SAND2019-8201PE

Maximizing Storage Value in Regional Markets and the QuESt App

PRESENTED BY

Alexander Headley

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and 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.

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 <u>when</u> and <u>where</u> 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

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

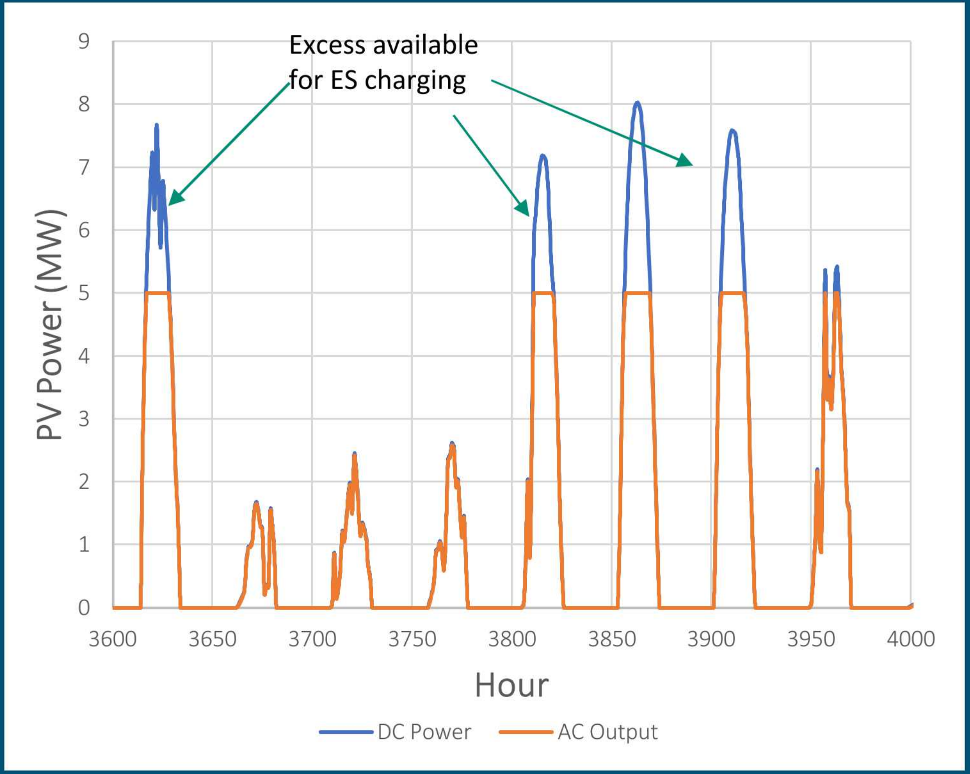
Subject to transmission limits, PV potential, etc.

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

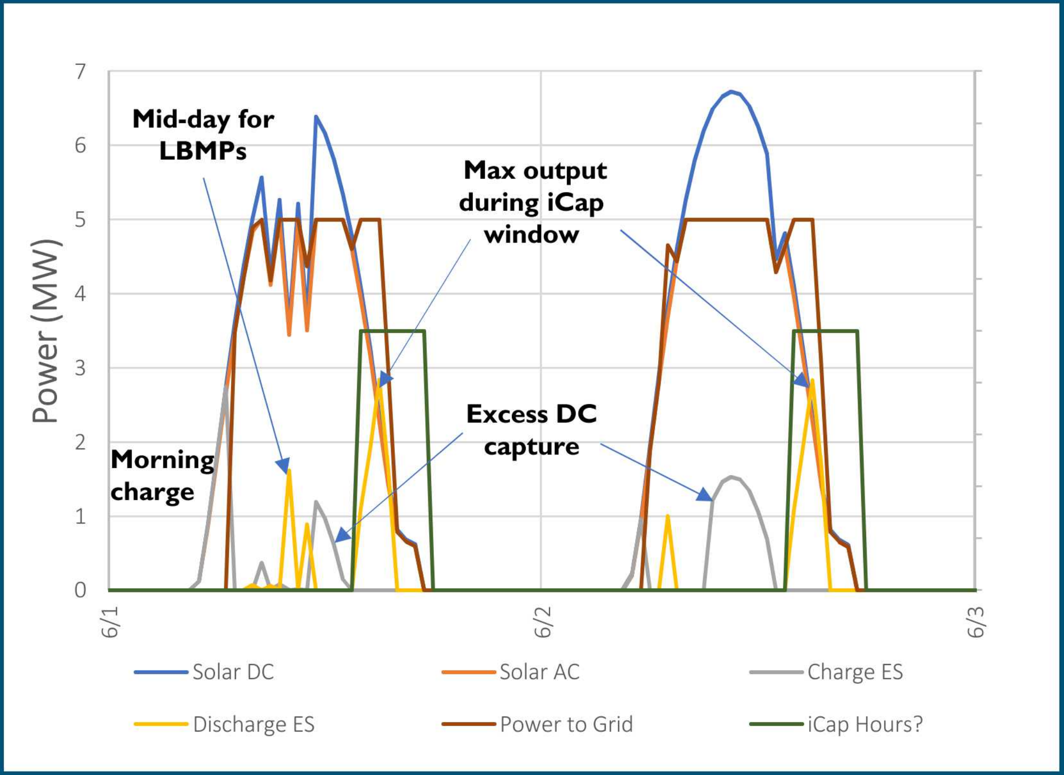
Charge early morning and from clipped power

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

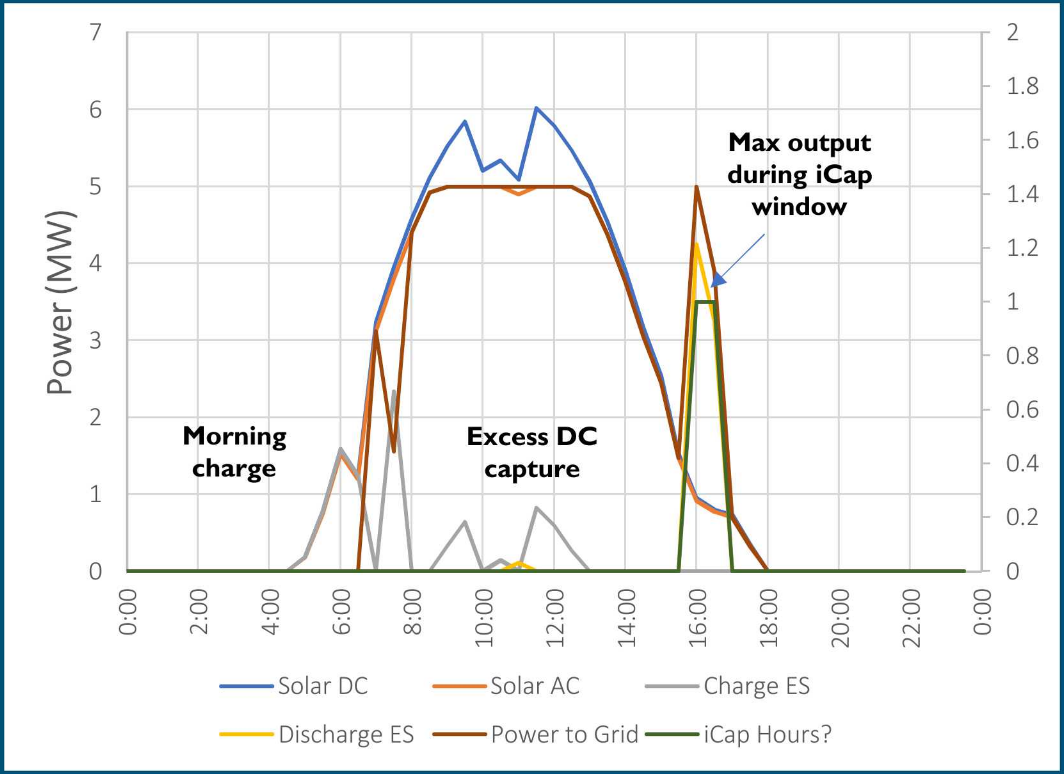
Coincident Peak Value Stream

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

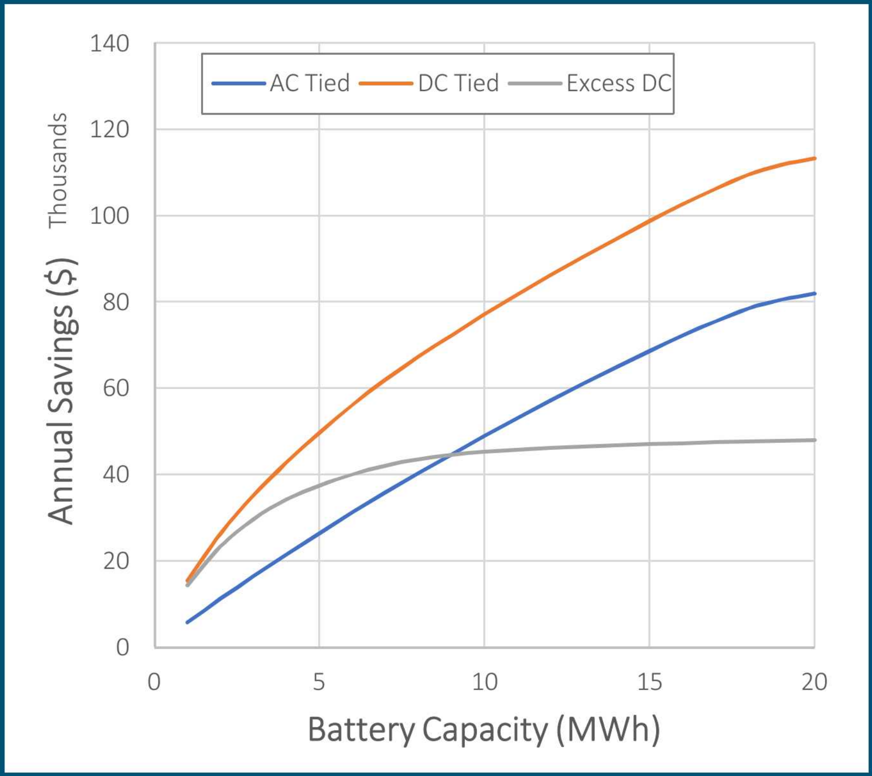
Major difference here is the iCap window
- 1 hour long
- Only once a month
- MUST be properly forecast or NO value



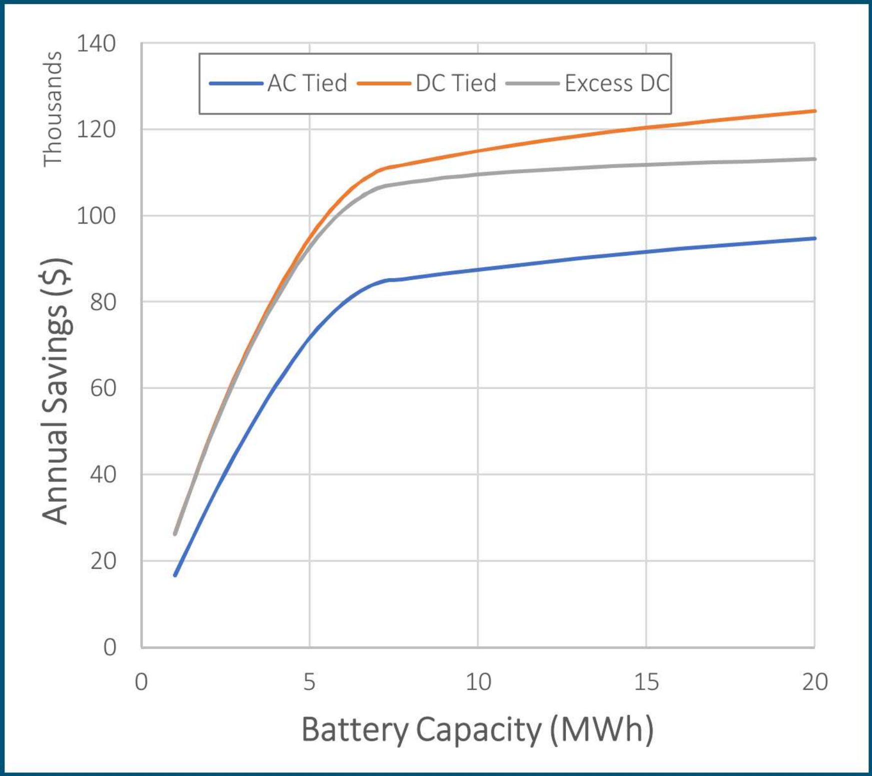
5 MW / 5 MWh

Maximum Project Values

2-6PM June-August



Monthly Coincident Peak



Connecting PV and battery DC has advantages over AC connections

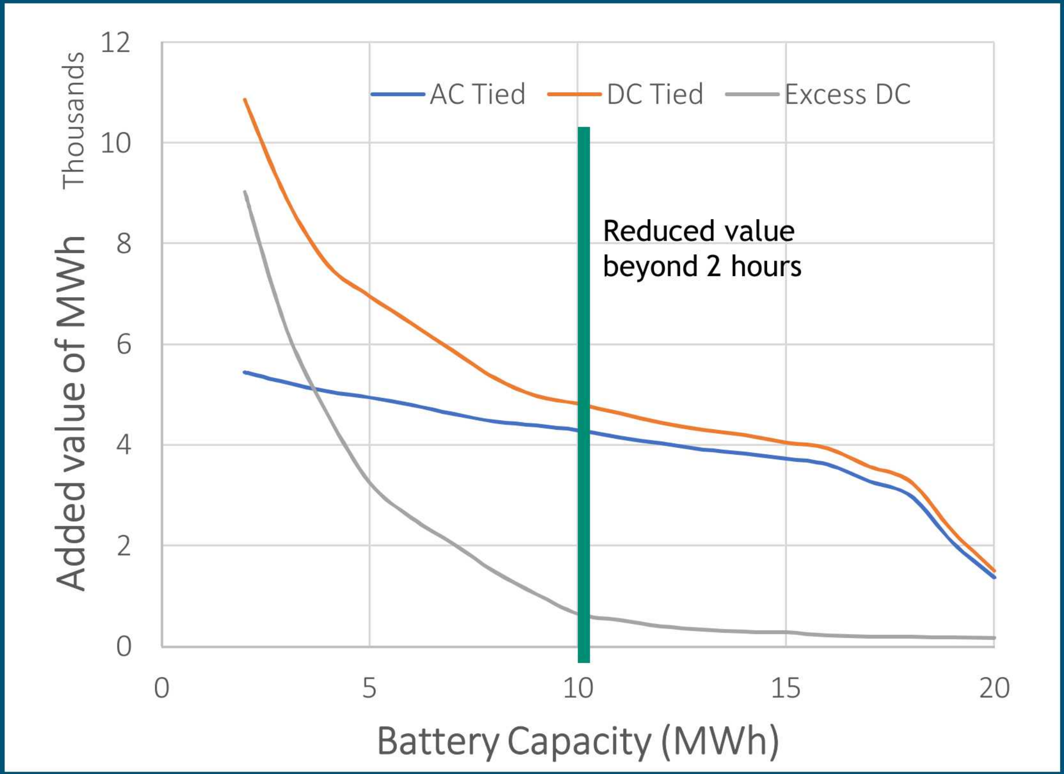
In higher energy applications, charging from all available energy is essential

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

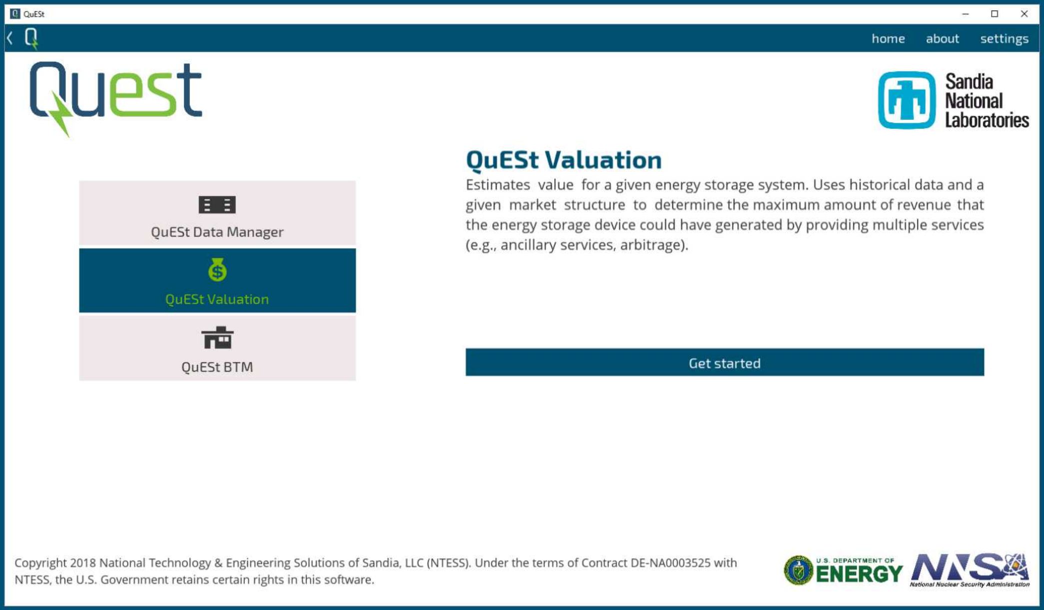
Changing pricing landscapes can make it difficult for developers

- 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?



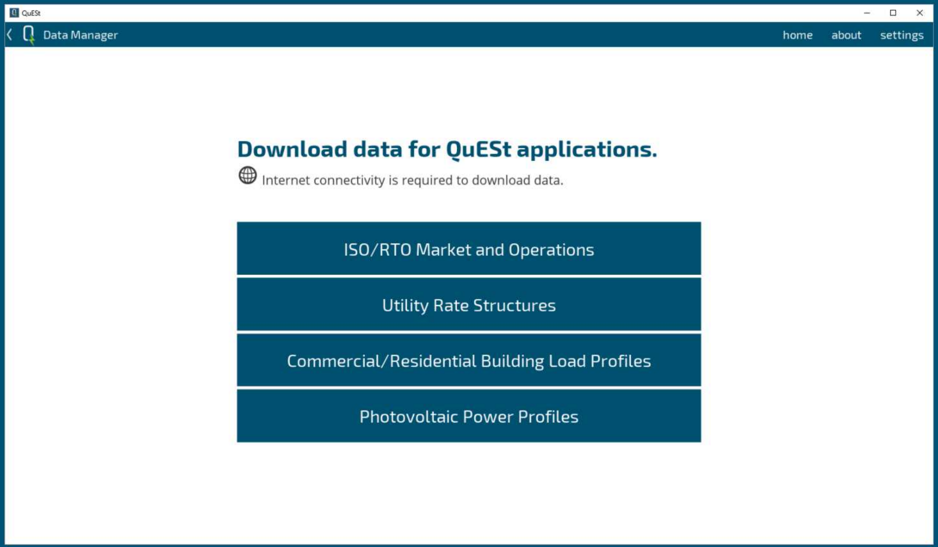
- Open source, Python-based energy storage analysis software application suite
- Developed as a graphical user interface (GUI) for the optimization modeling capabilities of Sandia's energy storage analytics group
- Version 1.0 publicly released in September 2018
- Version 1.1 available on GitHub; Version 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

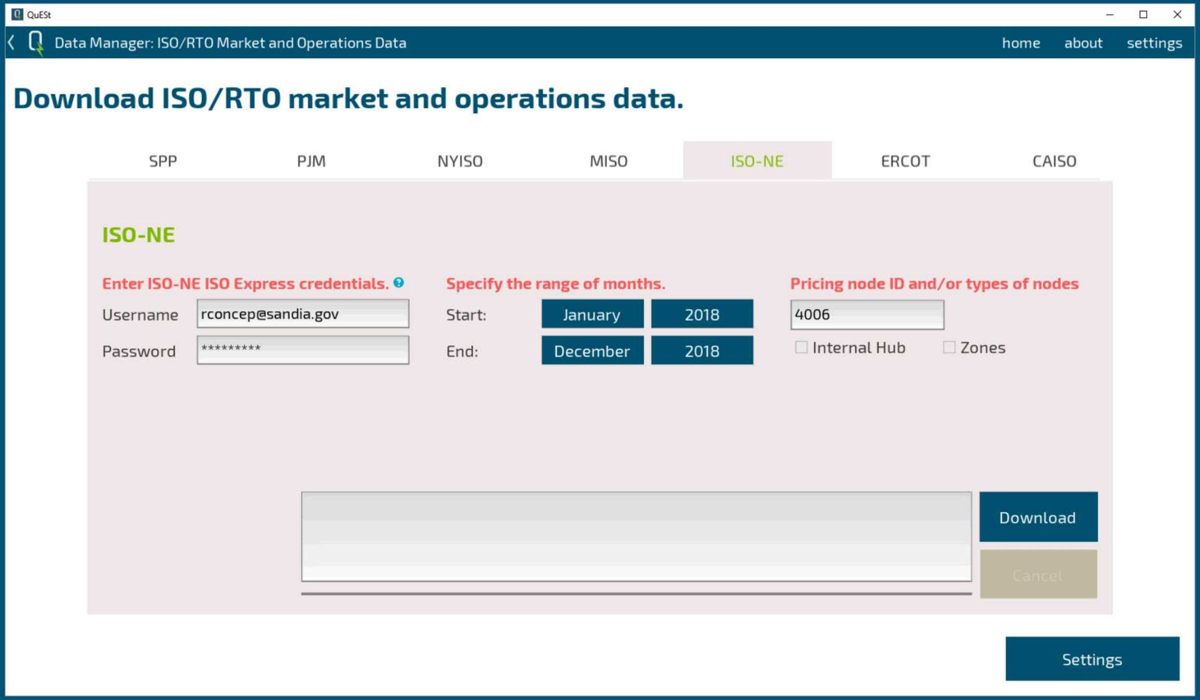
QuESt Data Manager



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

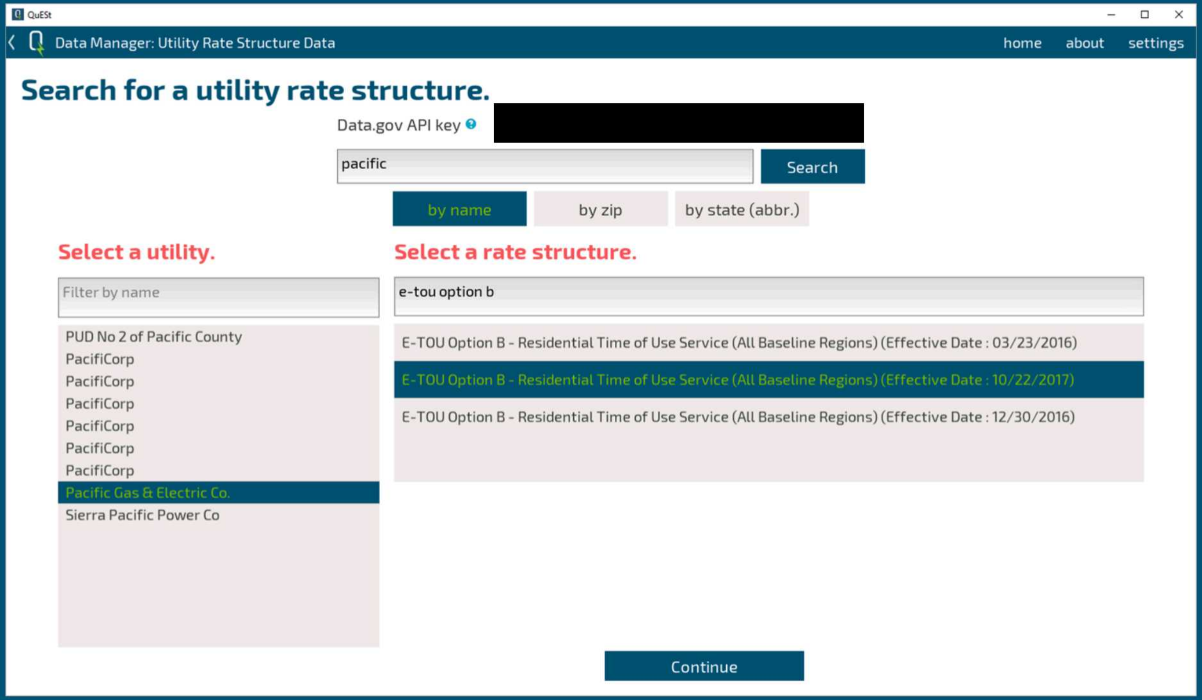
- LMPs, frequency regulation performance/capacity clearing prices, etc. posted by ISOs/RTOs
- U.S. utility rate structures sourced and validated by OpenEI.org
- Commercial and residential hourly load profiles for all TMY3 (typical meteorological year) locations in the U.S. by OpenEI.org
- Hourly photovoltaic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

QuESt Data Manager



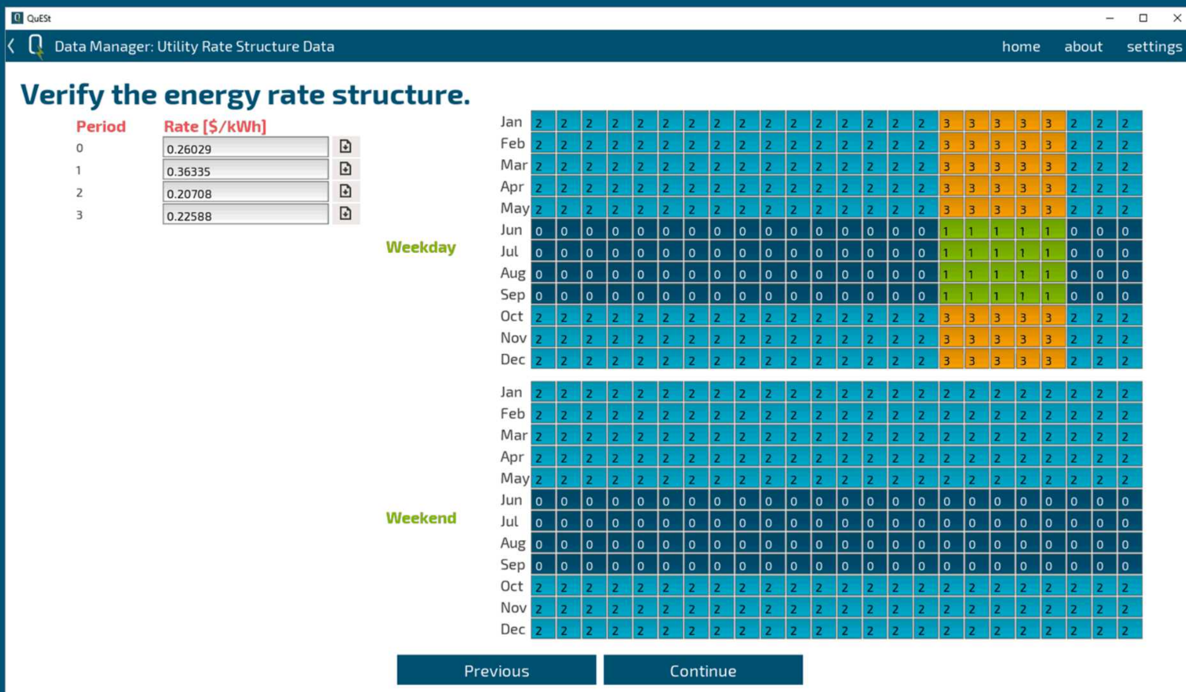
- LMPs, frequency regulation performance/capacity clearing prices, etc. posted by ISOs/RTOs
- Use operator-provided APIs, some requiring a short registration for an API key
  - ISONE, PJM
- Use web crawling libraries to parse marketplace data portals to find data files

QuESt Data Manager



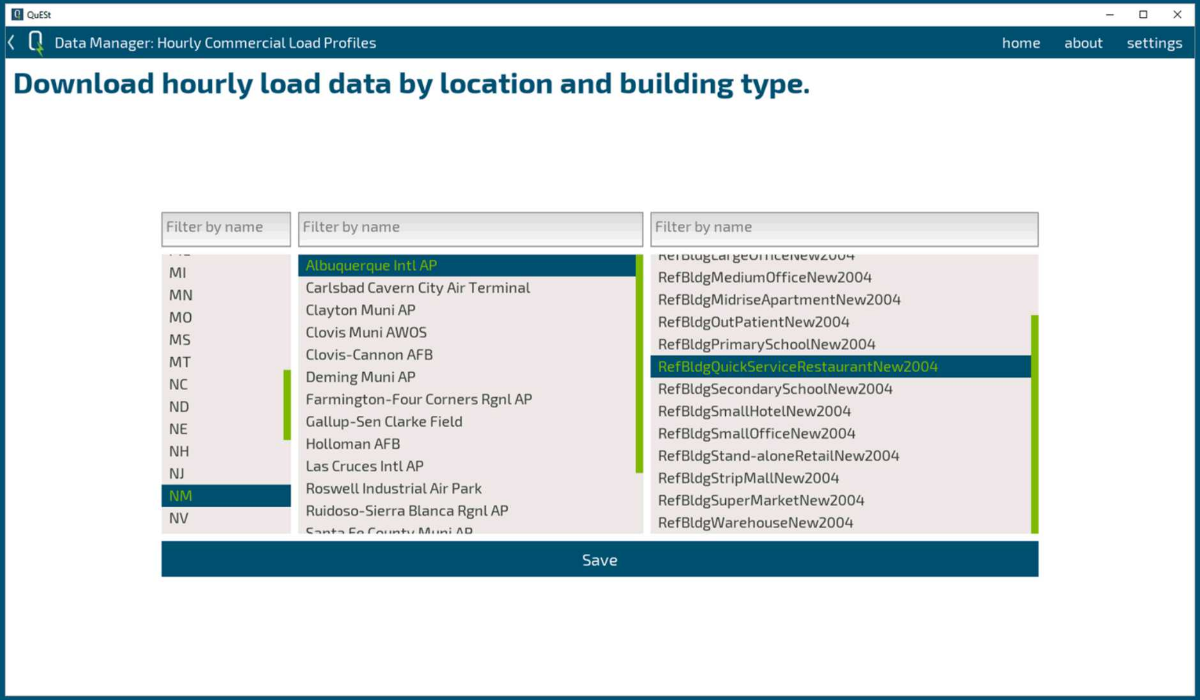
- OpenEI.org, maintained by NREL, hosts a database for U.S. utility rates
- Time-of-use energy rate schedules
- Peak demand and flat demand rate schedules

QuESt Data Manager



- 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

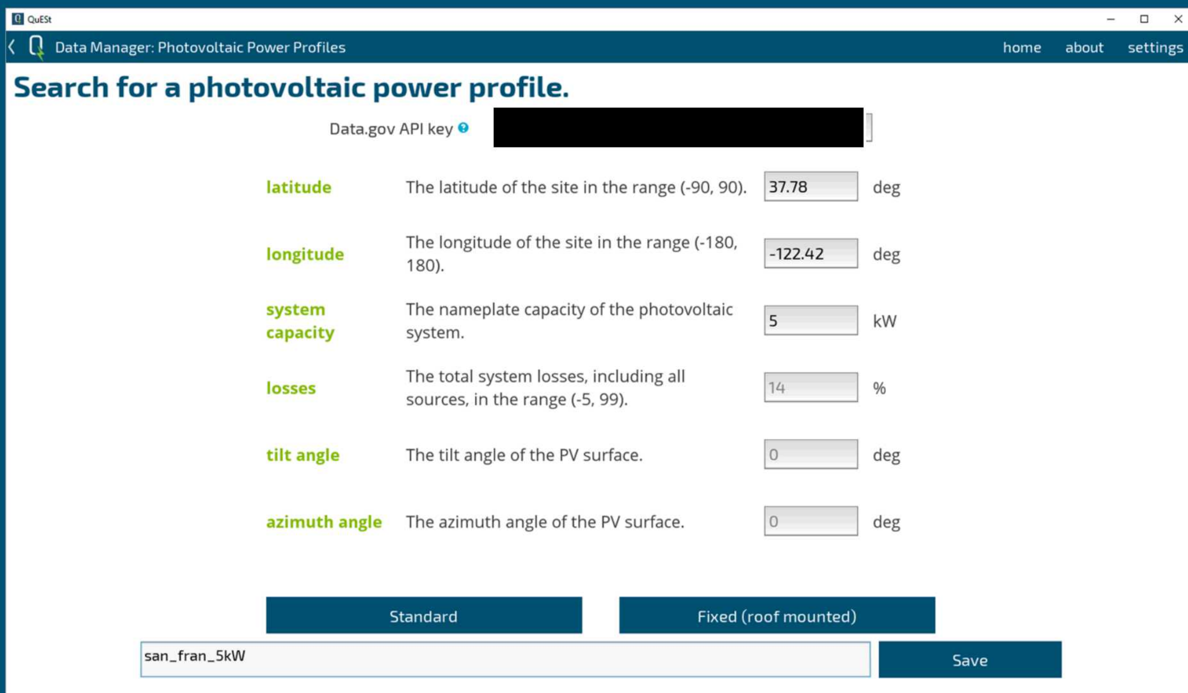
QuESt Data Manager



- OpenEI.org also hosts simulated hourly load profiles for TMY3 (typical meteorological year)
  - Residential (base, low, high)
  - Commercial (16 reference building types by DOE)

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

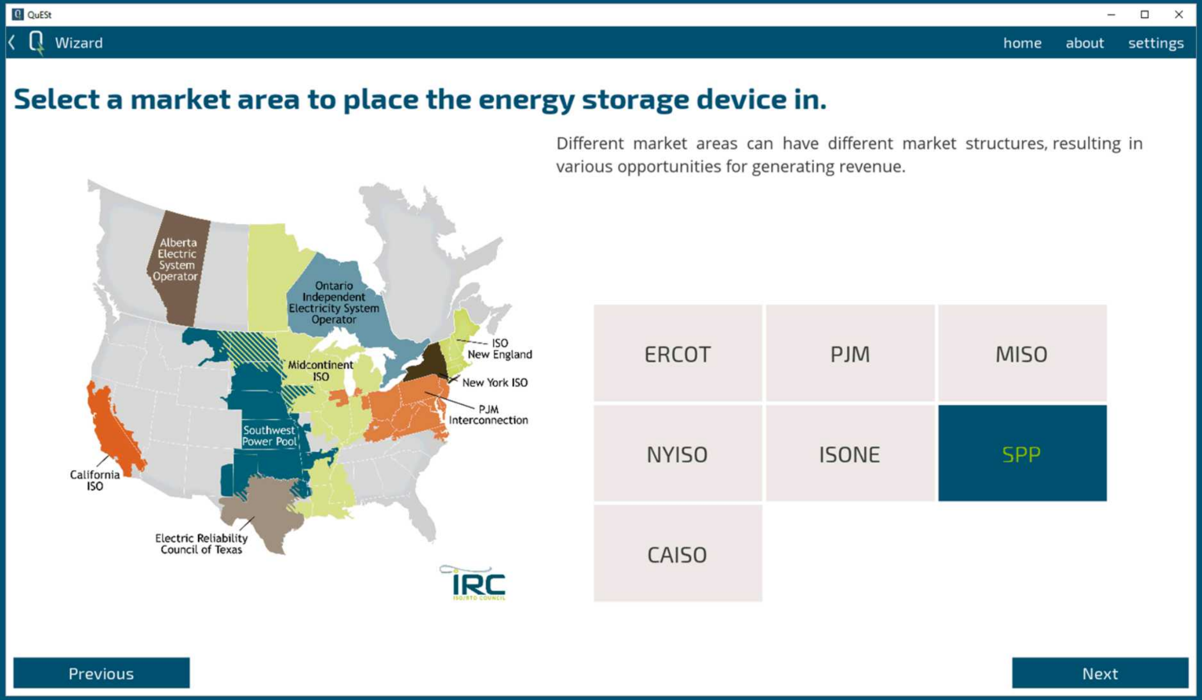
QuESt Data Manager



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

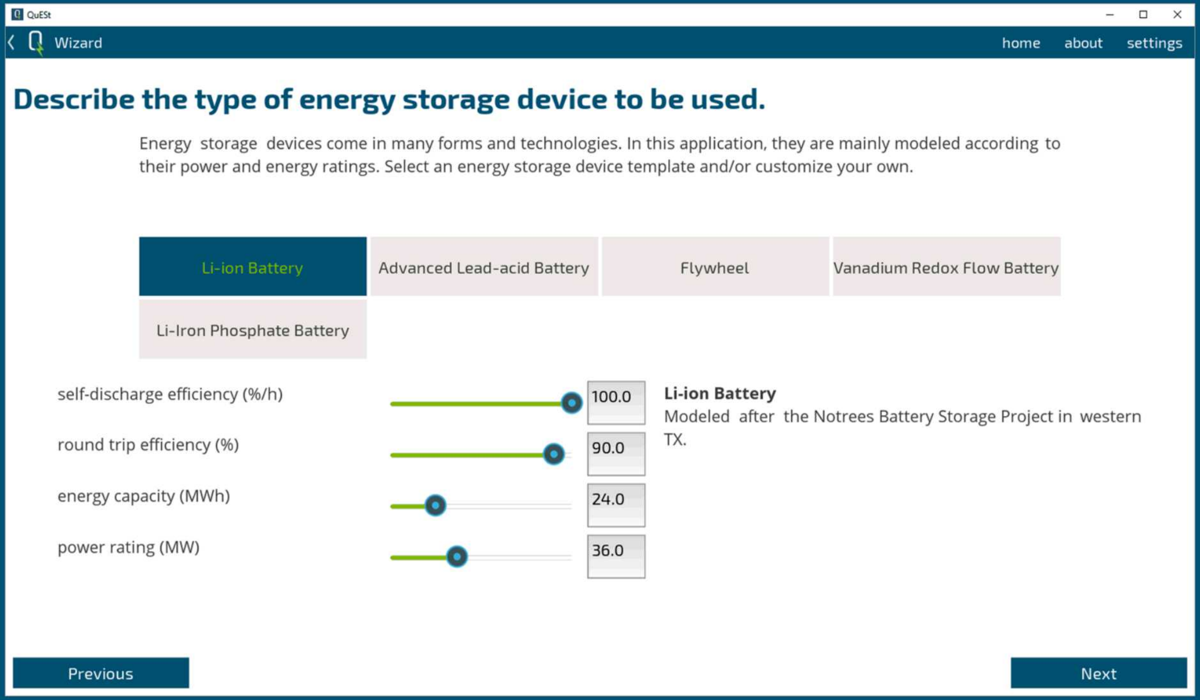
https://pvwatts.nrel.gov/version_6.php

QuESt Valuation



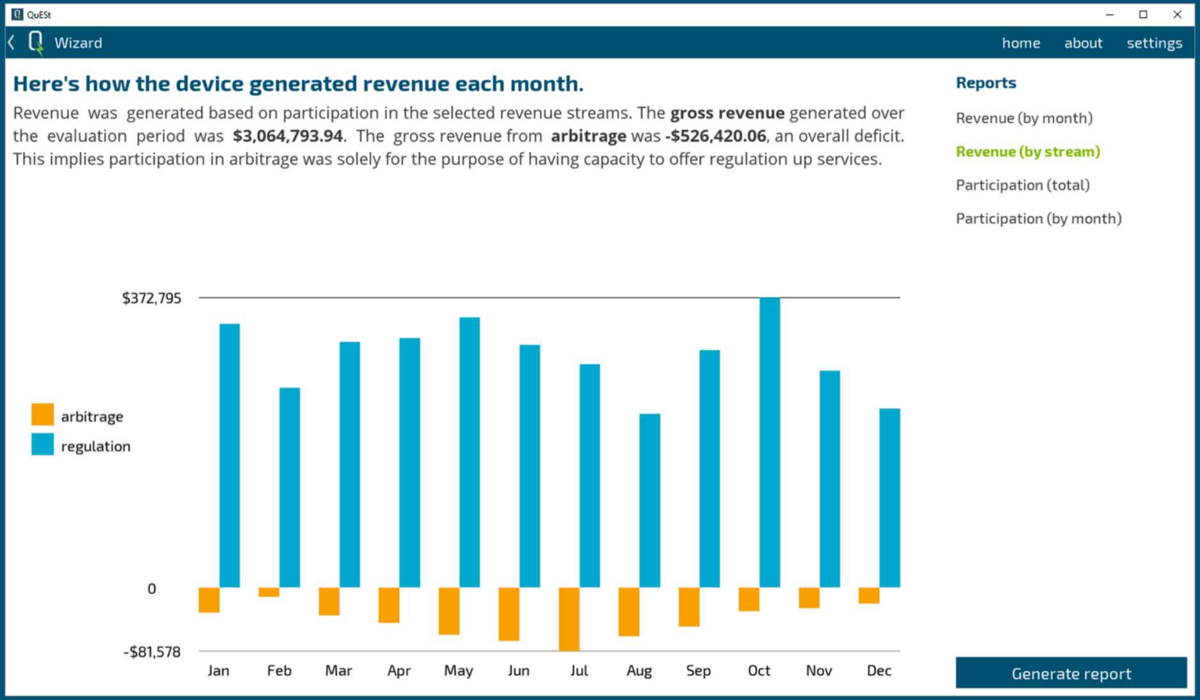
- Market area
- Arbitrage and Frequency Regulation streams
- Historical dataset to study
- Energy storage model parameters

QuESt Valuation



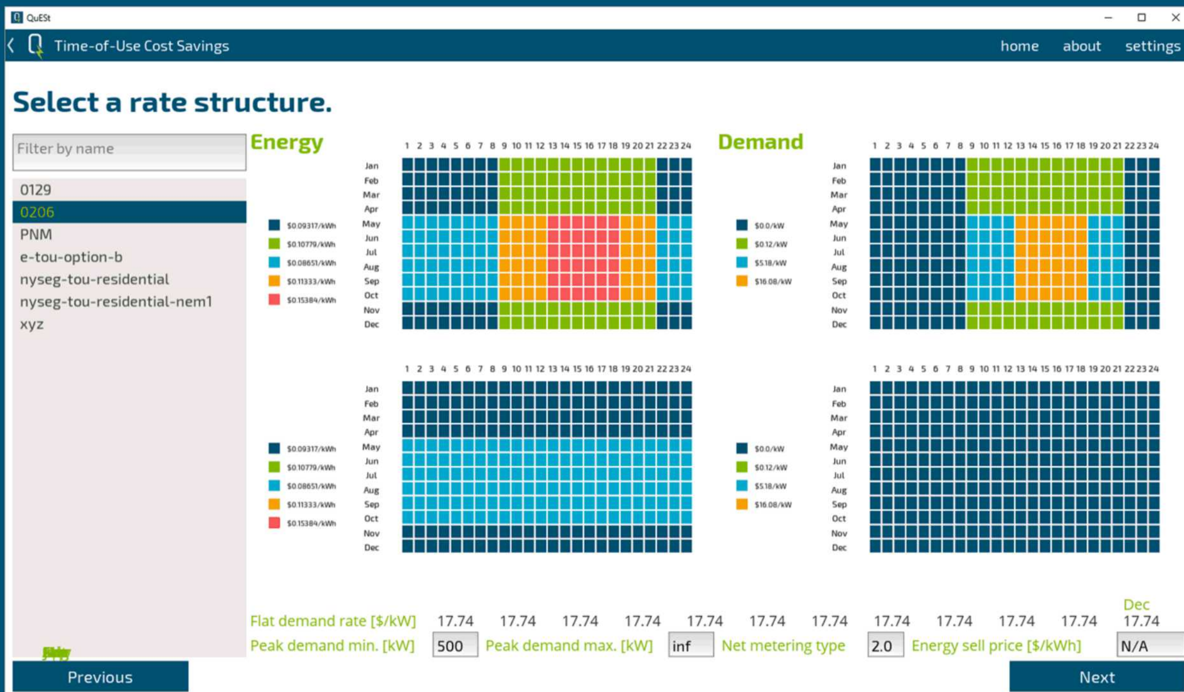
- Market area
- Revenue streams
- Historical dataset to study
- Energy storage model parameters

QuESt Valuation



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

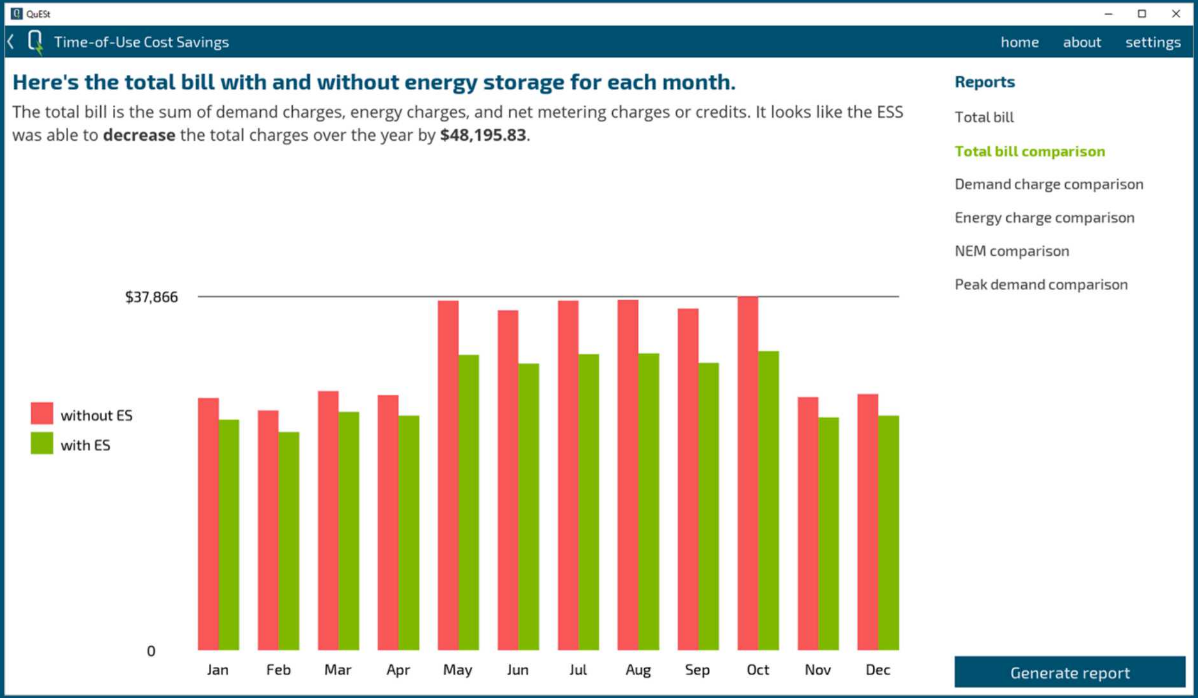
QuESt BTM*



- 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*



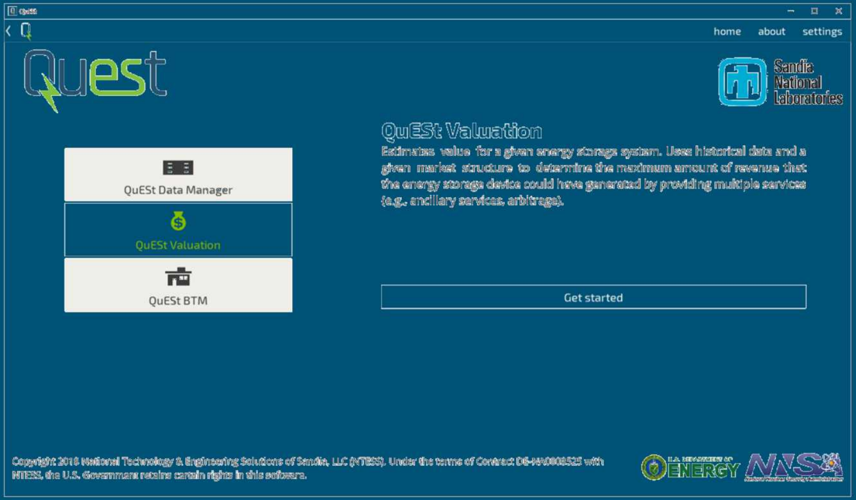
- Compare monthly bill with and without energy storage
- Peak demand reduction to decrease demand charges
- Time-shifting to reduce time-of-use energy charges
- Net metering credits

*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

The authors would like to acknowledge the support and guidance from Dr. Imre Gyuk, the program manager for the U.S. Department of Energy Office of Electricity Energy Storage program.

Authors

Ricky Concepcion

David Copp

Tu Nguyen

Felipe Wilches-Bernal

Inquiries to:

Ricky Concepcion

rconcep@sandia.gov

Follow us on GitHub:

github.com/rconcep/snl-quest

Questions?

Alexander Headley
aheadle@sandia.gov

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

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

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

$$P_D \le P_{sys}$$

$$\mathbf{P_{C,t} \le P_{DC,t} - P_{AC,t}}$$

$$P_{toGrid} \le P_{sys}$$

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