Peninsula Advanced Energy Community (PAEC)

Task 3.6: Final Dispatch Model for Energy Storage System

Prepared for
California Energy Commission
1516 Ninth St., MS-51
Sacramento, CA 95814

Prepared by
Sovereign Energy Storage, LLC
PO Box 170684
San Francisco, CA 94117
www.sovereignstorage.com

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About the Authors

Sovereign Energy Storage

Sovereign Energy provides utilities with intelligent and cost effective solutions for integrating renewables, improving system reliability and power quality, and lowering operating costs. Our success will accelerate the adoption and penetration of renewable energy, while modernizing and improving the stability of the grid.

Visit SES online at http://sovereignstorage.com

About the Clean Coalition

The Clean Coalition is a nonprofit organization whose mission is to accelerate the transition to renewable energy and a modern grid through technical, policy, and project development expertise.

The Clean Coalition drives policy innovation to remove barriers to procurement and interconnection of distributed energy resources (DER)—such as local renewables, advanced inverters, demand response, and energy storage—and we establish market mechanisms that realize the full potential of integrating these solutions. The Clean Coalition also collaborates with utilities and municipalities to create near-term deployment opportunities that prove the technical and financial viability of local renewables and other DER.

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I. Summary

Sovereign Energy Storage (SES) evaluated multiple energy storage revenue and dispatch modeling tools for behind the meter applications in the California market. SES has experience vetting tools from private companies and public source market tools. SES selected the Electric Power Research Institute's (EPRI) Energy Storage Valuation Tool (ESVT) as the analytical engine to move forward with the Peninsula Advanced Energy Community (PAEC) initiative for several reasons:

1) ESVT is currently the only open-source, online tool which can be used by all market participants. A team of experts manages at the Electric Power Research Institute (EPRI) has been developing the tool in collaboration with a consortium of market participants to test and validate various functionalities, inputs, and use cases.

2) For energy storage projects to meet acceptable returns, projects will need to be integrated into wholesale markets. The EPRI tool is capable of evaluating performance of an energy storage asset in the California Independent System Operator (CAISO) wholesale market across revenue streams, and can also perform demand charge management (DCM) for the site.

3) StorageVET is a California Energy Commission funded project/tool. Sovereign has been involved with the development of the tool for the last two years. The open-source nature of the tool will allow other potential developers to run scenarios for projects without having to contract with a private entity.

II. Alternative Software Packages Considered

The following is a list of public and private modeling tools and key criteria analyed by SES:

Table 1: Dispatch Modeling Tools – Key Criteria Analysis

Provider	Tool Name	Open Source	DCM + DR	+ Grid Services	Backup Power
Geli	Esyst	No	Yes	No	No
Enbala	Symphony	No	Yes	Yes	Yes
EPRI	StorageVET	Yes	Yes	Yes	Yes

III. Modeled Scenarios and Analysis

The first model runs indicated that the StorageVET tool (the tool) can properly assess a distribution or transmission (in front of the meter) asset performance in the wholesale market.

The analysis was performed using a variety of system sized and stacked use cases in PG&E service territory:

- 100kW, 400kWh (4hr, C/4)
- Demand charge management under PG&E's E-19 tariffs
- Participation in DR programs (Capacity Bidding Program, Bi-lateral DR programs)
- Wholesale Market Participation: Regulation Up/Down, Spin/Non-Spinning Reserve, Energy

The aforementioned project sizing is the minimum allowed to participate in the CAISO markets. A 100kW load is a fairly large commercial, or small industrial load. A 100kW/400kWH battery can fit in the footprint of a parking space.

IV. Model Issues and Solutions

During the initial run of tool, Sovereign identified three issues with the results:

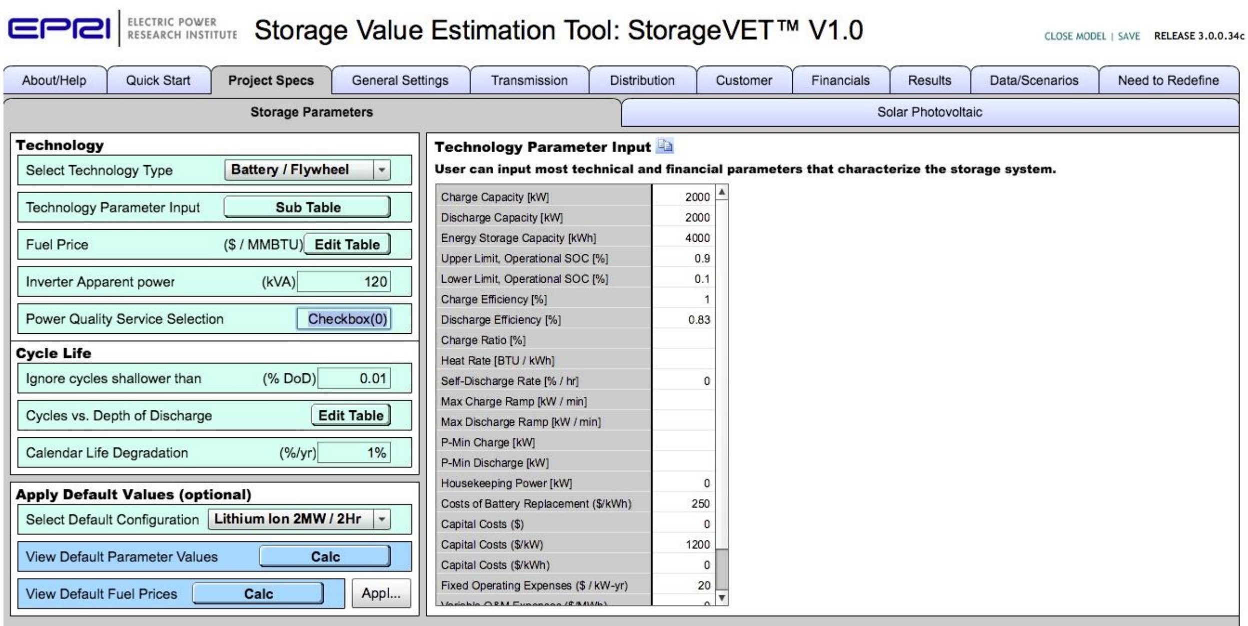
1) The tool does not have the correct constraints to properly assess participation of a behind the meter resource. Specifically, the tool was not correctly calculating performance of a resource according to the "10 in 10 baseline rule", which is the methodology used to settle DR in California.
2) The tool also did not use load on-site as a constraint in its analysis - a DR resource must be limited by the peak load on-site during an event window.
3) The tool could not assess the capability of a behind the meter resource to participate in Regulation Up/Down in the CAISO market, which is the highest value revenue stream after Demand Charge Management and Demand Response.

After significant correspondence with EPRI, the bugs in the tool were corrected, allowing SES to complete the dispatch model analysis.

V. Screenshots of StorageVET Tool

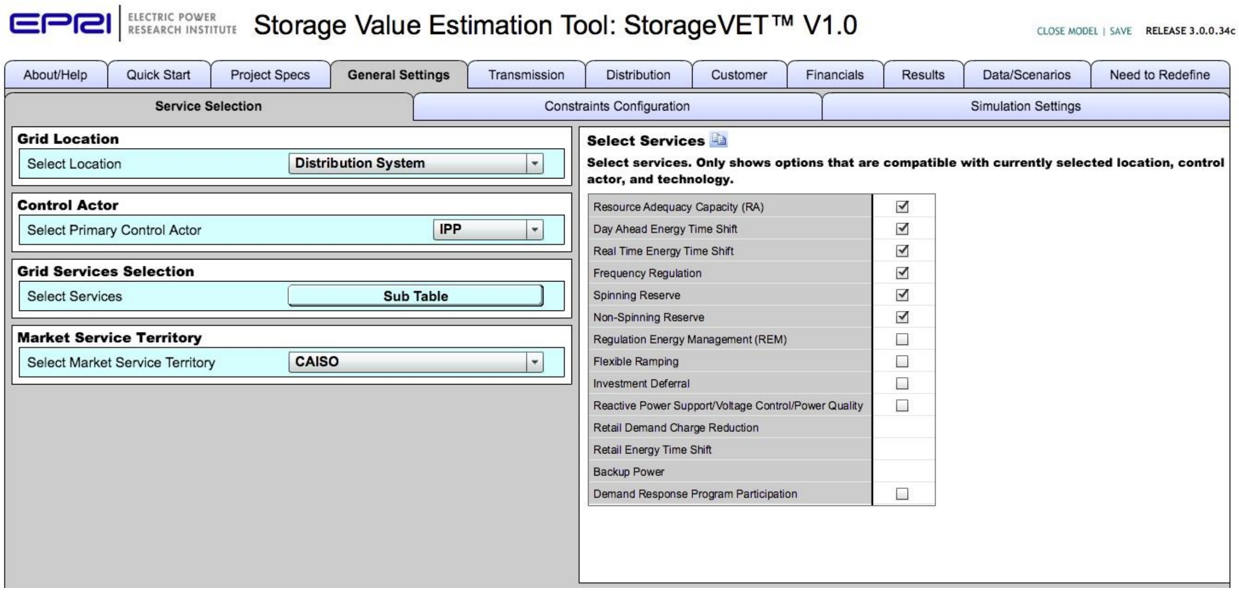
The below screenshots walk the user through the technical inputs and revenue assumptions, as well as the revenue and battery cycling results produced by the tool.

Figure 1: Screenshot - Technology Inputs for Battery Energy Storage



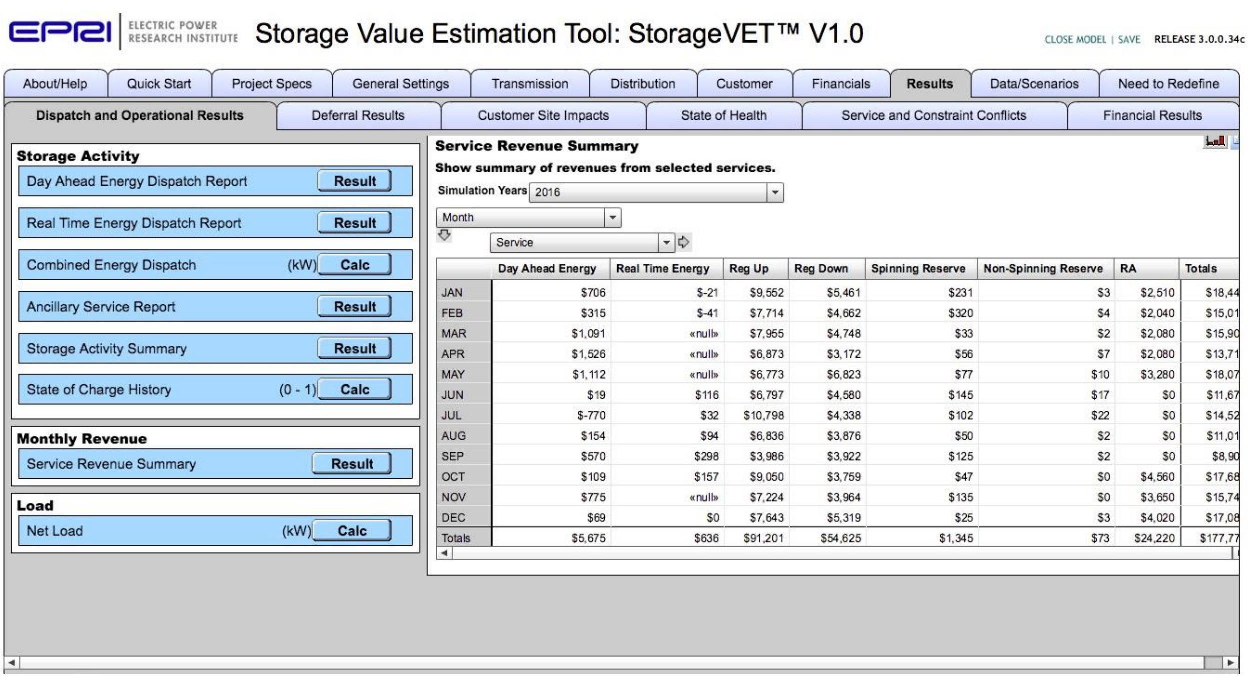
The tool allows for detailed inputs on project size (kW/kWh), efficiency, charging capacity, capital cost, and operations and maintenance (O&M) costs.

Figure 2: Screenshot – Revenue "Service" Inputs for Battery Energy Storage



The tool allows for the simultaneous evaluation of multiple use cases and revenue stream; the model optimizes for the highest value dispatch for each interval.

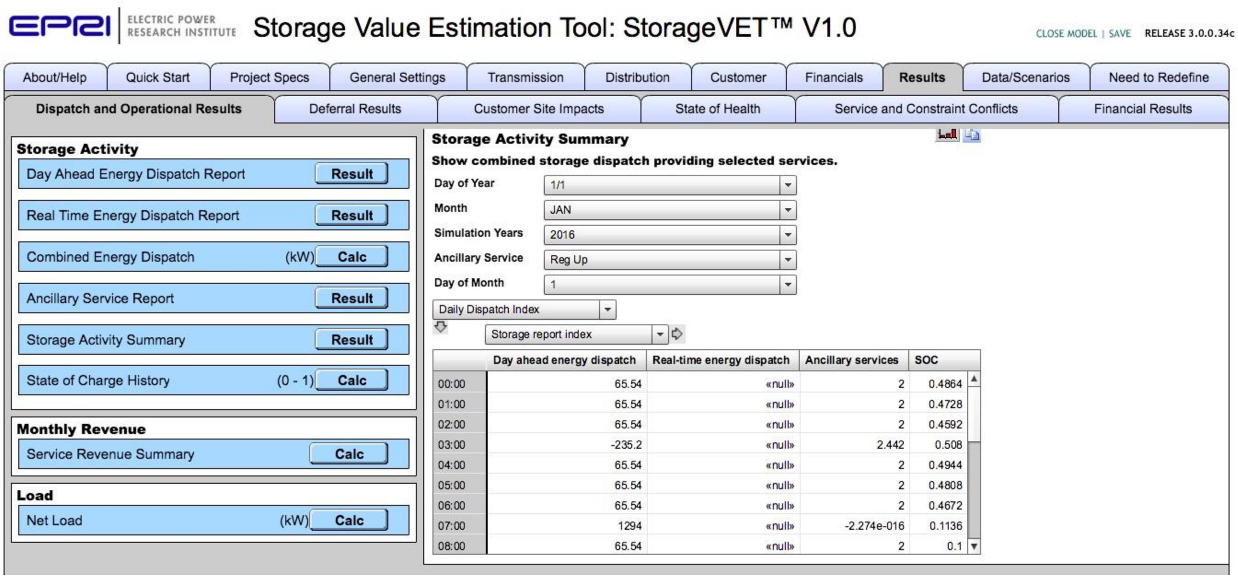
Figure 3: Screenshot – Revenue by Service



	Day Ahead Energy	Real Time Energy	Reg Up	Reg Down	Spinning Reserve	Non-Spinning Reserve	RA	Totals
JAN	$706	$-21	$9,552	$5,461	$231	$3	$2,510	$18,44
FEB	$315	$-41	$7,714	$4,662	$320	$4	$2,040	$15,01
MAR	$1,091	«null»	$7,955	$4,748	$33	$2	$2,080	$15,90
APR	$1,526	«null»	$6,873	$3,172	$56	$7	$2,080	$13,71
MAY	$1,112	«null»	$6,773	$6,823	$77	$10	$3,280	$18,07
JUN	$19	$116	$6,797	$4,580	$145	$17	$0	$11,67
JUL	$-770	$32	$10,798	$4,338	$102	$22	$0	$14,52
AUG	$154	$94	$6,836	$3,876	$50	$2	$0	$11,01
SEP	$570	$298	$3,986	$3,922	$125	$2	$0	$8,90
OCT	$109	$157	$9,050	$3,759	$47	$0	$4,560	$17,68
NOV	$775	«null»	$7,224	$3,964	$135	$0	$3,650	$15,74
DEC	$69	$0	$7,643	$5,319	$25	$3	$4,020	$17,08
Totals	$5,675	$636	$91,201	$54,625	$1,345	$73	$24,220	$177,77

The model provides best-in-class detail into the revenue generated by service by month. This table provides the critical financial information to determine project economics.

Figure 4: Screenshot – Storage Activity Summary



The tool produces dispatch by service, in hourly increments, allowing the developer to see how the battery is dispatched, and for which service. The model does this while imposing State of Charge restrictions (also noted).

VI. EPRI ESVT Tool Manual (Overview)

The EPRI's StorageVET tool is free for all users, however, a registration and confirmation process is required to gain access to the tool. Once registered, login information is emailed to the user.

After registering to use the tool, follow the below steps to utilize the ESVT for BTM energy storage dispatch and revenue modeling:

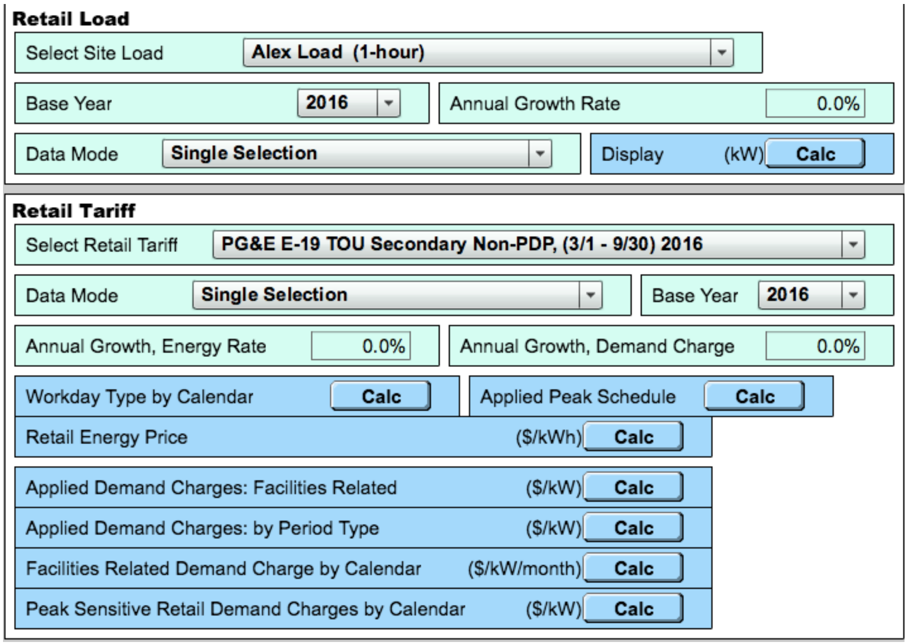
1. Login to ESVT:
    a. http://www.storagevet.com/storageVet/client/AnalyticaCloudPlayer.aspx

2. Go to Project Specs:
    a. Select Technology Type: Battery/Flywheel
    b. Select Sub-Table: (the following items are variables that are inputted by the user for the project):

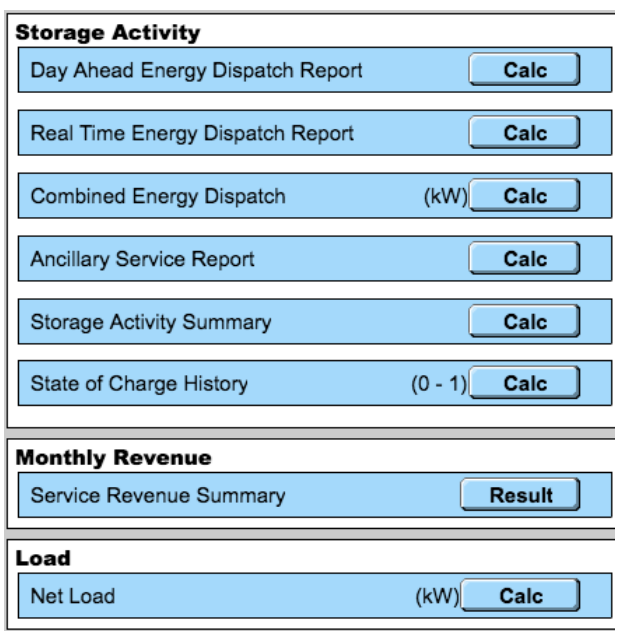
Charge Capacity [kW]	100
Discharge Capacity [kW]	100
Energy Storage Capacity [kWh]	400
Upper Limit, Operational SOC [%]	1
Lower Limit, Operational SOC [%]	0.1
Charge Efficiency [%]	1
Discharge Efficiency [%]	0.9
Charge Ratio [%]	
Heat Rate [BTU / kWh]	
Self-Discharge Rate [% / hr]	0
Max Charge Ramp [kW / min]	
Max Discharge Ramp [kW / min]	
P-Min Charge [kW]	
P-Min Discharge [kW]	
Housekeeping Power [kW]	0
Costs of Battery Replacement ($/kWh)	200
Capital Costs ($)	500K
Capital Costs ($/kW)	1200
Capital Costs ($/kWh)	0
Fixed Operating Expenses ($ / kW-yr)	20

3. Go to General Settings, and make the following selections:
    a. Grid Location: Customer Side of Meter
    b. Control Actor: Customer
    c. Grid Services Selection:
        i. Retail Demand Charge Reduction
        ii. Demand Response Program Participation
        iii. Both

4. Go to Customer
    a. To select customer load, you must go to 'Import Data' tab and import a load profile to be used in the analysis. In this case, Sovereign uploaded the load profile of a food distribution center in San Jose, CA.



5. Go to Results Tab
   a. Run all results to get dispatch, state of charge, and revenue results based on the inputs (Project Specs, Step 2) and customer Load Profile (Step 4).



Illustrative Example: Food Distribution Company on PG&E E-19 Tariff

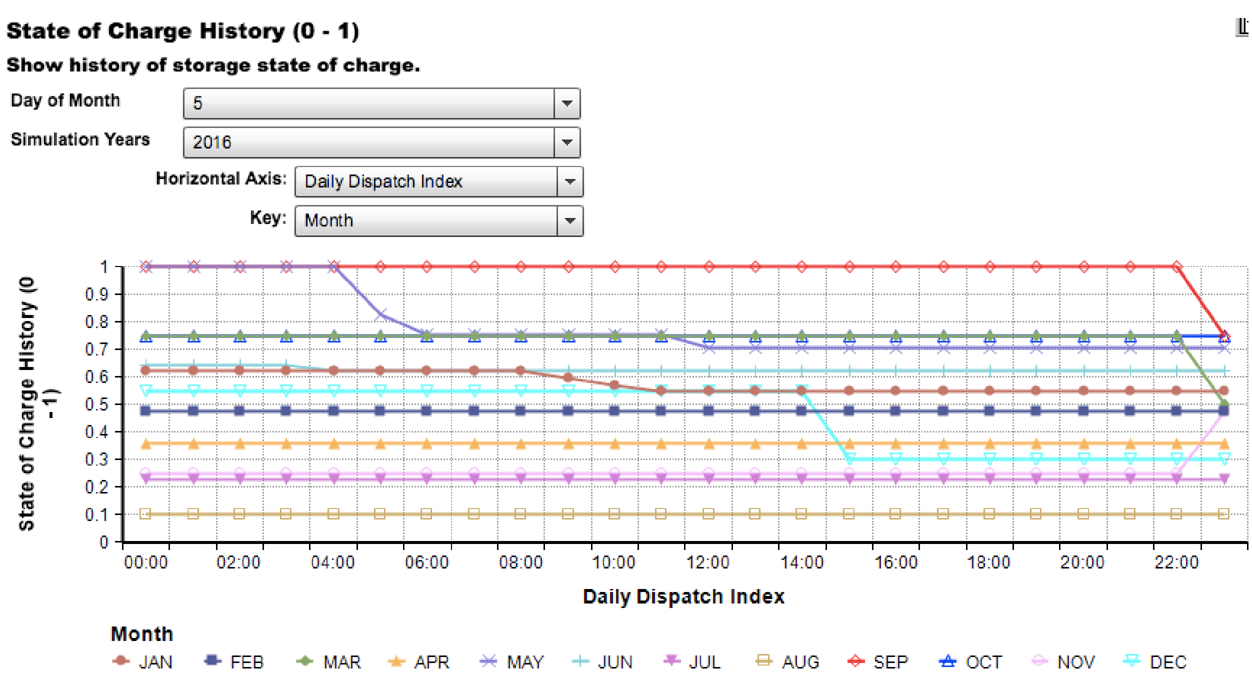
SES ran multiple cases for a 100kW, 400kWh battery system at a food distribution center in San Jose California, under the PG&E's E-19 Tariff. The analysis focused on three use case types:

1. Performing demand charge management (DCM) only (behind the meter only)
2. Performing demand response (DR) only (behind the meter only)
3. Optimization of demand charge management (DCM) and demand response (DR) (behind the meter and in front of the meter)
4. Performing CAISO wholesale market revenue streams, no DCM or DR, (behind the meter and in front of the meter)

Note: StorageVET does not currently optimize Demand Charge Management (DCM) with wholesale market revenue. This functionality will be added in subsequent versions of the tool. The combination of wholesale and DCM + DR revenue will give a potential owner/equity investor in the project a more complete view of the project.

Case 1: Demand Charge Management Only

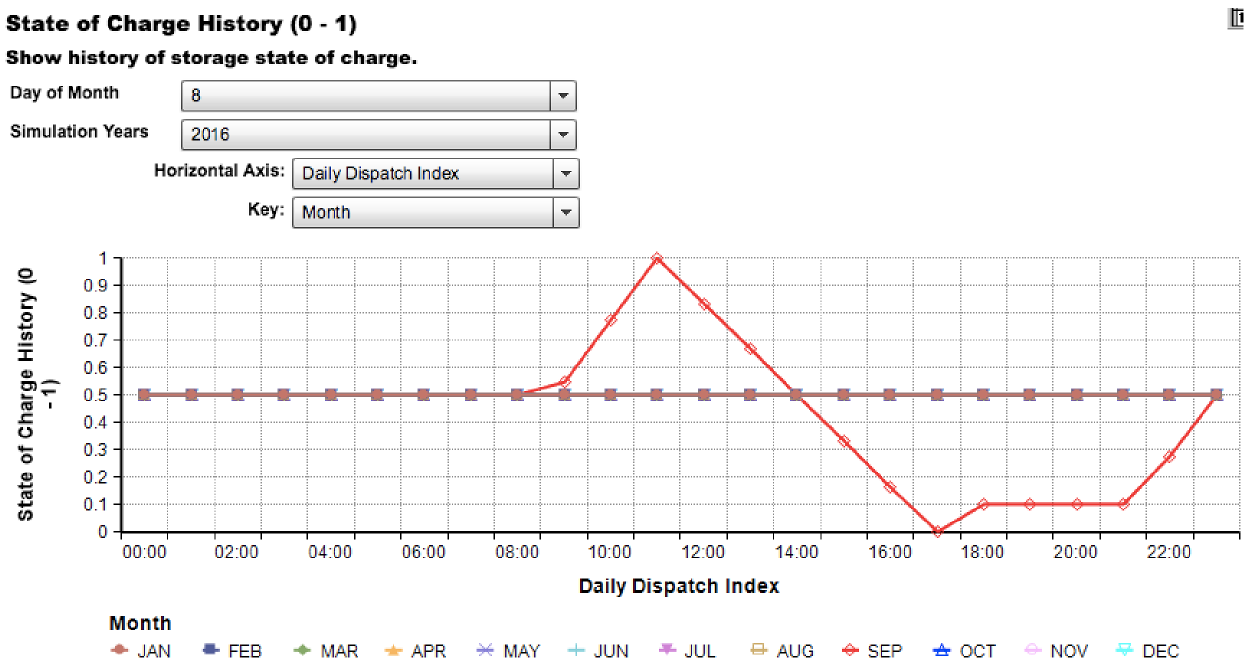
In the DCM-only case, the battery is dispatching 10 – 20 times per month to lower peak demand charges. The battery would be otherwise available to provide DR and participate in the wholesale market.



The graph indicates that demand charge management requires dispatch almost daily every month to successfully lower the peak demand charges at the facility. This would result in 100 – 300 cycles annually.

<u>Case 2: Demand Response Only</u>

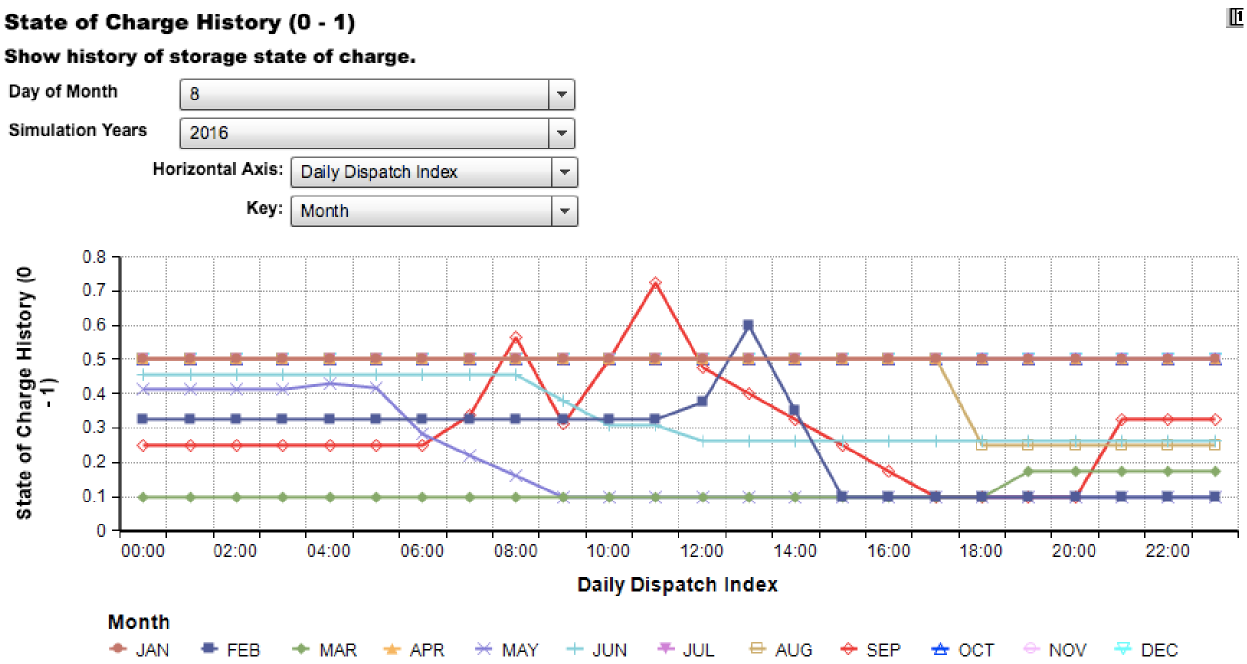
In the Demand Response Only case, the battery is discharging 2 – 4 times per month in the summer months when called upon by the ISO or DR provider to perform. The battery would be otherwise available to provide DCM and participate in the wholesale market.



The graph indicates that the storage resource is sitting idle most the hours, and is available to dispatch to provide service to the wholesale market, increasing revenue. This use case would result in 20 – 50 total cycles annually. Each demand response program has different specifications; California typically requires 4 hours of continuous discharge energy to comply with capacity obligations.

<u>Case 3: Demand Charge Management and Demand Response</u>

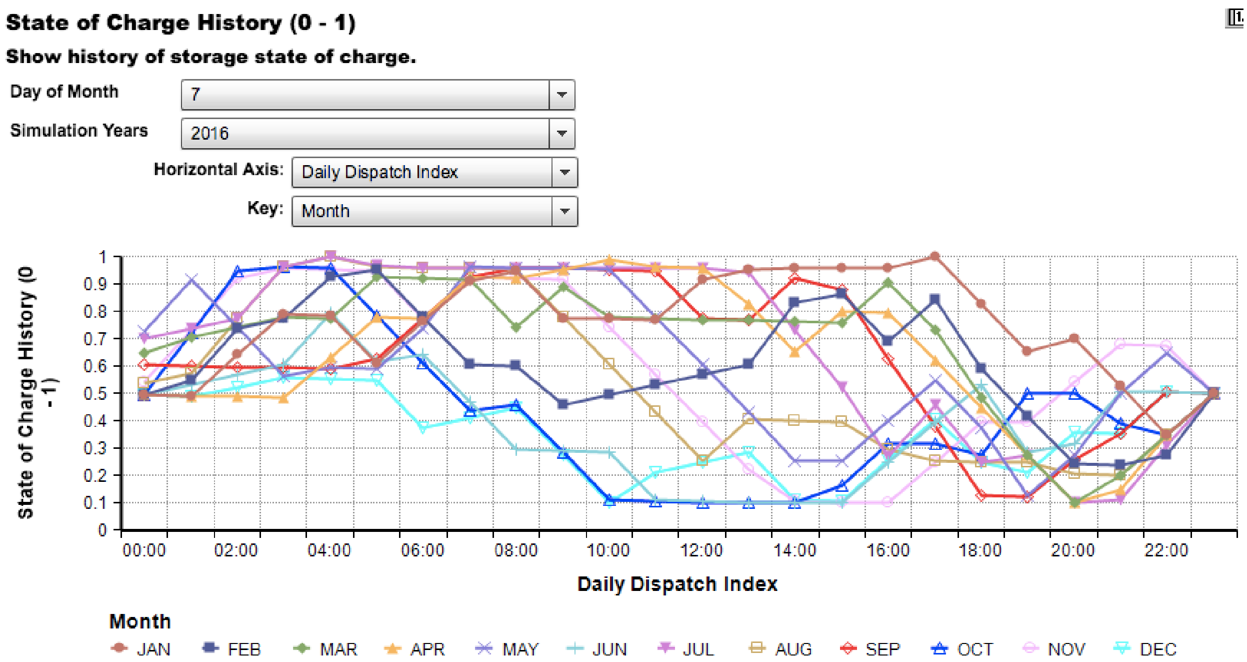
In the DCM + DR case, the battery is performing DCM with the full kW capacity (100kW), and reserving a small portion of the capacity to perform DR. In this case, 30% of the battery inverter capacity (30kW) is reserved for DR.



This use case in a battery system that has a more complex charge discharge cycle of 150 – 200 cycles per year, but many of the cycles will be below 100% depth of discharge.

Case 4: Wholesale Market Participation Only

In the wholesale market participation case, the battery is charging and discharging daily to perform the highest value service to the grid. In this case, the battery is performing its RA (Resource Adequacy) capacity obligation daily, and is performing frequency regulation during all other hours.



In the wholesale market participation case, the battery is cycling every day at different depths of discharge according to the highest value use case which can be performed in any given hour. It is following multiple signals and has a daily schedule which it can depart from if a higher value use case presents itself.

VII. Conclusion

The dispatch model results were able to validate SES's initial assumptions around financial viability of various use cases in the CAISO market. Demand charge management on its own is a high value use case that can support battery storage (if SGIP is obtained). However, it is also very risky to perform because the battery control system has to forecast individual site load.

The subsequent iteration of the ESVT tool will optimize across all revenue streams (DCM, DR, Wholesale Market), and as participation rules continue to evolve the EPRI team will accept feedback in order to ensure that the ESVT tool can conform to performance requirements of each application. Given that the participation rules will continue to evolve, SES will provide feedback on an ongoing basis to the EPRI team. SES's feedback will further ensure that the ESVT tool will be able to adapt to application performance requirements.