

Maximizing Storage Value in Regional Markets and the QuESt App

PRESENTED BY

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Outline



Planning for energy storage can be a tricky process

Before commissioning a system, you want to get an idea of what it could do

- What are the value streams?
- What system size?
- How will it operate?

A number of factors can significantly affect the potential of a system

- Pricing structures
- System configurations
- Load Requirements

Sandia helps many entities determine value to help planning efforts

- Analyses of regional markets for specific applications
 - NY State VDER Program
- The QuEST tool streamlines analyses for common scenarios

NY State Case Study



NY State has undertaken an ongoing process to change compensation for distributed energy

- Value of Distributed Energy Resources (VDER)
- Replaces net metering
- Assigns value to when and where energy is produced

Multiple values that can stack depending on time and location

- Day Ahead LBMP
- iCap - Value for beneficial production capacity
 - 3 Alternatives that provide value for different production times
- E – Environmental Component
- DRV – Demand reduction value
 - Production during 10 annual peak hours
- LSRV – locational system relief value
 - Extra incentive for generation in certain areas
- MTC – market transition credit
 - Fudge factor to make people happy

iCap Alternative Options

Multiple options can be selected for capacity VDER pricing

Alternative 1

- Fixed monthly \$/kWh price for all generation
- Price set monthly
 - Typically higher in summer and fall months
- ES in a DC-tied configuration increases this value by delivering clipped DC power

Alternative 2

- Fixed monthly \$/kWh for generation between 2pm and 6pm weekdays
- Only available during summer months (June-August)
- Much higher rate than Alt 1 in most areas
- ES value for AC-tied and DC-tied

Alternative 3

- Monthly \$/kW value for generation during coincident peak hours
- Potential ES value as peak hours are typically from 4-8pm

Focus on Alternatives 2 and 3

5 Projects under consideration

Three candidate Community Distributed Generation (CDG) projects considered

- 3 different locations
- 3 different project sizes (sized for the needs of the area?)

Estimate additional value that could be obtained with energy storage systems

- AC-Tied, separate inverter
- DC-Tied, shared inverter
 - Clipped DC power at the inverter can be used to charge the batteries

Subject to transmission limits, PV potential, etc.

Optimized battery dispatch schedule using Python/PYOMO

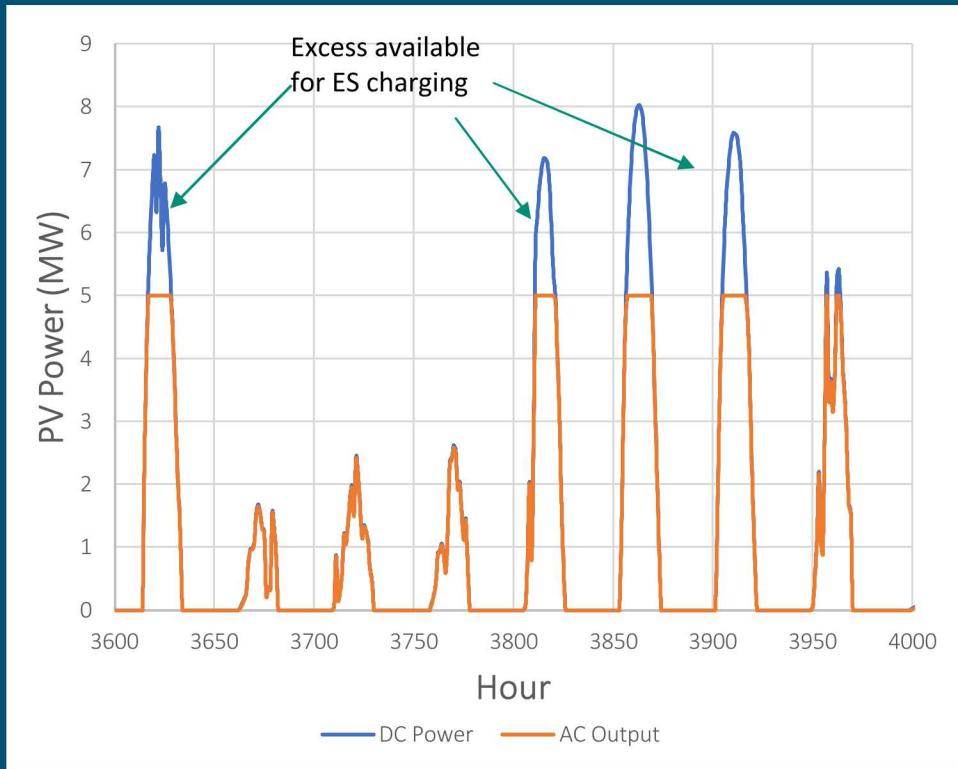
- Open source tools

	A	B	C
Service Territory	ConEd Westchester	National Grid	Central Hudson
NYISO Zone	H	A	G
MW DC	0.75	7.5	2.98
MW AC	0.577	5	2
ESS Connection	AC	DC	DC

Fixed VDER Values (2018)

E - \$/kWh	0.02741	0.02741	0.02741
DRV - \$/kW	0	0	0.5
LSRV - \$/kW	0.034	0	0
MTC - \$/kWh	0.1435	0.0229	0

Modeling PV output



30-min simulation using NSRDB irradiance data

All projects using an DC/AC ratio of ~ 1.5

- DC-tied systems can store excess power that would be curtailed
- DC connections save on system cost by sharing an AC-DC inverter
- AC-tied systems do not share an inverter

PV output was modeled using the data from the System Advisor Model (SAM) and PVLIB

2-6PM June-August Value Stream

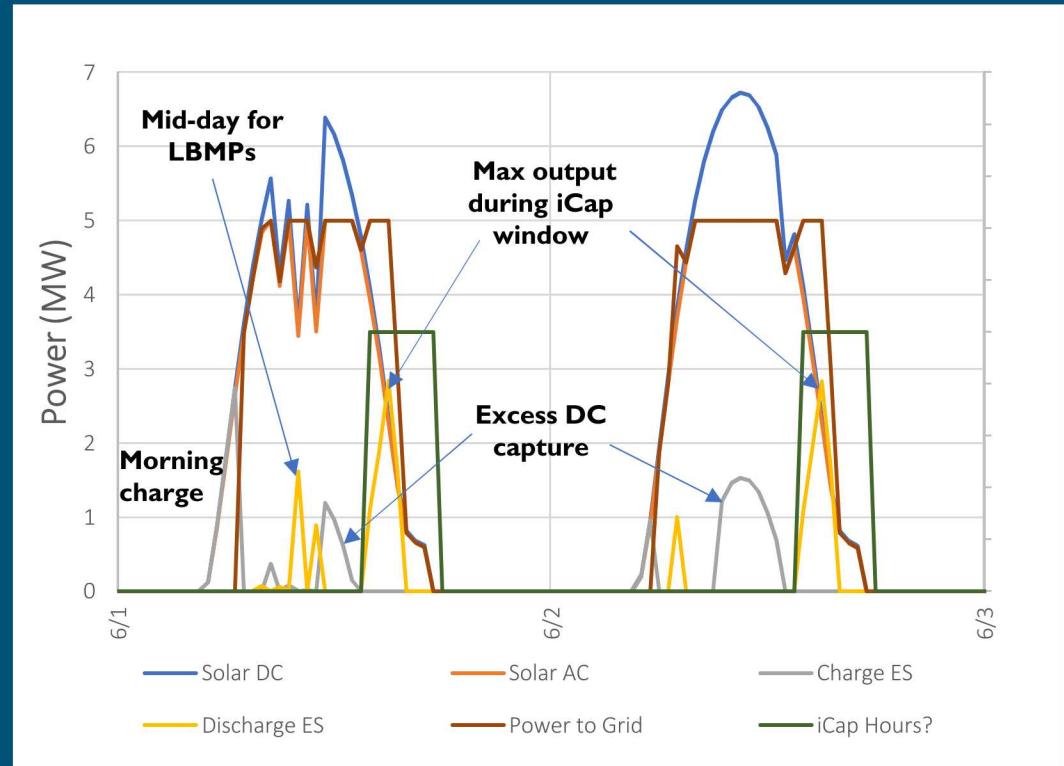
Charge early morning and from clipped power

Discharge mid-day to maximize LBMP

- Fully charge for start of iCap window

Discharge during iCap window to maintain peak power

- Until battery hits lower SOC limit



5 MW / 5 MWh

8 Coincident Peak Value Stream

Charge early morning and from clipped power

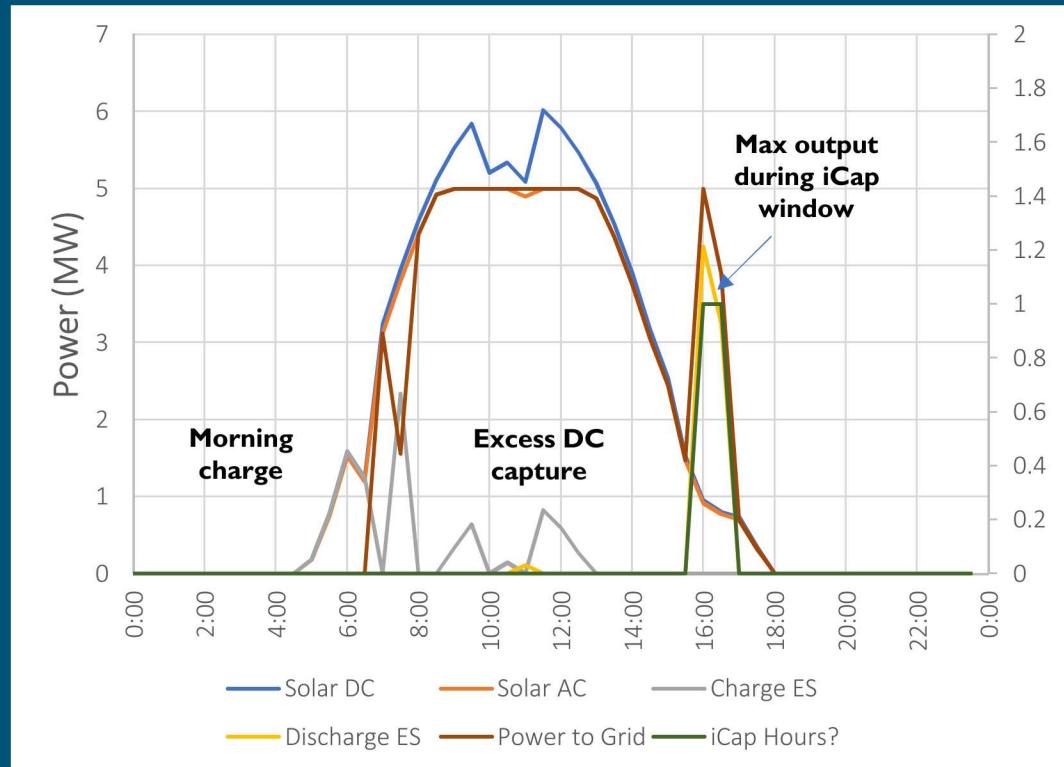
Discharge mid-day to maximize LBMP revenue

- Fully charge for start of iCap window

Discharge during monthly coincident peak

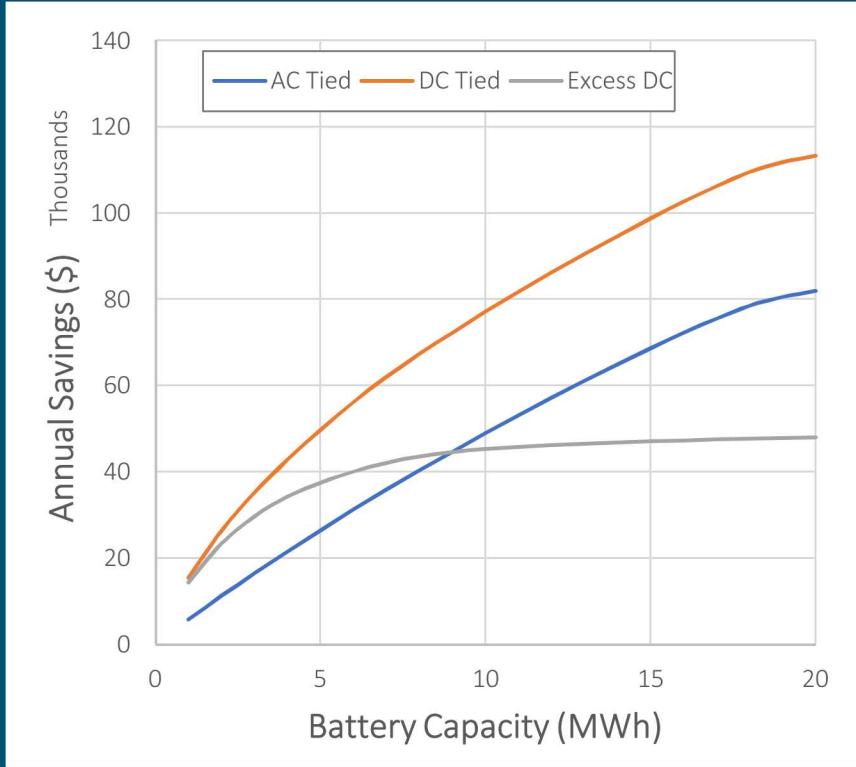
Major difference here is the iCap window

- 1 hour long
- Only once a month
- MUST be properly forecast or NO value

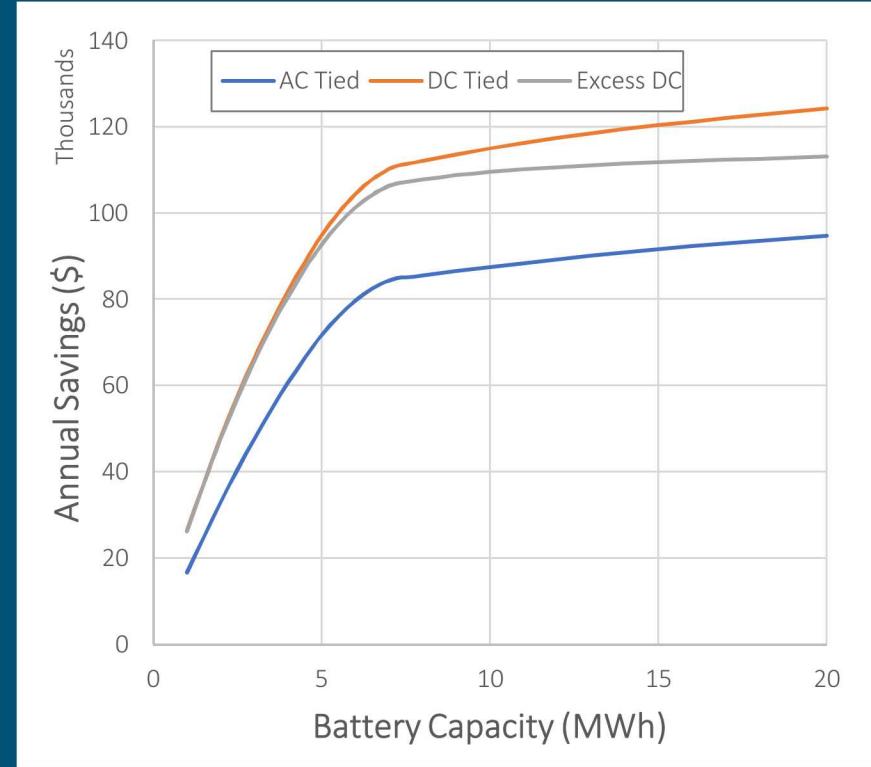


Maximum Project Values

2-6PM
June-August



Monthly
Coincident Peak



Connecting PV and battery DC has advantages over AC connections

In higher energy applications, charging from all available energy is essential

Low energy applications yield the most value per MWh

- Depending on the pricing at the node

Initial Battery Selection

For revenue, bigger is better

Maximizing net benefits comes down to system cost

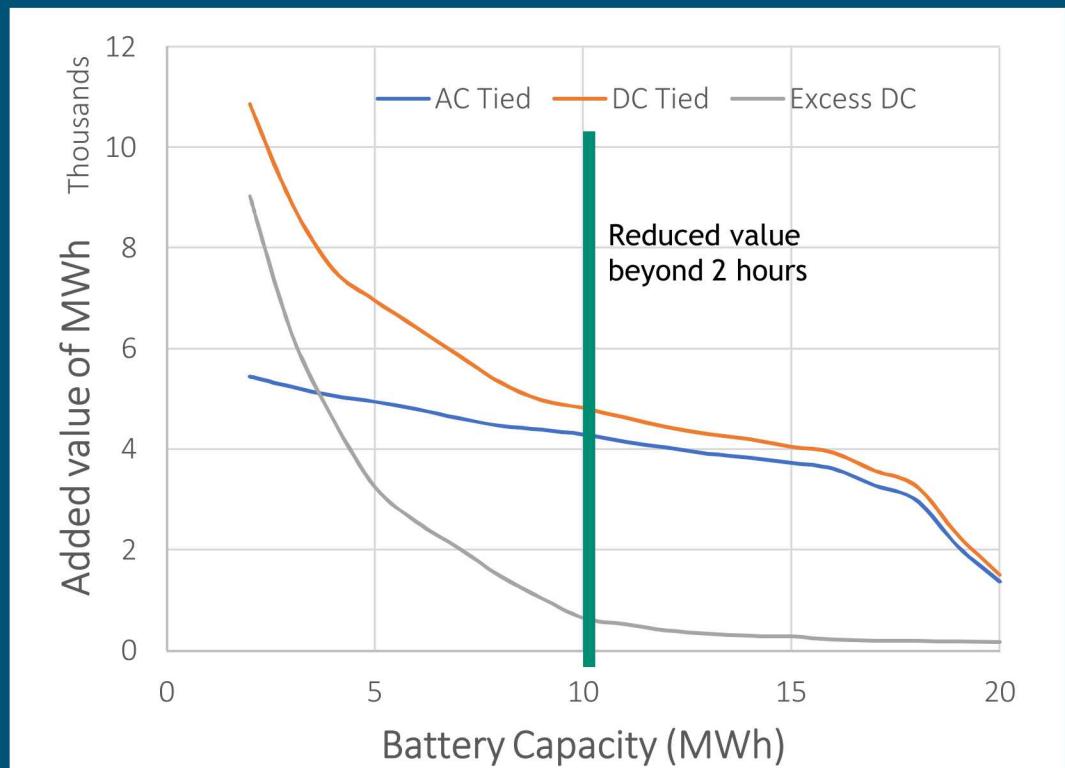
- How do you determine batteries sizes for RFPs?

Diminishing returns indicate upper limits

- Calculate additional savings from next smallest capacity
- Similar calculation is useful for varying power ratings

iCap 2 application, 10 MWh hour battery good center point for search

- 7.5 MWh for iCap 3



Lessons from Case Studies

To give accurate estimates of energy storage value, scenario details need to be represented accurately

- Local pricing structures
- System configurations
- Generation if being paired with renewables

Low energy applications generally yield the most value per kWh

For PV/storage systems, DC-DC connections take advantage of energy that would be curtailed

- Depends on PV inverter size and transmission limits

Forecasting is important to capture coincident peak benefits

- This is often a high value application
- Peaks are often at the same hour in a month year-to-year

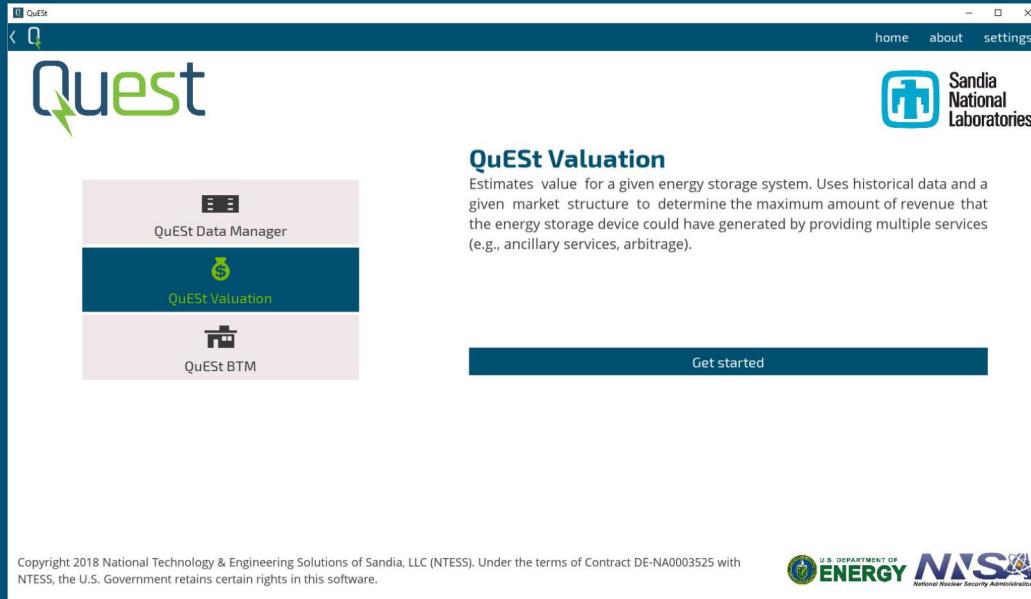
Changing pricing landscapes can make it difficult for developers

- NY made major changes to VDER policies shortly after this analysis

Net revenue comes down to system cost coming from RFPs

- Prior analysis helps to determine what to request and assessment of bids

What is it?



- Open source, Python-based energy storage analysis software application suite
- Developed as a graphical user interface (GUI) for the optimization modeling capabilities of Sandia's energy storage analytics group
- Version 1.0 publicly released in September 2018
- Version 1.1 available on GitHub; Version 1.2 coming soon
 - github.com/rconcep/snl-quest or sandia.gov/ess



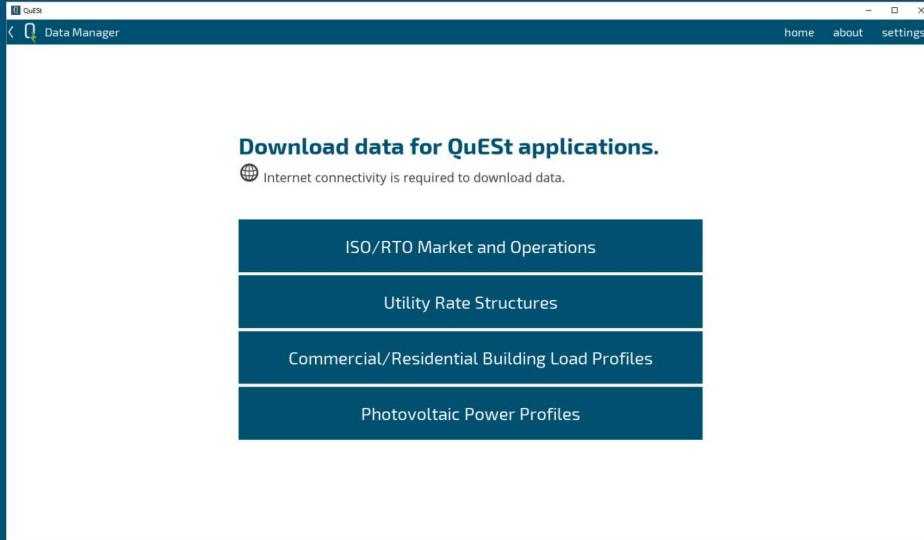
Why QuEST?

- For energy storage project stakeholders
 - Accessible and easy-to-use software tool for energy storage valuation and related applications
- For engineers/developers
 - Open source software project
 - GUI design, application design, Pyomo optimization modeling
 - Pyomo models and other optimization code can be adjusted to fit specific needs
- It's free
 - Written in Python; no software licenses required
- Current application list
 - QuEST Data Manager - Manages acquisition of ISO market data, US utility rate data, commercial and residential load profiles, etc.
 - QuEST Valuation - Estimate potential revenue generated by energy storage systems providing multiple services in the electricity markets of ISOs/RTOs.
 - QuEST BTM* - Estimate the cost savings for time-of-use/net energy metering customers using behind-the-meter energy storage systems.
 - Continuing to add functionality to cover more cases

* For v1.2 release



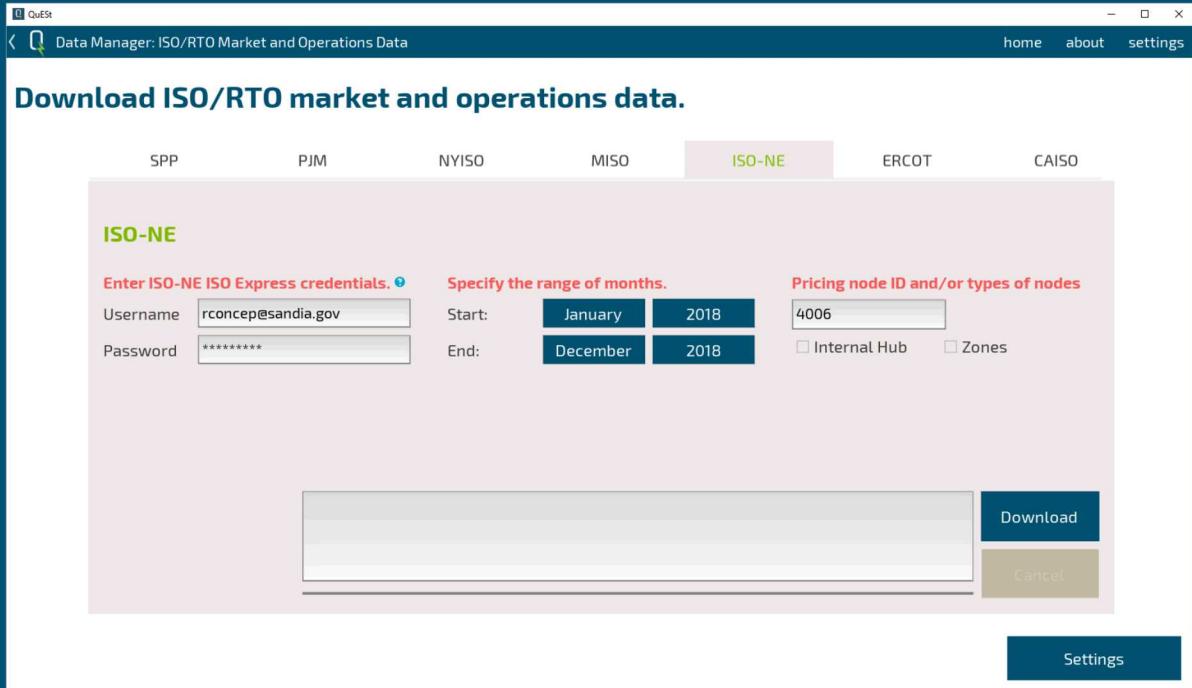
QuEST Data Manager



We use publicly available APIs, posted market data, and crowd-sourced data.

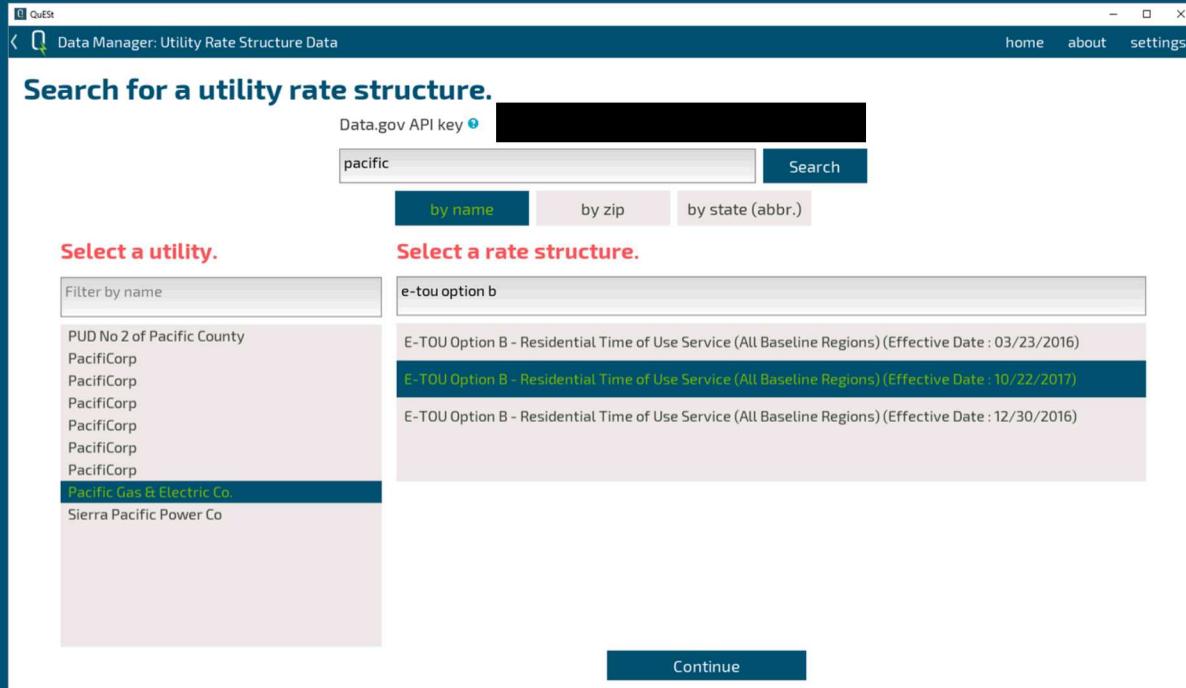
- LMPs, frequency regulation performance/capacity clearing prices, etc. posted by ISOs/RTOs
- U.S. utility rate structures sourced and validated by OpenEI.org
- Commercial and residential hourly load profiles for all TMY3 (typical meteorological year) locations in the U.S. by OpenEI.org
- Hourly photovoltaic power profiles by PVWatts

QuEST Data Manager



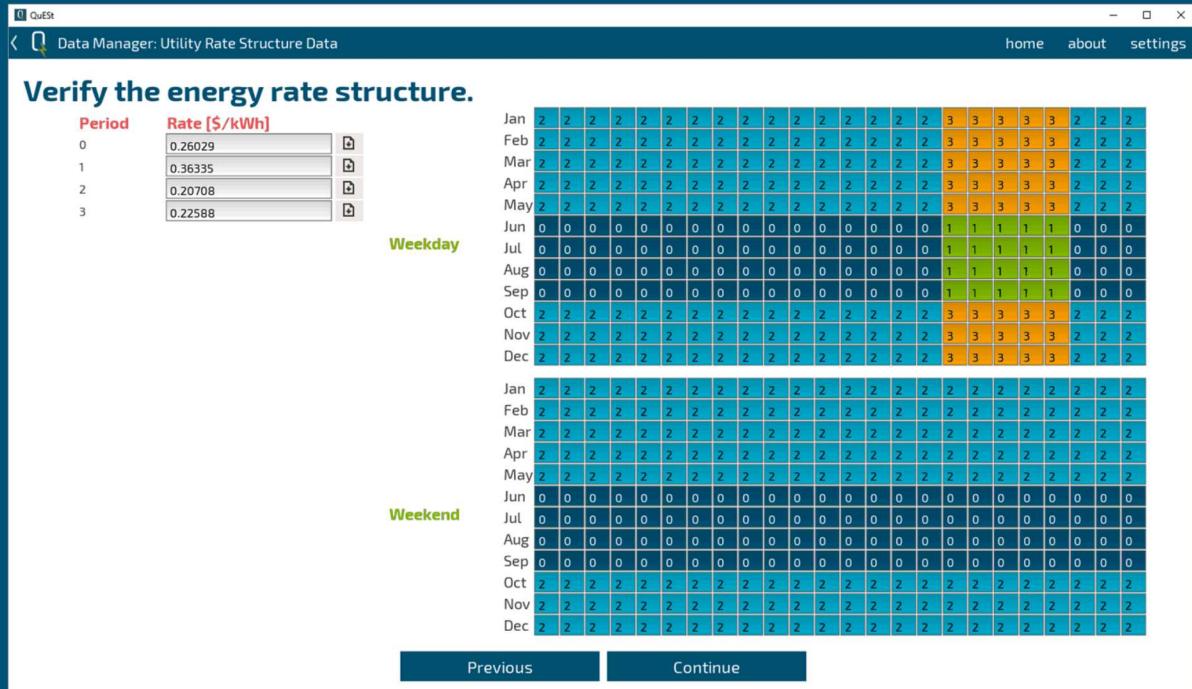
- LMPs, frequency regulation performance/capacity clearing prices, etc. posted by ISOs/RTOs
- Use operator-provided APIs, some requiring a short registration for an API key
 - ISONE, PJM
- Use web crawling libraries to parse marketplace data portals to find data files

QuEST Data Manager



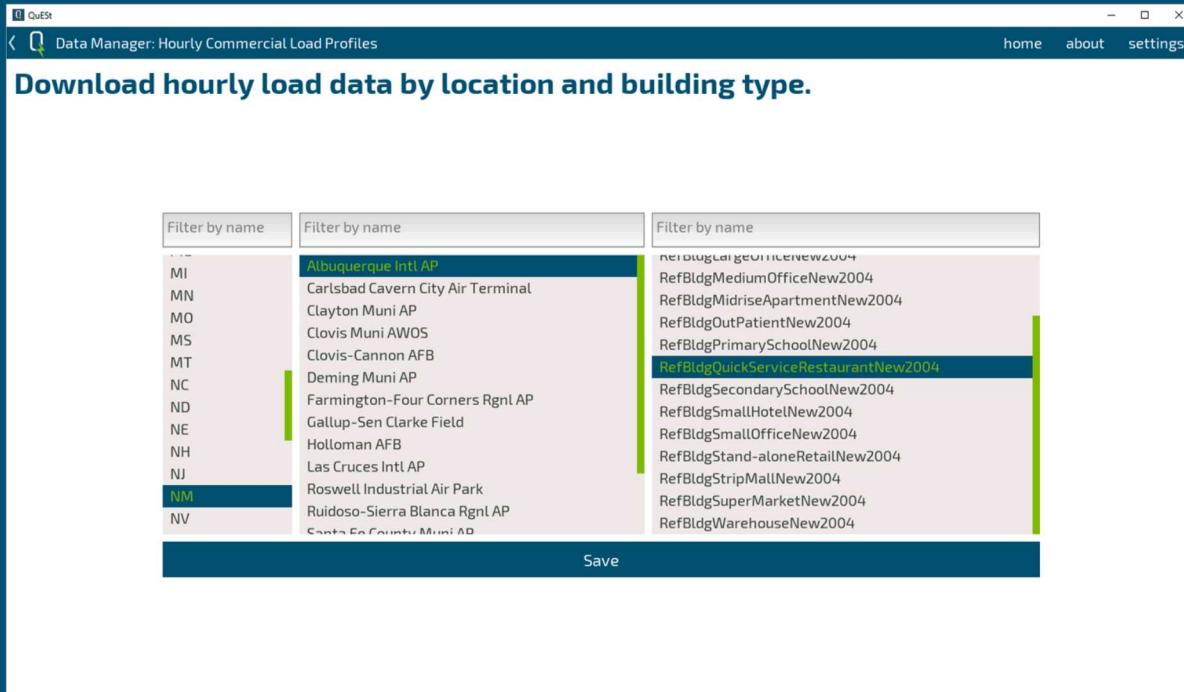
The screenshot shows a search interface for utility rate structures. At the top, there is a search bar with the text "pacific" and a "Search" button. Below the search bar are three buttons: "by name" (highlighted in green), "by zip", and "by state (abbr.)". The main search results are divided into two sections: "Select a utility." and "Select a rate structure." The "Select a utility." section on the left lists several utility names, with "Pacific Gas & Electric Co." and "Sierra Pacific Power Co." highlighted in green. The "Select a rate structure." section on the right lists several rate structures, with "E-TOU Option B - Residential Time of Use Service (All Baseline Regions) (Effective Date : 10/22/2017)" highlighted in green. A "Continue" button is located at the bottom of the search results.

- OpenEI.org, maintained by NREL, hosts a database for U.S. utility rates
- Time-of-use energy rate schedules
- Peak demand and flat demand rate schedules



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QuEST Data Manager



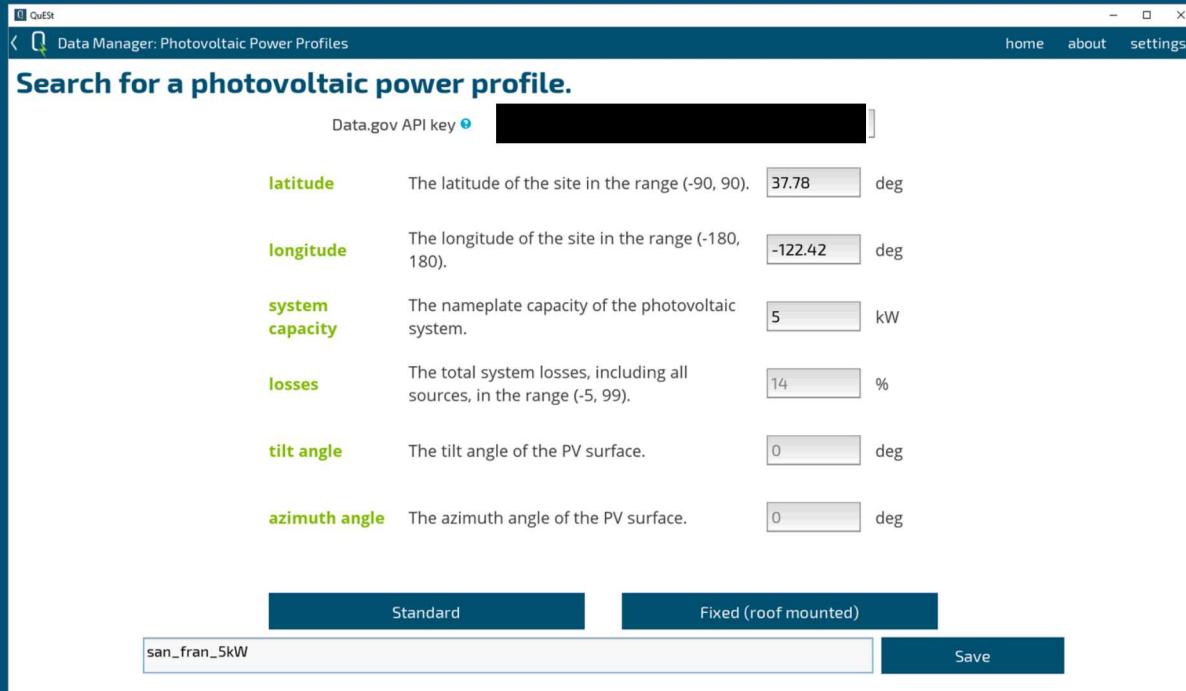
The screenshot shows a window titled "Data Manager: Hourly Commercial Load Profiles". The main content area displays a list of locations and building types. On the left, a vertical list of US states is shown, with "NM" selected. To the right of the states are three filter boxes: "Filter by name" for locations, "Filter by name" for building types, and another "Filter by name" for building types. The location list includes: Albuquerque Intl AP, Carlsbad Cavern City Air Terminal, Clayton Muni AP, Clovis Muni AWOS, Clovis-Cannon AFB, Deming Muni AP, Farmington-Four Corners Rgnl AP, Gallup-Sen Clarke Field, Holloman AFB, Las Cruces Intl AP, Roswell Industrial Air Park, Ruidoso-Sierra Blanca Rgnl AP, and Santa Fe County Muni AP. The building type list includes: RefBldgLargeOfficeNew2004, RefBldgMediumOfficeNew2004, RefBldgMidriseApartmentNew2004, RefBldgOutPatientNew2004, RefBldgPrimarySchoolNew2004, RefBldgQuickServiceRestaurantNew2004, RefBldgSecondarySchoolNew2004, RefBldgSmallHotelNew2004, RefBldgSmallOfficeNew2004, RefBldgStand-aloneRetailNew2004, RefBldgStripMallNew2004, RefBldgSuperMarketNew2004, and RefBldgWarehouseNew2004. A "Save" button is located at the bottom of the list.

<https://openei.org/datasets/dataset/commercial-and-residential-hourly-load-profiles-for-all-tmy3-locations-in-the-united-states>

- OpenEI.org also hosts simulated hourly load profiles for TMY3 (typical meteorological year)

- Residential (base, low, high)
- Commercial (16 reference building types by DOE)

QuEST Data Manager



The screenshot shows a web application window titled "Data Manager: Photovoltaic Power Profiles". The main heading is "Search for a photovoltaic power profile." Below it is a "Data.gov API key" input field with a redacted value. The form contains the following fields:

Parameter	Description	Value	Unit
latitude	The latitude of the site in the range (-90, 90).	37.78	deg
longitude	The longitude of the site in the range (-180, 180).	-122.42	deg
system capacity	The nameplate capacity of the photovoltaic system.	5	kW
losses	The total system losses, including all sources, in the range (-5, 99).	14	%
tilt angle	The tilt angle of the PV surface.	0	deg
azimuth angle	The azimuth angle of the PV surface.	0	deg

At the bottom, there are two buttons: "Standard" and "Fixed (roof mounted)". Below the buttons is a text input field containing "san_fran_5kW" and a "Save" button.

PVWatts by NREL

- Uses data from the National Solar Radiation Database and a solar panel system model to simulate hourly power output

https://pvwatts.nrel.gov/version_6.php

QuEST

Wizard

home about settings

Select a market area to place the energy storage device in.

Different market areas can have different market structures, resulting in various opportunities for generating revenue.



Alberta Electric System Operator

Ontario Independent Electricity System Operator

ISO New England

New York ISO

PJM Interconnection

ERCOT

PJM

MISO

NYISO

ISONE

SPP

CAISO

IRC

Previous

Next

A grid of market areas:

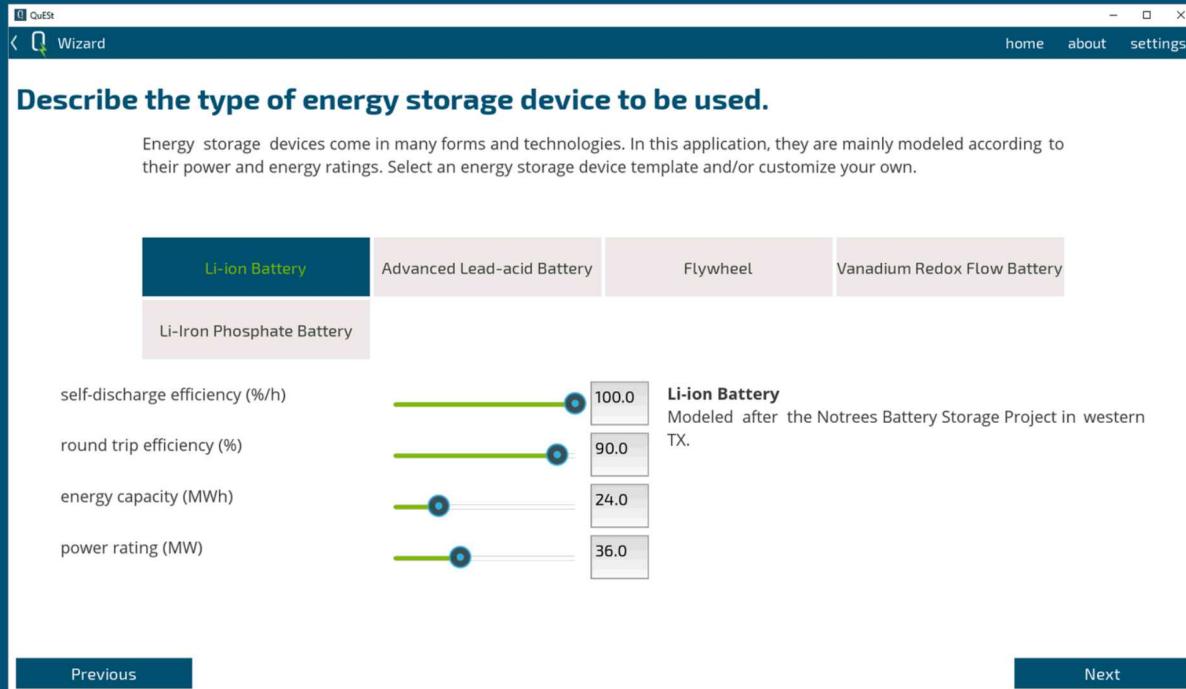
ERCOT	PJM	MISO
NYISO	ISONE	SPP
CAISO		

- Market area

- Arbitrage and Frequency Regulation streams

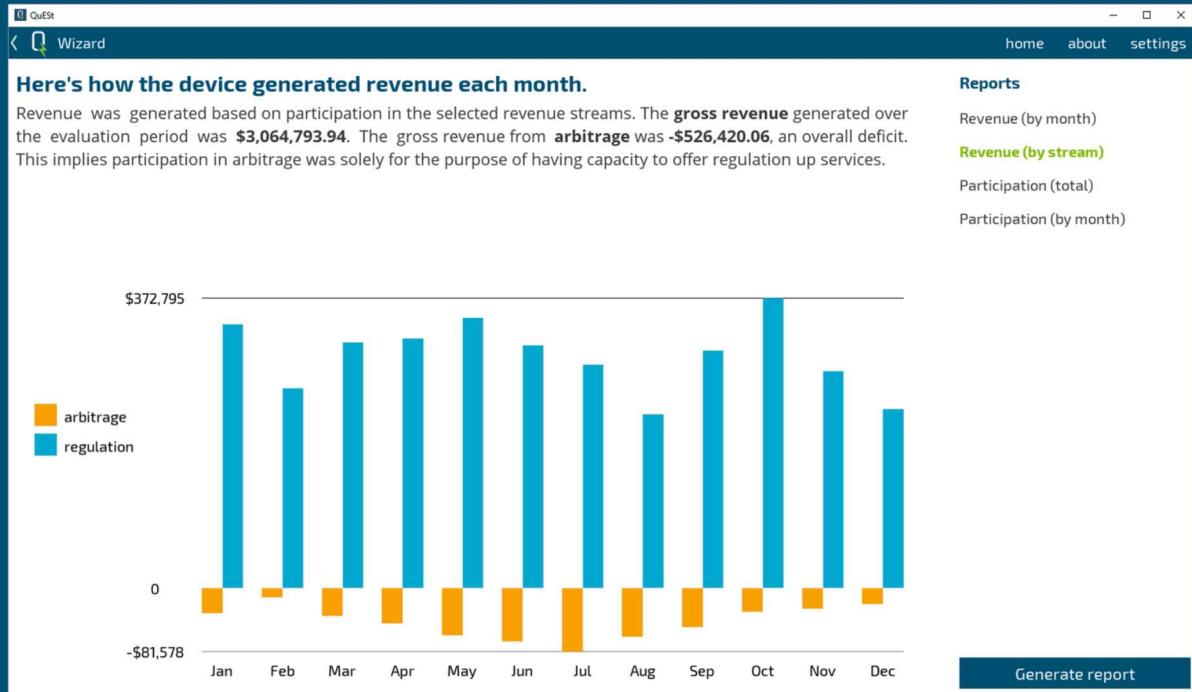
- Historical dataset to study

- Energy storage model parameters

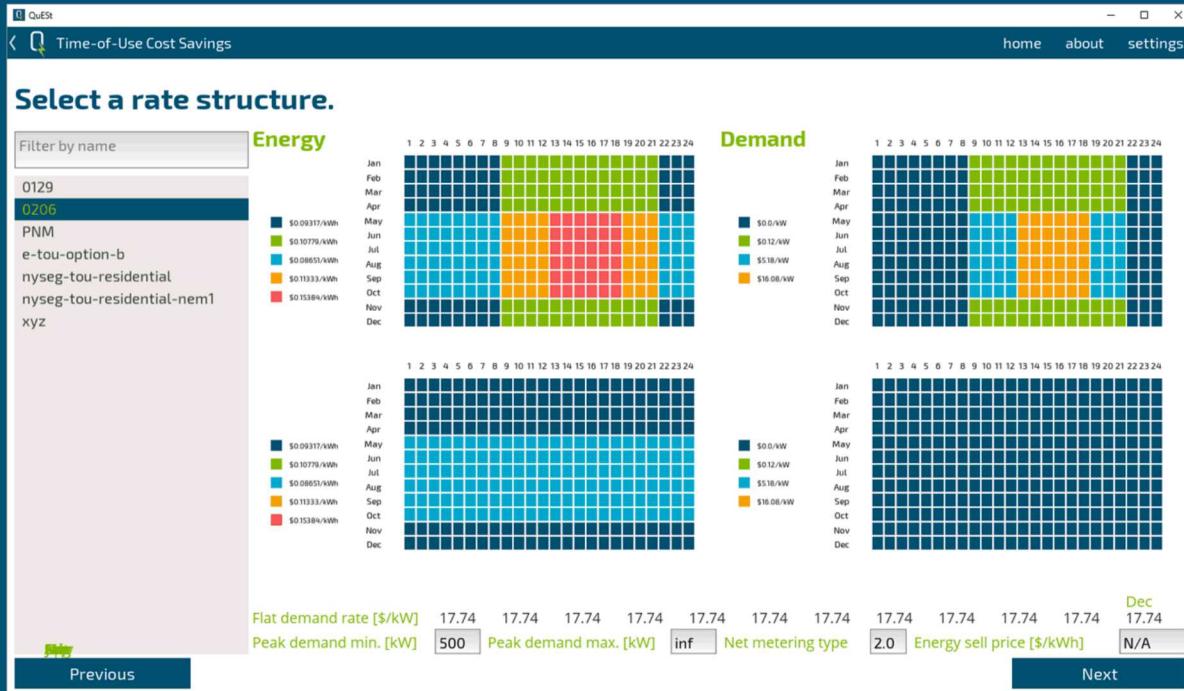


The screenshot shows the QuEST Wizard interface. The title bar reads "QuEST Wizard". The main content area has a heading "Describe the type of energy storage device to be used." Below this, a text block states: "Energy storage devices come in many forms and technologies. In this application, they are mainly modeled according to their power and energy ratings. Select an energy storage device template and/or customize your own." A horizontal navigation bar at the top includes "home", "about", and "settings". Below the heading, there are four tabs: "Li-ion Battery" (selected), "Advanced Lead-acid Battery", "Flywheel", and "Vanadium Redox Flow Battery". Under the "Li-ion Battery" tab, there is a sub-section titled "Li-Iron Phosphate Battery". On the left, there are four sliders with their respective values: "self-discharge efficiency (%/h)" at 100.0, "round trip efficiency (%)" at 90.0, "energy capacity (MWh)" at 24.0, and "power rating (MW)" at 36.0. To the right of these sliders, the text "Li-ion Battery" is followed by the subtext "Modeled after the Notrees Battery Storage Project in western TX." At the bottom, there are "Previous" and "Next" buttons.

- Market area
- Revenue streams
- Historical dataset to study
- Energy storage model parameters



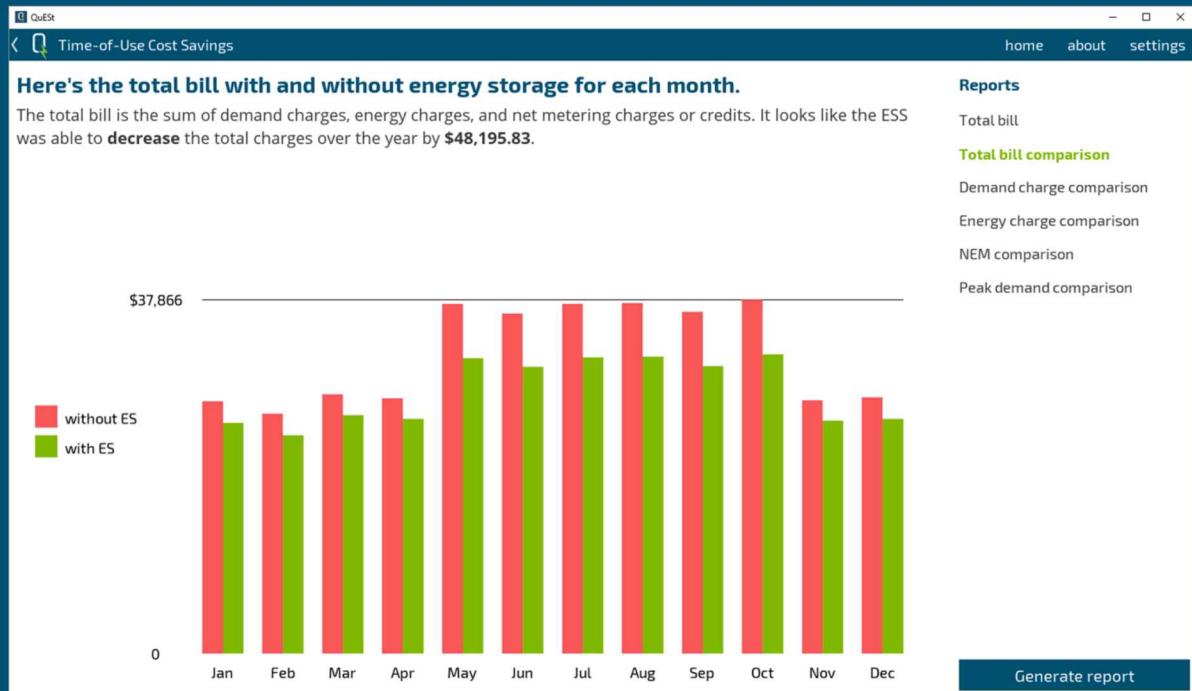
- Revenue by month
- Revenue by revenue stream
- Frequency of participation in each available revenue stream



- Utility rate structure for time-of-use energy rate schedules, demand rate schedules, net metering, etc.
- Load profile based on building type
- PV profile if solar + storage configuration
- Energy storage system parameters

*For v1.2 release; content is under development and subject to change.

QuEST BTM*



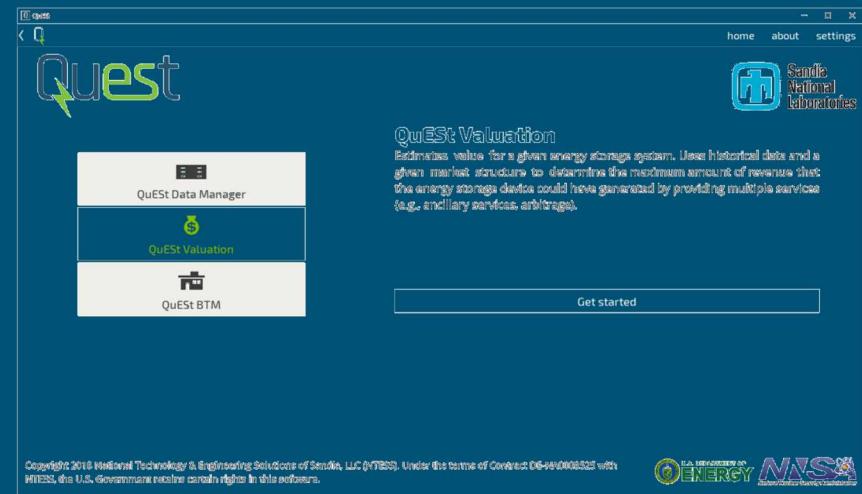
- Compare monthly bill with and without energy storage
- Peak demand reduction to decrease demand charges
- Time-shifting to reduce time-of-use energy charges
- Net metering credits

*For v1.2 release; content is under development and subject to change.

The Future

Mission: Continue adding applications and new capabilities to the suite, building upon the software architecture and GUI foundation that we have established.

- Consider more complex valuation models, such as modeling degradation
- New applications
 - Technology selection assistant
 - Explorer for energy storage project cost data
 - Optimal sizing of energy storage for solar + storage
 - ?



Acknowledgements

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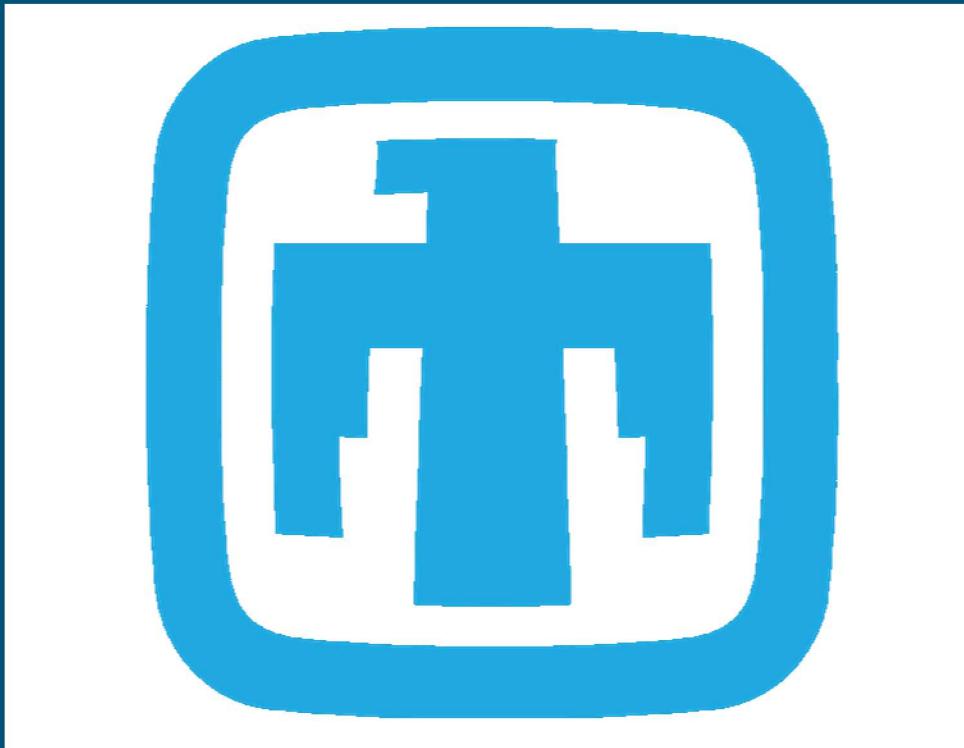
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Follow us on GitHub:

github.com/rconcep/snl-quest



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Optimal Battery Dispatch for Peak Revenue

The objective of the optimization is to maximize revenue subject to:

- Battery state-of-charge model – 25% minimum SOC
- PV generation
- Time-variant pricing structure

Battery charging options

- Only clipped DC power
- Full generation range
- AC-tied battery/PV

Optimized battery dispatch schedule using Python/PYOMO

- Open source tools

$$\max_{P_C, P_D, P_{curtail}} \quad \sum_{t=1}^T P_{toGrid,t} \cdot (iCap_t \cdot \mathbf{iCap}_{hour,t} + E + MTC + LBMP_t)$$

$$subject\ to \quad \delta E_{sys} \leq SOC_{t-l} \eta_s + \Delta t (P_{C,t-1} \eta_C - P_{D,t-1}) \leq (1 - \delta) E_{sys}$$

$$P_D \leq P_{sys}$$

$$P_{C,t} \leq P_{DC,t} - P_{AC,t}$$

$$P_{toGrid} \leq P_{sys}$$

$$P_{toGrid,t} = \eta_{inv} (P_{DC,t} + P_{D,t} - P_{C,t} - P_{curtail,t})$$