td>
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<tr>
<td></td>
<td>2.4 Hour</td>
<td>6.1 Hours</td>
<td>1 Hour</td>
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<td></td>
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<td>0 MW</td>
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<td>0 MWh</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 Hours</td>
</tr>
<tr>
<td><strong>Distribution Upgrade Cost</strong></td>
<td>Reconfigure feeder and loads $1.1 Million</td>
<td>Reconfigure feeder and loads $0.1 Million</td>
<td>Build new substation $5.9 Million</td>
</tr>
<tr>
<td><strong>Estimate for Storage Installed Cost</strong> (assuming $900/kWh)</td>
<td>~$4.2 Million</td>
<td>~$8.1 Million</td>
<td>~$3.1 Million</td>
</tr>
</tbody>
</table>

Substation transformer bank is the best candidate for detailed energy storage analysis due to the relatively high cost of the new substation transformer bank as compared to the cost of the energy storage asset.

* The energy storage cost estimates here do not include the value of storage secondary services, which will improve the overall economics of the storage project. The valuation of stacked secondary services is a part of the detailed storage analysis.

Screening Analysis Results – Storage Requirements

Capacity Limits (Before Any Distribution Upgrades)
- Feeder 3 operational capacity is originally limited to 400A by a substation switch. This switch will be upgraded increasing the feeder capacity to 491 Amps limited by feederhead voltage regulator.
- Substation transformer bank capacity is 15,451 kVA.

Storage Capacity Requirement in Year 10
- 1.22 MW / 3.4 MWh (2.8 hrs)
- The capacity is needed seldom leaving room for stacked secondary services.

Stacked secondary services: Storage is not utilized for its primary asset deferral objective for much of the year. What additional services could it provide when available?

* No inverter oversizing was considered for volt/var or other secondary services.
Screening Analysis Results – Storage Scenarios

Consider two energy storage scenarios for stacked-service and cost-benefit analysis

- **Scenarios 1:** Install full energy storage capacity (Year 10 requirement 1.22 MW / 3.4 MWh / 2.8 hrs) in Year 1
  - Advantage: More storage capacity immediately available for secondary services
  - Disadvantage: High initial capital investment

- **Scenario 2:** Increase energy storage capacity *modularly* as the capacity need increases
  - Advantages:
    - Take advantage of lower storage costs in the future
    - Deferring some of the initial investment
    - Hedge against uncertainty: If the projected load growth does not materialize, no unnecessary energy storage investments are made
  - Disadvantage: Limited storage capacity initially available for secondary services

- Several energy storage vendors, e.g., Tesla Powerpack, offer such modular solutions
  - For example, assuming 50kW – 4 hour modular storage packs (e.g., Tesla Powerpack), 30 Powerpacks would be required in Year 10 (total capacity of 1.5 MVA – 6 MWh – 4 hours)*

* Less capacity may be needed if the load grows slower than anticipated.
## Secondary Non-Distribution Services Overview

<table>
<thead>
<tr>
<th>Service</th>
<th>Scenario B</th>
<th>Scenario C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Storage Size</td>
<td>1.5 MW, 3.75 MWh</td>
<td>3 X (0.5 MW, 1.25 MWh)</td>
</tr>
<tr>
<td>Year(s) Deployed</td>
<td>2018</td>
<td>2018, 2021, 2024</td>
</tr>
<tr>
<td>Analysis Timeframe</td>
<td>10 years</td>
<td>10 years</td>
</tr>
<tr>
<td>ES RT Efficiency</td>
<td>85%</td>
<td>85%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Service</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day Ahead Energy Price</td>
<td>Local LMPs from 2017</td>
</tr>
<tr>
<td>Day Ahead Ancillary Services</td>
<td>Market Clearing Prices from 2017</td>
</tr>
<tr>
<td>Services Modeled</td>
<td>Day Ahead Energy Arbitrage Spinning &amp; Non Spinning Reserves</td>
</tr>
</tbody>
</table>
Energy storage activity driven by price on an unconstrained day
Storage Activity on a Constrained Day (2026)

Energy storage activity driven by distribution requirements on a constrained day

Constraints

ESS Activity
Storage Activity Unconstrained vs. Constrained Day
Cost-Benefit Analysis: Financial Parameters Assumed

MN - 2019 Electric Multi-year

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Debt/Equity Ratio</td>
<td>~50%</td>
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<tr>
<td>Interest Rate</td>
<td>~5%</td>
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<tr>
<td>ROE</td>
<td>~10%</td>
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<tr>
<td>Discount Rate</td>
<td>~7%</td>
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<tr>
<td>Inflation Rate</td>
<td>2.70%</td>
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<tr>
<td>Federal Income Tax Rate</td>
<td>21%</td>
</tr>
<tr>
<td>State Income Tax Rate</td>
<td>9.80%</td>
</tr>
<tr>
<td>Property Tax Rate</td>
<td>1.19%</td>
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</tbody>
</table>

Allowed return on LTD
Assumed after-tax WACC
Assumed weighted
## Cost Assumptions for Measures Considered

### 2. Storage

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>4 hrs</td>
<td>$2,070/kW</td>
<td>$1,360/kW</td>
<td>-8.06%</td>
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</tr>
<tr>
<td>2.5 hrs*</td>
<td>$1,473/kW</td>
<td>$980/kW</td>
<td>-7.83%</td>
<td>-5.34%</td>
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<tr>
<td>2 hrs</td>
<td>$1,274/kW</td>
<td>$853/kW</td>
<td>-7.71%</td>
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<tr>
<td>O&amp;M**</td>
<td>$10/kW-yr</td>
<td>$11/kW-yr</td>
<td>2.07%</td>
<td></td>
</tr>
</tbody>
</table>

*Costs linearly interpolated from 2hrs and 4hrs configurations

**O&M costs are highly project specific and can vary widely, from $8 to $37/kW-yr.

### All-in Storage System Cost ($)

<table>
<thead>
<tr>
<th>All-in Storage System Cost ($)</th>
<th>2017 ($2017)</th>
<th>2022 E ($2017)</th>
<th>Annual Esc. Rate incl. inflation</th>
<th>Useful Life</th>
<th>Calculated Economic Carrying Cost (ECC)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5 MW / 2.5 Hrs</td>
<td>2,209,500</td>
<td>1,469,625</td>
<td>-5.34%</td>
<td>10 yrs</td>
<td>19.54%</td>
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<tr>
<td>0.5 MW / 2.5 Hrs</td>
<td>736,500</td>
<td>489,875</td>
<td>-5.34%</td>
<td>10 yrs</td>
<td>19.54%</td>
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<tr>
<td>O&amp;M**</td>
<td>$10/kW-yr</td>
<td>$11/kW-yr</td>
<td>2.70%</td>
<td>N/A</td>
<td>N/A</td>
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</tbody>
</table>

*ECC calculated assuming financial parameters shown above

**O&M costs are highly project specific and can vary widely, from $8 to $37/kW-yr.
### Time Horizon

Analysis horizon considered: 2019-2028

<table>
<thead>
<tr>
<th>Scenario</th>
<th>19</th>
<th>20</th>
<th>21</th>
<th>22</th>
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</tbody>
</table>

*Note that years on this slide refers to in-service years, while years on previous slide refers to construction years.*
## CBA Results

<table>
<thead>
<tr>
<th>Scenario / $2017</th>
<th>A (avoided)</th>
<th>CAPEX</th>
<th>OPEX</th>
<th>MKT REV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-</td>
<td>3,460,026</td>
<td>3,062,132</td>
<td>115,429</td>
<td>352,466</td>
<td>634,931</td>
</tr>
<tr>
<td>B - market only</td>
<td>3,460,026</td>
<td>3,062,132</td>
<td>115,429</td>
<td>352,528</td>
<td>634,993</td>
</tr>
<tr>
<td>C-</td>
<td>3,460,026</td>
<td>1,845,991</td>
<td>77,209</td>
<td>228,716</td>
<td>1,765,542</td>
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<tr>
<td>C - market only</td>
<td>3,460,026</td>
<td>1,845,991</td>
<td>77,209</td>
<td>228,776</td>
<td>1,765,602</td>
</tr>
</tbody>
</table>

1. All scenarios considered yield positive economic returns. This is true even when not considering market revenues.

2. Scenario C –three smaller ES installed sequentially– yields better returns than a larger ES.
   - **Note**: For ES #2 and #3, some costs are still to be recovered after 2028

3. Operation constraints for primary service only marginally reduce market revenues.
Long Duration Energy Storage Case Study
Long Duration Energy Storage (LDES) DER-VET Analysis

<table>
<thead>
<tr>
<th>Type</th>
<th>Technology</th>
<th>Acronym</th>
<th>TRL</th>
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<tbody>
<tr>
<td></td>
<td>Concrete Thermal Energy Storage</td>
<td>CTES</td>
<td>4</td>
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<td>Electro-Thermal Energy Storage</td>
<td>ETES</td>
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<td>Gravitational Energy Storage</td>
<td>GES</td>
<td>6</td>
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<td></td>
<td>Liquid Air Energy Storage</td>
<td>LAES</td>
<td>6</td>
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<tr>
<td></td>
<td>Lithium-Ion Battery Storage</td>
<td>Li-Ion</td>
<td>9</td>
</tr>
</tbody>
</table>

- **Modeling Inputs**
  - Round-Trip Efficiency (RTE) (Total AC power generated / total AC energy consumed)
  - Capital Costs (Anticipated costs for power [$/kW] & energy [$/kWh])
  - Operating Costs (Dwell energy losses, maintenance, and augmentation)
  - Startup Energy (Energy consumed during startup)
DER-VET Base Case and Sensitivities

Base
- All technologies were run using the original pricing curves in each region for the 6-, 8-, and 10-hour duration cases (Li-ion batteries were also run at their prevalent 4-hour duration case)

Sensitivities
- Capital costs were adjusted +10% / -30%
- Energy prices were modified (mod) from their original (orig)
- RTE was adjusted +/- 5% points

<table>
<thead>
<tr>
<th>Pricing</th>
<th>Orig</th>
<th>Orig</th>
<th>Orig</th>
<th>Orig</th>
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</tr>
</thead>
<tbody>
<tr>
<td>RTE</td>
<td>Base</td>
<td>Base</td>
<td>Base</td>
<td>High</td>
<td>High</td>
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<td>High</td>
<td>Low</td>
<td>Base</td>
<td>High</td>
<td>Base</td>
</tr>
</tbody>
</table>

18 Cases per Technology per Hours of Duration

Significant number of DER-VET cases: 1728 total
Energy Pricing Sensitivity

- **Original**
  - Predicted based on expected energy mix and demand profiles

- **Modified**
  - Original prices amplified 2x from overall annual average
  - When negative values occur, these are reset to zero
  - All pricing data offset to achieve equivalent average values vs. original average prices
DER-VET Results: Tech Duration vs. Revenue Requirements

Technology cost forecast is a key driver for LDES analysis

<table>
<thead>
<tr>
<th>Duration, hours</th>
<th>LDES A</th>
<th>LDES B</th>
<th>LDES C</th>
<th>LDES D</th>
<th>Li-ion</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
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</table>
LDES Deployment Driven by Future Macro-Economic Scenarios

**GENERATION MIX**

- **Scenario**
  - Reference
  - Net-Zero
  - Carbon-Free
  - Renewable

- **Generation Share in 2035 (%)**
  - Hydrogen: 46.4%
  - Storage: 21.9%
  - CCS: 8.9%
  - Renewables: 19%
  - Gas: 14.8%
  - Coal: 13.5%
  - Oil: 64.7%
  - Nuclear: 84.8%

**STORAGE DURATION**

- **Tech A**
- **Tech B**
- **Tech C**
- **Tech D**

Preliminary results: Do NOT cite or quote

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Military Installation Microgrids
PROBLEM STATEMENT (WHY?)

1. Design an ES enabled microgrid with the similar or better **reliability** than the traditional DG based baseline microgrid

2. Check if net cost of operation of the ES enabled microgrid is same/lesser than the traditional diesel generator-based baseline microgrid
SITES ANALYZED

Sites Considered:
A. Naval Base Ventura County
B. March ARB
C. Holloman Air Force Base (AFB)
D. Fort Bliss
E. NAS Corpus Christi

Installations Modeled are a Cross-Section of:
- Geographies
- Energy Market Areas
- Sizes
- Mission Activities
- Military Services
### Three Types of Variables

<table>
<thead>
<tr>
<th>Military Installation Conditions</th>
<th>Secondary Services</th>
<th>Energy Storage Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Critical Load Size &amp; Shape</td>
<td>- Utility Retail Tariff Structure</td>
<td>- Lithium-Ion</td>
</tr>
<tr>
<td>- Solar and DG Assets</td>
<td>- Wholesale Market Prices</td>
<td></td>
</tr>
<tr>
<td>- Other Conditions</td>
<td>- Regulatory Rules in different service territories</td>
<td></td>
</tr>
</tbody>
</table>
### EXAMPLE MILITARY INSTALLATION CONDITIONS

- **Peak load:** 14 MW
- **Peak critical load:** 4 MW
- **7 diesel generators available:**
  - 750 kW each
  - 50,000 gallons of diesel available
- **PV Nameplate rating:** 830 kW
  - Hourly PV irradiance resolution

---

**Critical Load Profile**

<table>
<thead>
<tr>
<th>Power (kW)</th>
<th>Critical Load</th>
<th>Critical Load -20 %PV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours</td>
<td>N gen</td>
<td>N-1 gen</td>
</tr>
<tr>
<td>293</td>
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</table>
Secondary Services

BILL REDUCTION

- Energy charge reduction
- Demand charge reduction
- Demand response

WHOLESALE MARKET

- Energy arbitrage
- Frequency regulation
- Spinning reserves and non-spinning reserves
STORAGE TECHNOLOGY CONSIDERED

- Li-Ion battery (Mature technology)
- Round Trip Efficiency: 91%
- Battery Replaced every 7 years over the 20-year analysis horizon
- CAPEX cost derived from EPRI’s 2019 cost study*
- O&M Cost: $10/kW-yr


Also considered Flow Battery technology, but that data was proprietary
BASELINE ANALYSIS – PERFORMANCE METRICS

- Reliability Analysis - Critical load coverage probability as a function of outage length (hours)

![Load Coverage Probability Graph]

Baseline Microgrid configuration: DG – 7x750kW + PV – 830 kW

<table>
<thead>
<tr>
<th>Duration</th>
<th>Probability (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 hours</td>
<td>99.46%</td>
</tr>
<tr>
<td>168 hours</td>
<td>85.94%</td>
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</tbody>
</table>

- Cost Benefit Analysis

<table>
<thead>
<tr>
<th>Cost Benefit Analysis Components</th>
<th>Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline NPV (20 Yr) (Cost)(Millions of $)</td>
<td>$108.95</td>
</tr>
<tr>
<td>Baseline Critical Load Coverage ($/kW-yr)</td>
<td>$135.50</td>
</tr>
</tbody>
</table>
Energy Storage Enabled Microgrid Design

- Technical Reliability Performance
  (during power outages of 1 to 168 hours)

- Net Lifecycle Cost
  (per kW of peak critical load over 20 years)

Compared to Modeled Baseline Microgrid at each Installation with no Storage, N+1 Back-Up Diesel Generators, solar PV, and UPS
## Final Microgrid Design Output

<table>
<thead>
<tr>
<th></th>
<th>Baseline Microgrid Configuration</th>
<th>Li-ion ES Microgrid Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power and Duration</strong></td>
<td>-</td>
<td><strong>4375kW 4hr</strong></td>
</tr>
<tr>
<td><strong>SOC Reservation (Reliability)</strong></td>
<td>-</td>
<td><strong>5.16%</strong></td>
</tr>
<tr>
<td><strong># Gensets</strong></td>
<td><strong>7 x 750 kW</strong></td>
<td><strong>5 x 750kW</strong></td>
</tr>
<tr>
<td><strong>Secondary Services</strong></td>
<td>-</td>
<td><strong>Bill reduction</strong></td>
</tr>
</tbody>
</table>

**Note:**
1. Baseline and ES-enable design included PV
2. The final microgrid design with ES replaced two generators from the baseline microgrid
Both the designed microgrid has better reliability performance than the baseline microgrid.
Li-Ion Storage Microgrid – Economic Performance

Cost Benefit Analysis Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery Size</td>
<td>4375 kW, 4 hr</td>
</tr>
<tr>
<td>CAPEX Cost ($/kWh)</td>
<td>$445/kWh</td>
</tr>
<tr>
<td>O&amp;M Cost ($/kW-yr)</td>
<td>$10/kW-year</td>
</tr>
<tr>
<td>Baseline NPV (20 Yr) (Cost)(Millions of $)</td>
<td>$108.95</td>
</tr>
<tr>
<td>Investment Case NPV (20 Yr) (Cost)(Millions of $)</td>
<td>$105.27</td>
</tr>
<tr>
<td>% NPV Improvement</td>
<td>3.38%</td>
</tr>
<tr>
<td>Baseline Critical Load Coverage ($/kW-yr)</td>
<td>$135.50</td>
</tr>
<tr>
<td>Storage-Enabled Critical Load Coverage ($/kW-yr)</td>
<td>$85.20</td>
</tr>
<tr>
<td>% Critical Coverage Improvement</td>
<td>37.12%</td>
</tr>
<tr>
<td># Generators Retired</td>
<td>2</td>
</tr>
<tr>
<td>Profitable Secondary Service</td>
<td>Retail Bill Reduction</td>
</tr>
<tr>
<td>Total Sec. Service Revenue ($)</td>
<td>$8,785,963</td>
</tr>
<tr>
<td>Avoided Costs due to Demand Charge Reduction</td>
<td>$4,850,519</td>
</tr>
<tr>
<td>Avoided Costs due to Energy Cost Reduction</td>
<td>$3,935,444</td>
</tr>
</tbody>
</table>

NPV (20 Yr Cost in Millions of $)

Baseline: $108.95
Li-Ion Microgrid: $105.27
% NPV Improvement: 3.38%

Baseline Critical Load Coverage ($/kW-yr): $135.50
Storage-Enabled Critical Load Coverage ($/kW-yr): $85.20
% Critical Coverage Improvement: 37.12%

# Generators Retired: 2
Profitable Secondary Service: Retail Bill Reduction
Total Sec. Service Revenue ($) = $8,785,963
Avoided Costs due to Demand Charge Reduction = $4,850,519
Avoided Costs due to Energy Cost Reduction = $3,935,444

Annual $/kW Peak Critical Load

Baseline: $109.00
Li-Ion Microgrid: $80.00
Economic Metric Li-Ion Microgrid – All Sites
Microgrid Design for PSPS Events
(Study for SCE)
Introduction

Problems (Why?)
- Customer interruption during prolonged outages (PSPS, scheduled maintenance)
- California State push to meet **Clean Energy Targets** and **GHG Emission Reduction** targets

Solution
- Solar plus Storage Microgrids to build **Resilient Communities**

Design (How?)
- Microgrid Design – **Solar plus storage** using **DER-VET** to maximize **resiliency** and **cost-efficiency**

*DER-VET is a CEC funded open-source software tool*  
*PSPS: Public Safety Power Shutoff*
Solar plus Storage Microgrid Design Overview

**DER Technology Mix**
- Solar PV
- Energy Storage

**DER Sizing & Operation**
- **Primary Objective**: Customer Reliability/Resiliency for planned outage
- **Secondary Objective**: Maximize economic benefits from Wholesale market participation

**Cost Benefit Consideration**
- DER ownership model: FTM utility owned
- Lifetime of assets and replacement
- Analysis time horizon
- CBA Metrics: Total project NPV

---

### Outage Horizon

- **24 hrs**
- **48 hrs**

---

### Financials Summary

- **Lifetime Present Value**
  - Cost ($) [Red]
  - Benefit ($) [Green]
Microgrid Candidate Selection Scenario

1. High frequency PSPS circuits (based on 2018 and 2019 data)
2. Candidate that can safely remain energized during PSPS events
3. Screen out candidate with planned mitigation solutions
4. Prioritize candidates based on key criteria (low income, no. of PSPS, critical and/or disadvantaged customers, etc.)

Study conducted on one of SCE’s feeders:
- Peak demand approx. = 2.2 MW
- No. of customers = 137 customers
- Customer type = 98% commercial and industrial circuit
Microgrid Design - DER-VET Input

- Identify potential planned outages and duration
  - Load profile to identify microgrid demand

- Solar PV assumptions and limitations
  - Solar irradiance profile and dependability percentages – (0, 27%, 42%, 100%)
  - PV limited by land availability – Size varied between 0.5 MW - 30 MW (carport, ground mount)
  - PV can be curtailed

- Battery ES assumptions:
  - Initial SOC at the start of outage event is 90%
  - Battery round trip efficiency – 91%
  - Hybrid solar plus storage installation – co-located at the dc side
  - No duration constraint
24 Hour Outage DER Sizing
Min power rating for the storage = Peak Load (~2.2 MW)

Energy rating of the battery decreases with increase in installed PV capacity until the knee point

PV curtailment happens at and after the knee point

PV curtail % = [Sum of curtailed PV energy at each time step / Sum of total PV energy at each time step]
PV Curtailment and the ‘Knee Point’

- There is direct correlation between PV curtailment and Knee point
  - PV curtailment happens at and after the knee point

PV curtail % = [Sum of curtailed PV energy at each time step / Sum of total PV energy at each time step]
Outage Simulation – Solar (9 MW) + Storage (2.2MW/11.5MWh)

Load and PV Profile

SOC Profile

Min ES size:
Power= 2.2 MW
Energy= 11.5 MWh

• SOC is not 100%, so there is no PV curtailment in this case
• Excess PV generation is charged in ES and so there we can see an increase in battery SOC %
Cost-Benefit Analysis - Assumptions

- Benefit Services and Modeling Approach
  - **Reliability**: 100% Load coverage for Planned Outages (3 events X 24 hrs)
    - Reserve 100% Energy Storage Capacity for 24 hrs
  - **Wholesale Market Participation**: Co-optimized for
    - Energy arbitrage
    - Frequency Regulation

- EPRI Financial Assumptions
  - **Design Parameters**
    - Discount Rate: 10%
    - Inflation Rate: 2%
    - Economic Carrying Cost (PV): 10.64%
    - Economic Carrying Cost (ES): 15.11%*

*Reliability: Value of service calculated based on customer minutes of interruption (CMI) and customer type (residential, commercial, industrial)

*Considers Federal Income Tax Credit (ITC) for solar plus storage assets

For illustration propose only (not in scale)
48 Hour Outage DER Sizing
Min ES Size – Allowing PV Curtail – 48 hr Outage

Min power rating for the storage is about 2 MW (~peak load). Similar to the 24 hr outage case.

Energy rating follows the same trend as in previous case. The knee points are slightly different from the previous case.

ES duration trend is also similar to 24 hour outage.
PV curtailment happens at or after the knee point

PV curtail % = [Sum of curtailed PV energy at each time step / Sum of total PV energy at each time step]
Timeseries Plots for 42% PV Case’s Knee Point – 10 MW PV

Load and PV Profile

SOC Profile

There is some curtailment because excess generation is more than the Battery power rating of 2.03MW

Min ES size:
- Power=2.03 MW
- Energy=17.81 MWh
Microgrid Design Summary

- Solar plus storage microgrid design using DER-VET
  - Ensured **100% load coverage** during outage events and planned maintenance
  - Demonstrated ability to determine a minimum size system to **meet 24 hour** microgrid demand
  - Detailed cost-benefit analysis to estimate the net present value of the designed microgrid

- SCE issued RFP in Q1 for potential microgrids deployment in 2020
  - Decided to **not pursue** the proposed projects based on **costs, technology**
  - Following the Q1 RFP, **SCE started reevaluating possibilities**, applying lessons learned, and developed site selection & evaluation criteria for potential **2021/22** microgrid deployment
SCE’s EPIC Front-of-The-Meter (FTM) Microgrid Projects

- Control and Protection for Microgrids and Virtual Power Plants
  - Development of hardware-in-the-loop (HIL) microgrid test-bed and demonstration of control & protection schemes
  - Platform to design & integrate microgrids into SCE planning & operational processes

- Smart City Demonstration
  - Partner with City to deploy FTM microgrid supporting critical facilities
  - Customer and utility-owned DERs to operate FTM microgrid (100% inverter-based)
  - Interface between Microgrid Control System and Grid Management System for improved visibility and operation (island and resynchronize)

- Service and Distribution Centers of the Future
  - Integrated electric fleet center field demonstration with managed EV charging and DERs
  - Use of a FTM energy storage to support load management and resiliency
StorageVET® Background
StorageVET® in Action

StorageVET® is a free, open source energy storage project valuation tool informing decision-makers across the electric grid.

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<th>StorageVET Analysis Process</th>
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<td>Select Storage Project Specifications</td>
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<td>Technology</td>
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<td>Thermal</td>
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<td>Battery/Flow Battery</td>
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<td>Pumped Hydro</td>
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<td>T&amp;D Upgrade</td>
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<td>Optimize storage services</td>
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<td>Dispatch simulation</td>
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<td>Financial calculations</td>
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<td>Project Economics</td>
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<td>Site Impacts</td>
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<td>Customer Site Impacts</td>
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Peaker Substitution
T&D Deferral
Solar + Storage
...and many others
Together...Shaping the Future of Energy®