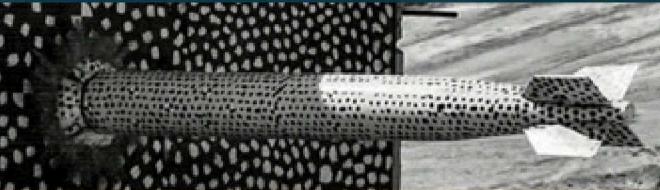




# An Energy Storage Application Suite



*PRESENTED BY*

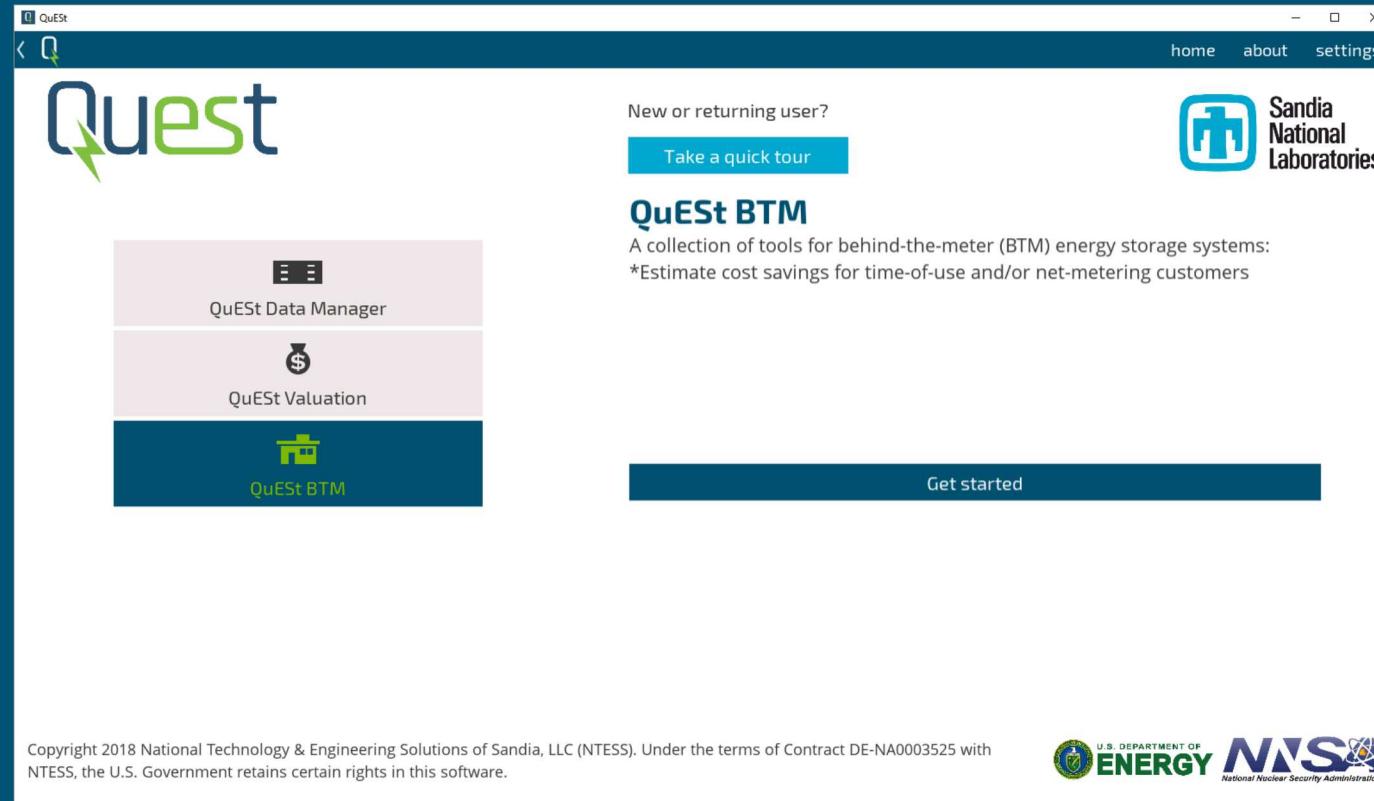
Ricky Concepcion



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# OUTLINE

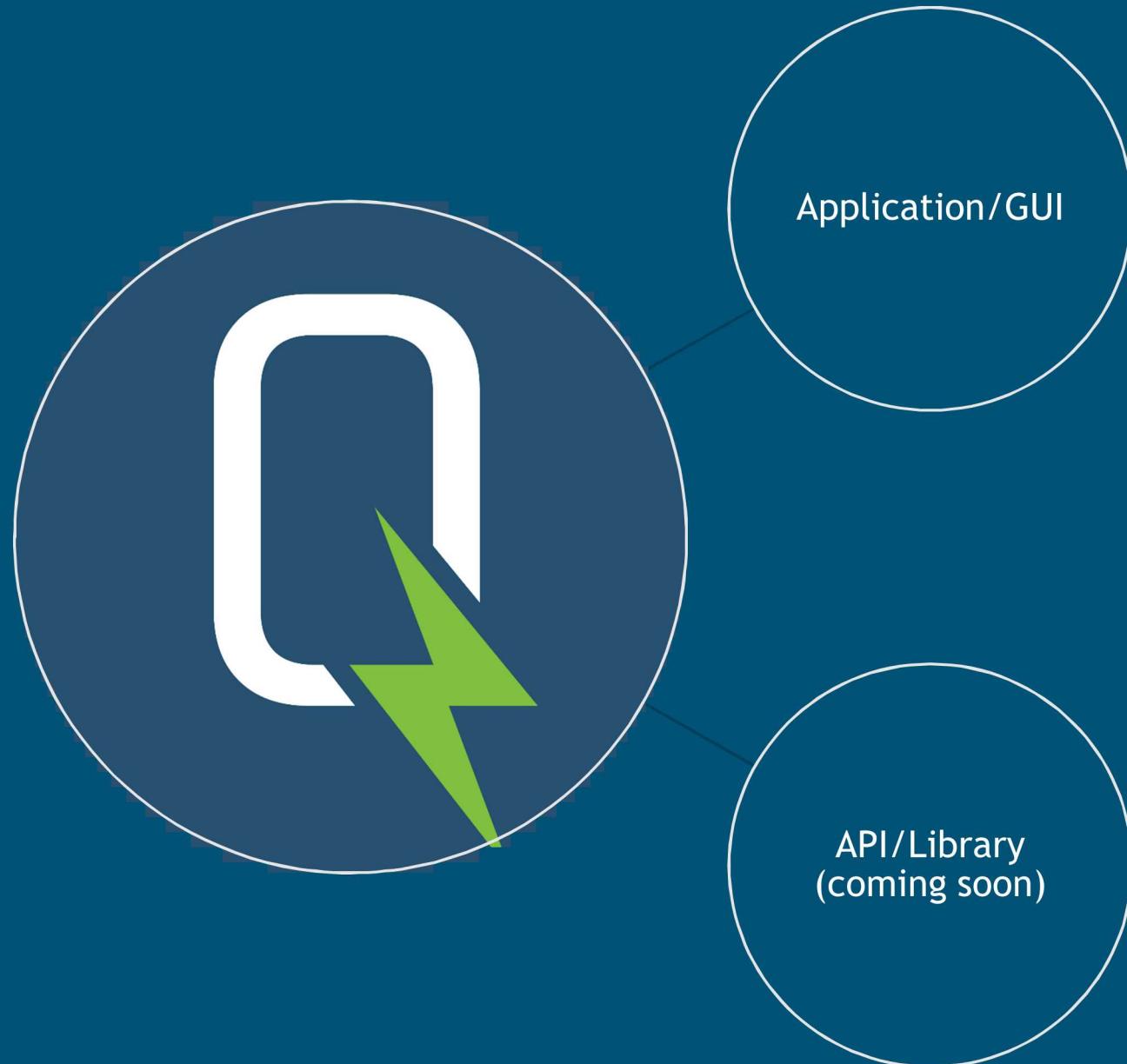
- QuEST overview
- QuEST applications
  - QuEST Valuation
  - QuEST Data Manager
  - QuEST BTM
- Case study with QuEST
- Wrap-up and conclusions



- Energy storage analysis/valuation 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 1.2 available on GitHub
  - [github.com/rconcep/snl-quest](https://github.com/rconcep/snl-quest) or [sandia.gov/ess \(tools\)](https://sandia.gov/ess/tools)

## WHY QUEST?

- For energy storage project stakeholders
  - Accessible and easy-to-use software for energy storage valuation
  - Diverse set of capabilities
- For engineers and software developers
  - Open source software project
  - GUI and application design; Pyomo optimization modeling
- It's free
  - Released under an open source distribution license
- 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.



- For most users
- Developed for user experience
- No hassle installation
- For power users
- Use for Python scripting
- More capabilities

# HOW TO OBTAIN QUEST

- Check the "tools" section of the Sandia ESS website
  - <https://www.sandia.gov/ess-ssl/tools/quest/>
- The code is hosted on GitHub
  - [github.com/rconcep/snl-quest](https://github.com/rconcep/snl-quest)
- General requirements:
  - Windows/OS X/Linux
  - Solver for optimization



DOE Global Energy Storage Database ES Safety Collaborative Conference Archive Events Publications Tools Resources Projects

DOE/EPRI ELECTRICITY STORAGE HANDBOOK

PUC HANDBOOK

QUEST

PROTOCOLS



UNITED STATES  
ENVIRONMENTAL PROTECTION AGENCY

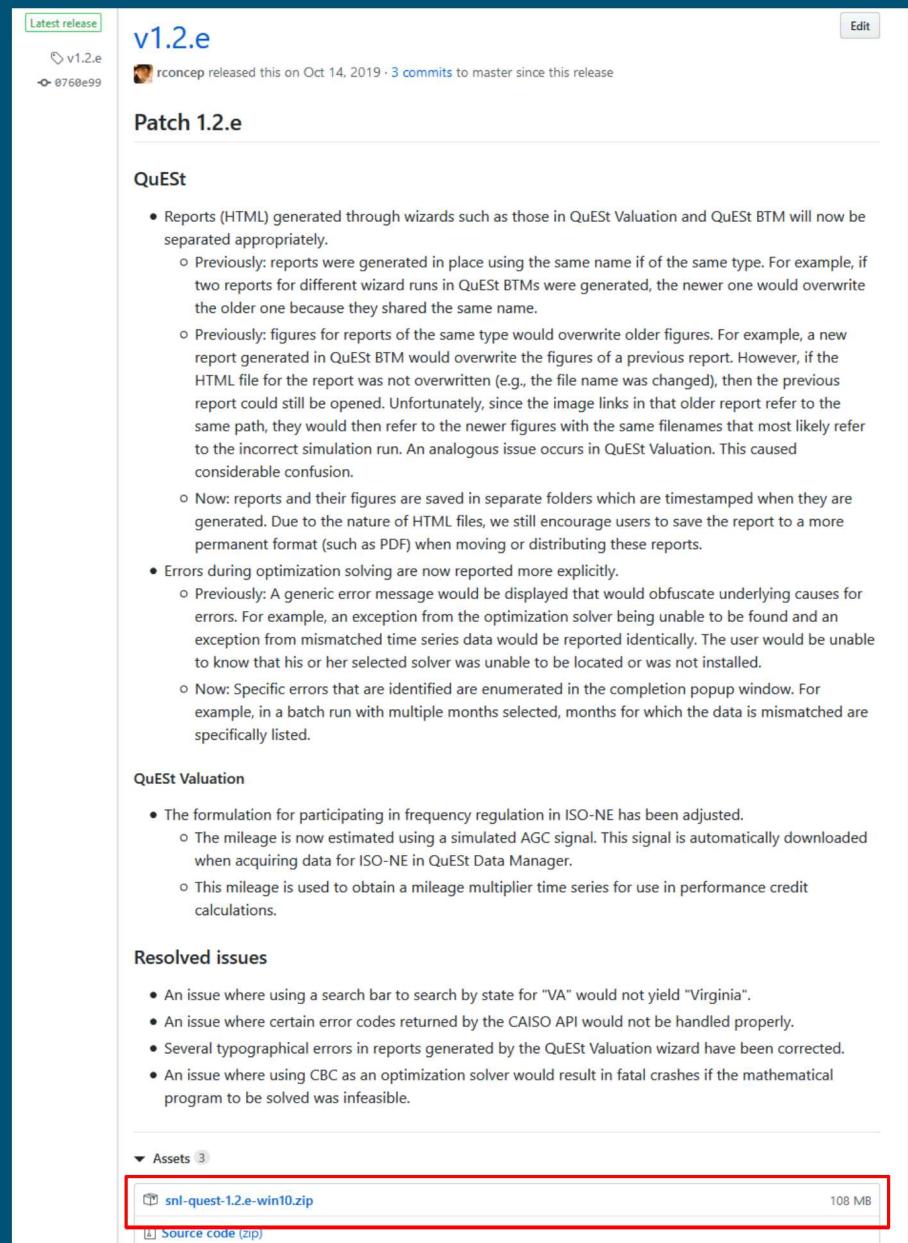
Prof. Sanjoy Banerjee of City College of New York and City University of New York Energy Institute, Sandia National Laboratories, Urban Electric Power, Inc., Brookhaven National Laboratory, and the Department of Energy Office of Electricity, Energy Storage Research Program won the 2019 US Environmental Protection Agency Green Chemistry Challenge Award in the Academic category. The team was recognized for creating large-scale zinc-manganese oxide batteries that can be recharged thousands of times without the typical decrease in the length of the battery's life-time. These batteries do not have some of the limitations of lithium-ion and lead-acid batteries, and they use materials that are abundant and common in existing supply chains. Sandians Tim Lambert, Mathew Lim, Igor Kolesnichenko, and Babu Chalamala, along with Prof. Igor Vasiliev from New Mexico State University were also involved in this research project.

Read more

.....

# HOW TO OBTAIN QUEST

- For Windows 10: we have an executable version of QuEST
  - Fully pre-configured, just run the .exe
  - Still requires an optimization solver
  - Under GitHub releases for each version
- We have portable preview versions of the upcoming Windows 10 release available



**v1.2.e**

rconcep released this on Oct 14, 2019 · 3 commits to master since this release

**Patch 1.2.e**

**QuEST**

- Reports (HTML) generated through wizards such as those in QuEST Valuation and QuEST BTM will now be separated appropriately.
  - Previously: reports were generated in place using the same name if of the same type. For example, if two reports for different wizard runs in QuEST BTMs were generated, the newer one would overwrite the older one because they shared the same name.
  - Previously: figures for reports of the same type would overwrite older figures. For example, a new report generated in QuEST BTM would overwrite the figures of a previous report. However, if the HTML file for the report was not overwritten (e.g., the file name was changed), then the previous report could still be opened. Unfortunately, since the image links in that older report refer to the same path, they would then refer to the newer figures with the same filenames that most likely refer to the incorrect simulation run. An analogous issue occurs in QuEST Valuation. This caused considerable confusion.
  - Now: reports and their figures are saved in separate folders which are timestamped when they are generated. Due to the nature of HTML files, we still encourage users to save the report to a more permanent format (such as PDF) when moving or distributing these reports.
- Errors during optimization solving are now reported more explicitly.
  - Previously: A generic error message would be displayed that would obfuscate underlying causes for errors. For example, an exception from the optimization solver being unable to be found and an exception from mismatched time series data would be reported identically. The user would be unable to know that his or her selected solver was unable to be located or was not installed.
  - Now: Specific errors that are identified are enumerated in the completion popup window. For example, in a batch run with multiple months selected, months for which the data is mismatched are specifically listed.

**QuEST Valuation**

- The formulation for participating in frequency regulation in ISO-NE has been adjusted.
  - The mileage is now estimated using a simulated AGC signal. This signal is automatically downloaded when acquiring data for ISO-NE in QuEST Data Manager.
  - This mileage is used to obtain a mileage multiplier time series for use in performance credit calculations.

**Resolved issues**

- An issue where using a search bar to search by state for "VA" would not yield "Virginia".
- An issue where certain error codes returned by the CAISO API would not be handled properly.
- Several typographical errors in reports generated by the QuEST Valuation wizard have been corrected.
- An issue where using CBC as an optimization solver would result in fatal crashes if the mathematical program to be solved was infeasible.

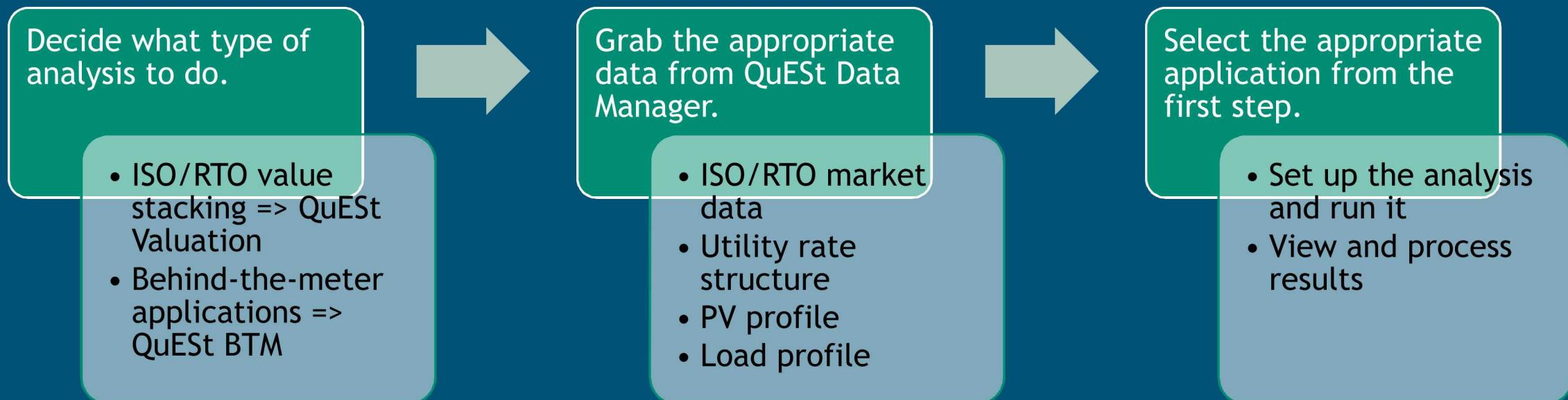
**Assets 3**

 <a href="#">snl-quest-1.2.e-win10.zip</a>	108 MB
 <a href="#">Source code (zip)</a>	



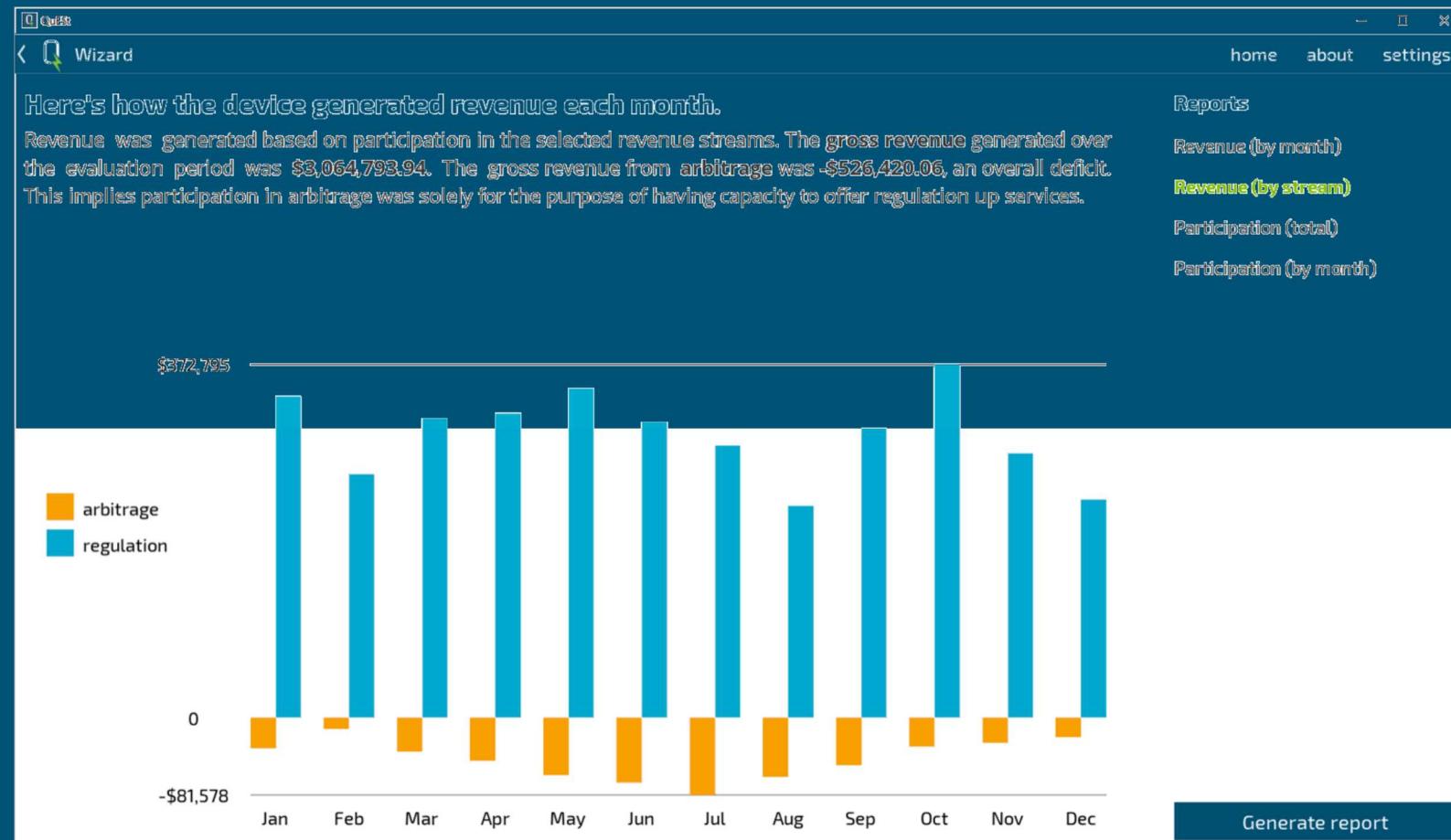
# QUEST APPLICATIONS OVERVIEW

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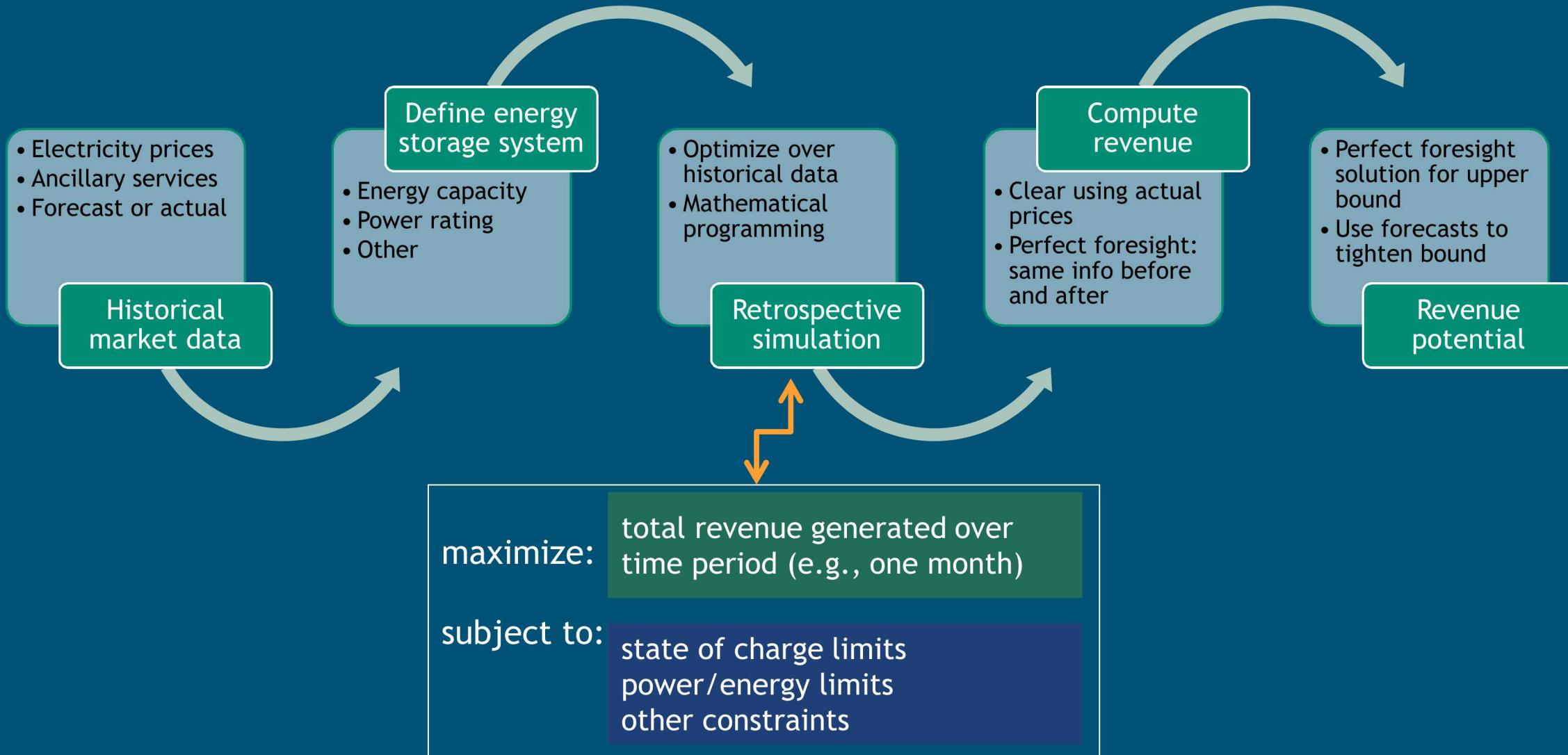


# QUEST VALUATION

Given an energy storage device, an electricity market with a certain payment structure, and market data, how would the device maximize the revenue generated and provide value?



# QUEST VALUATION



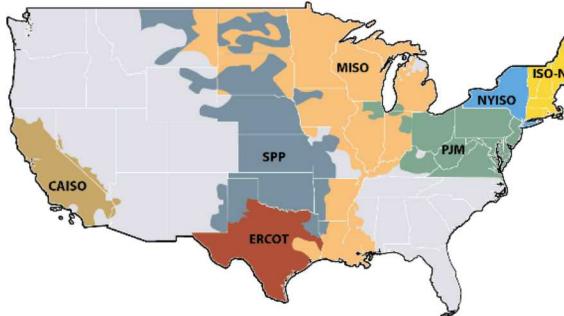
QuEST

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.



ERCOT	PJM	MISO
NYISO	ISONE	SPP
CAISO		

Previous

Next

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

# QUEST VALUATION

QuEST

Wizard

home about settings

**Describe the type of energy storage device to be used.**

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.

Li-ion Battery   Advanced Lead-acid Battery   Flywheel   Vanadium Redox Flow Battery

Li-Iron Phosphate Battery

self-discharge efficiency (%/h)

round trip efficiency (%)

energy capacity (MWh)

power rating (MW)

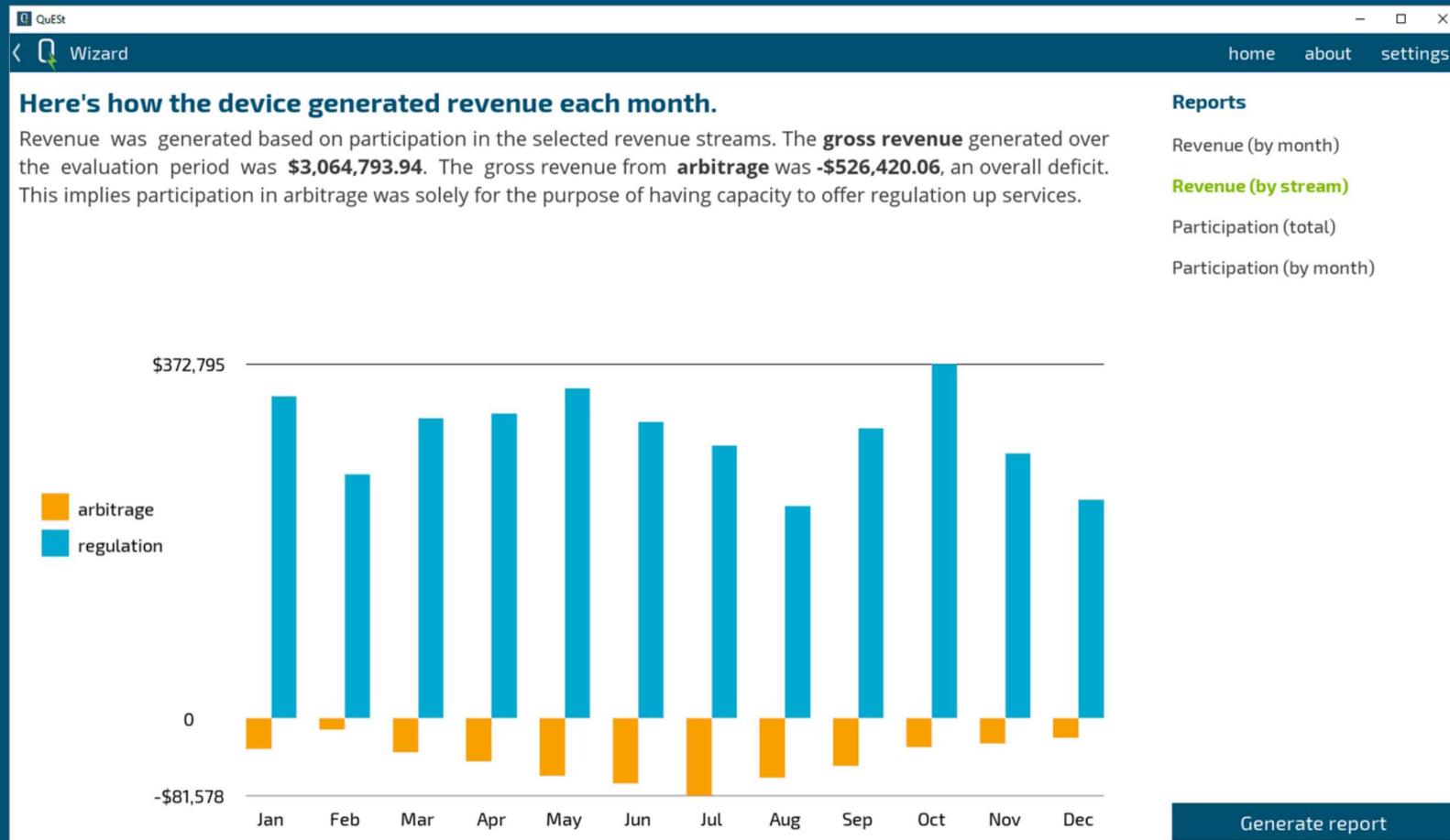
Li-ion Battery  
Modeled after the Notrees Battery Storage Project in western TX.

100.0   90.0   24.0   36.0

Previous   Next

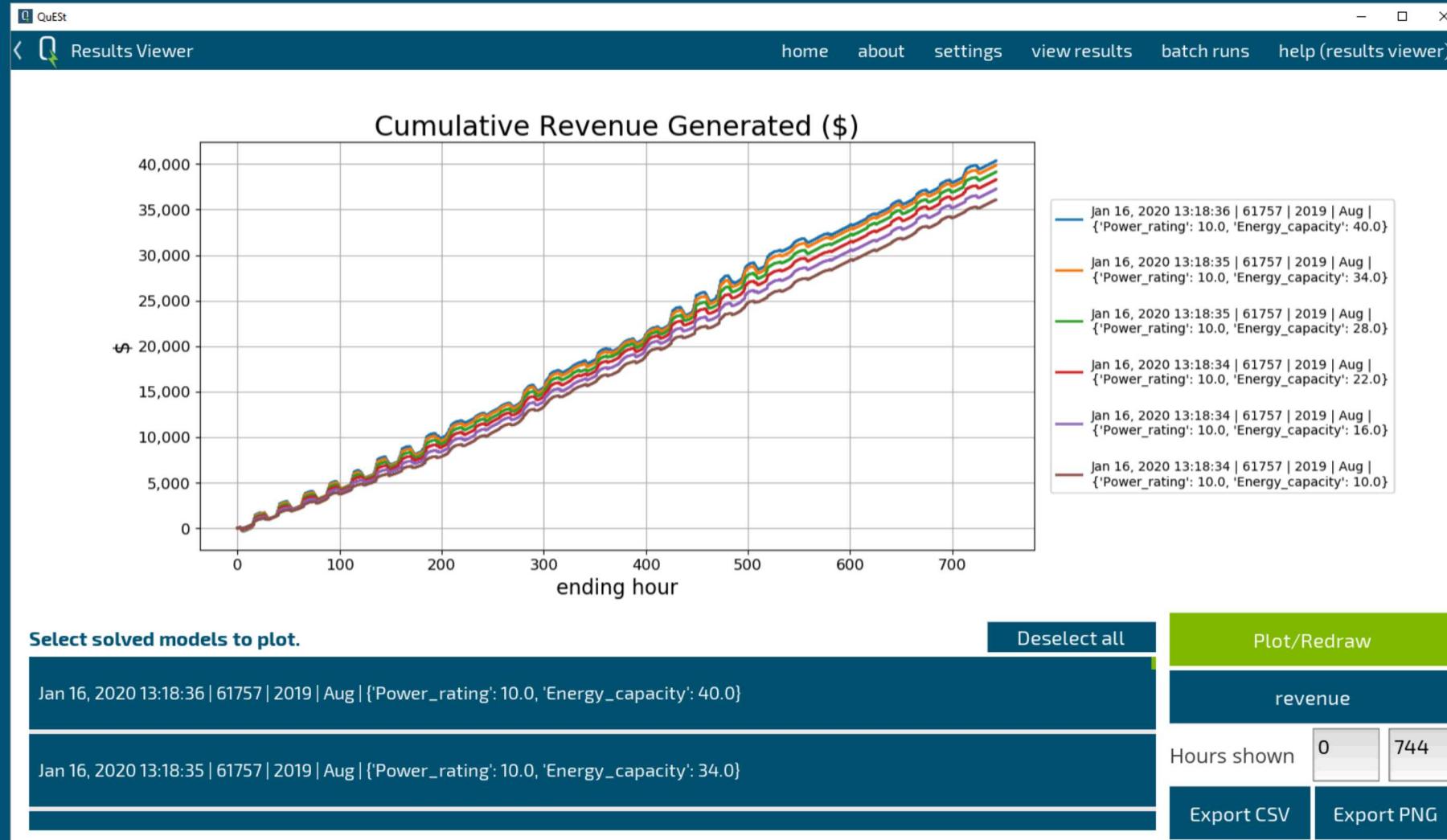
- Market area
- Revenue streams
- Historical dataset to study
- Energy storage model parameters

# QUEST VALUATION



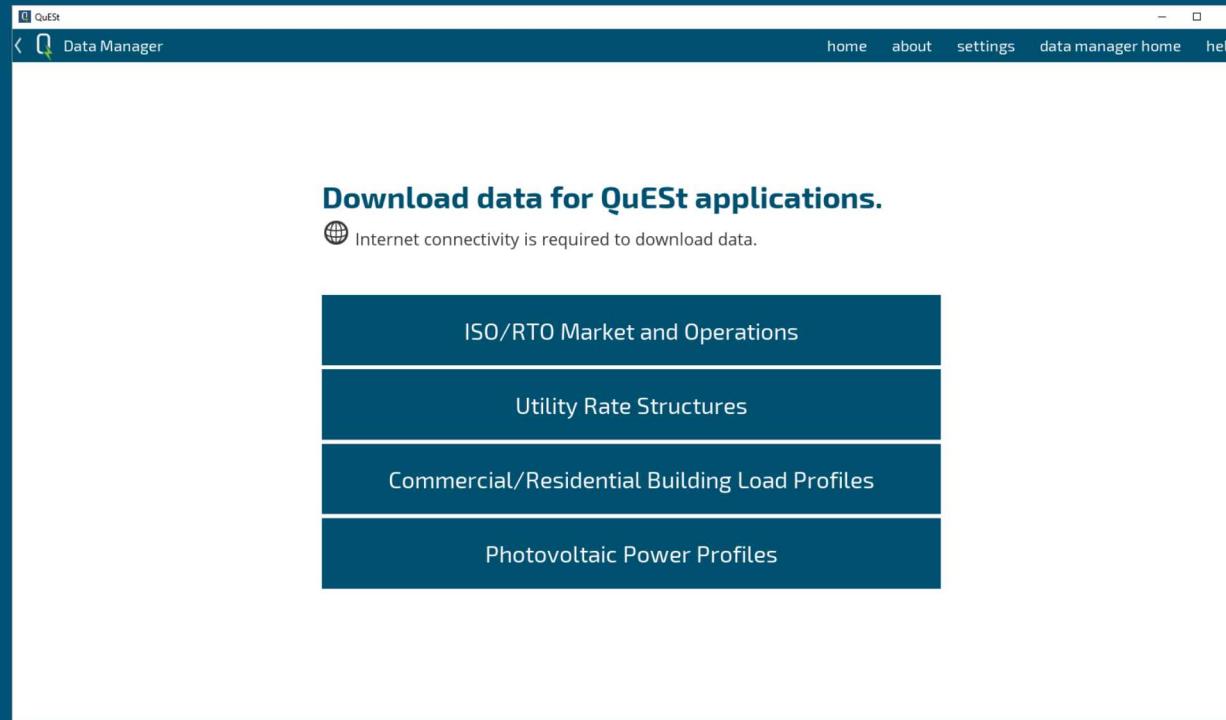
- Revenue by month
- Revenue by revenue stream
- Frequency of participation in each available revenue stream

# QUEST VALUATION



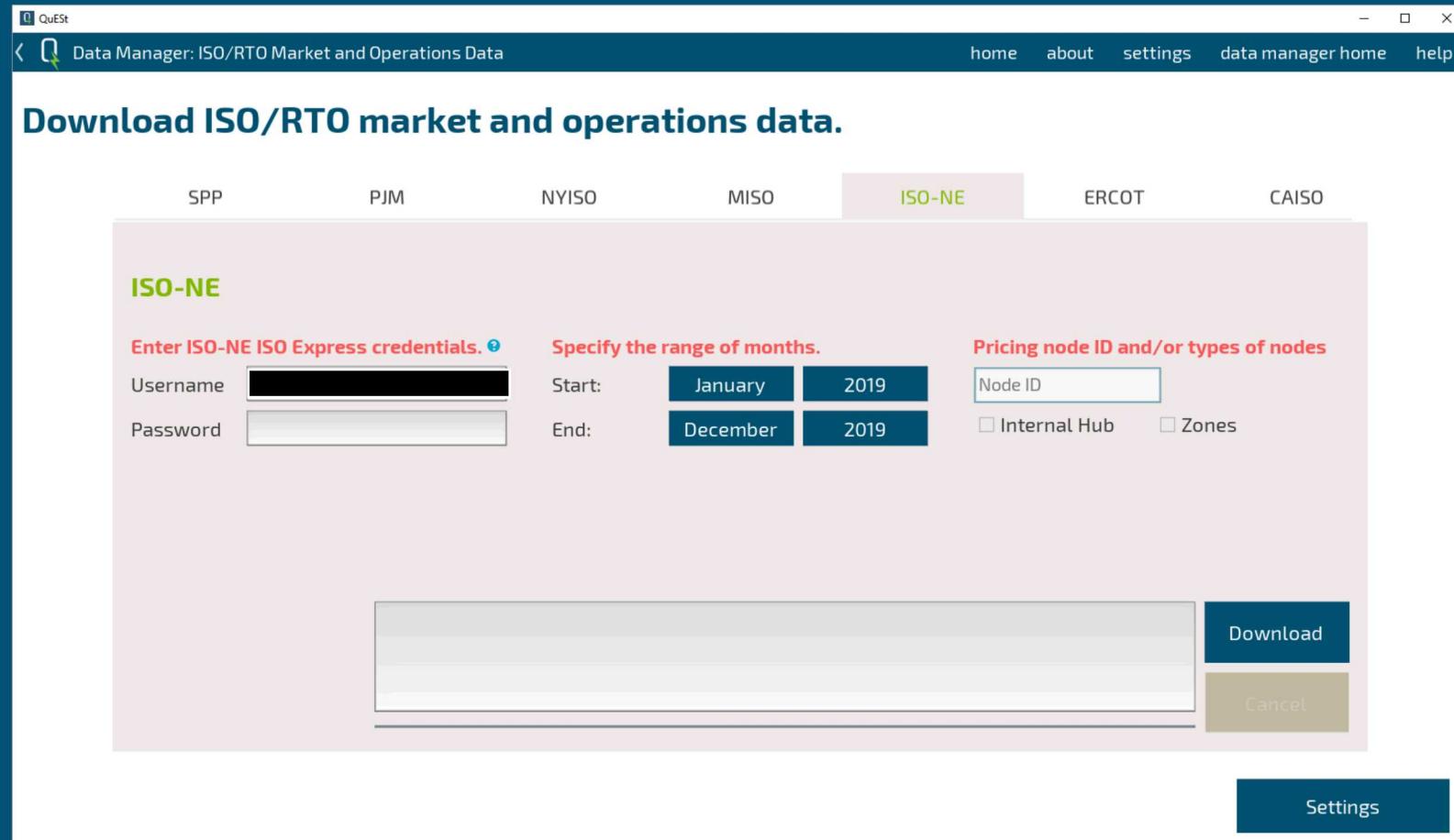
- Parameter sensitivity analysis (fixed power rating, varying energy capacity)
- NYISO, CAPITL pricing node, August 2019, arbitrage + regulation

# QUEST DATA MANAGER



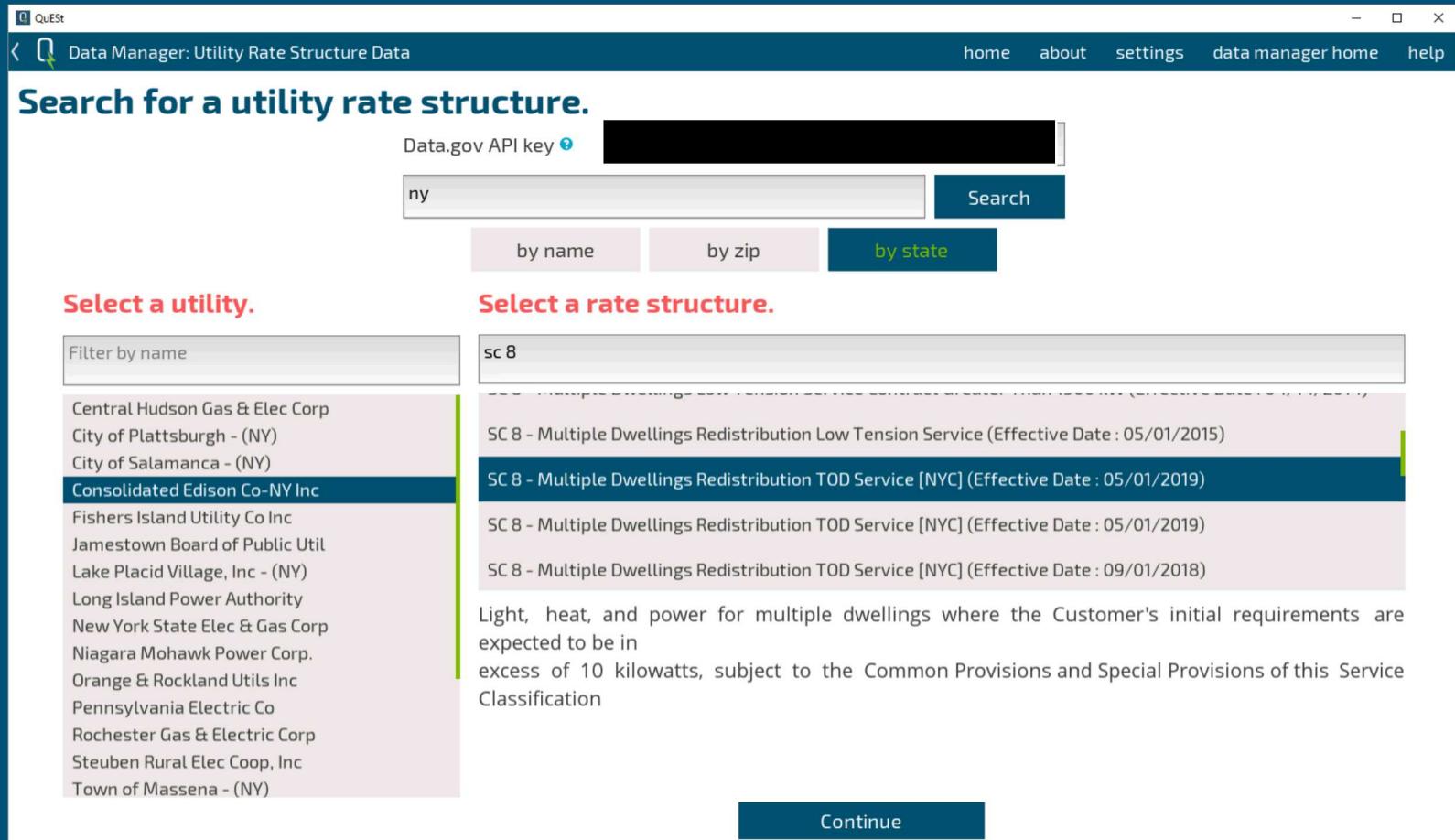
We use publicly available APIs, posted market data, and crowd-sourced data.

- LMPs, frequency regulation performance/capacity clearing prices, etc. 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



- LMPs, frequency regulation performance/capacity clearing prices, etc.

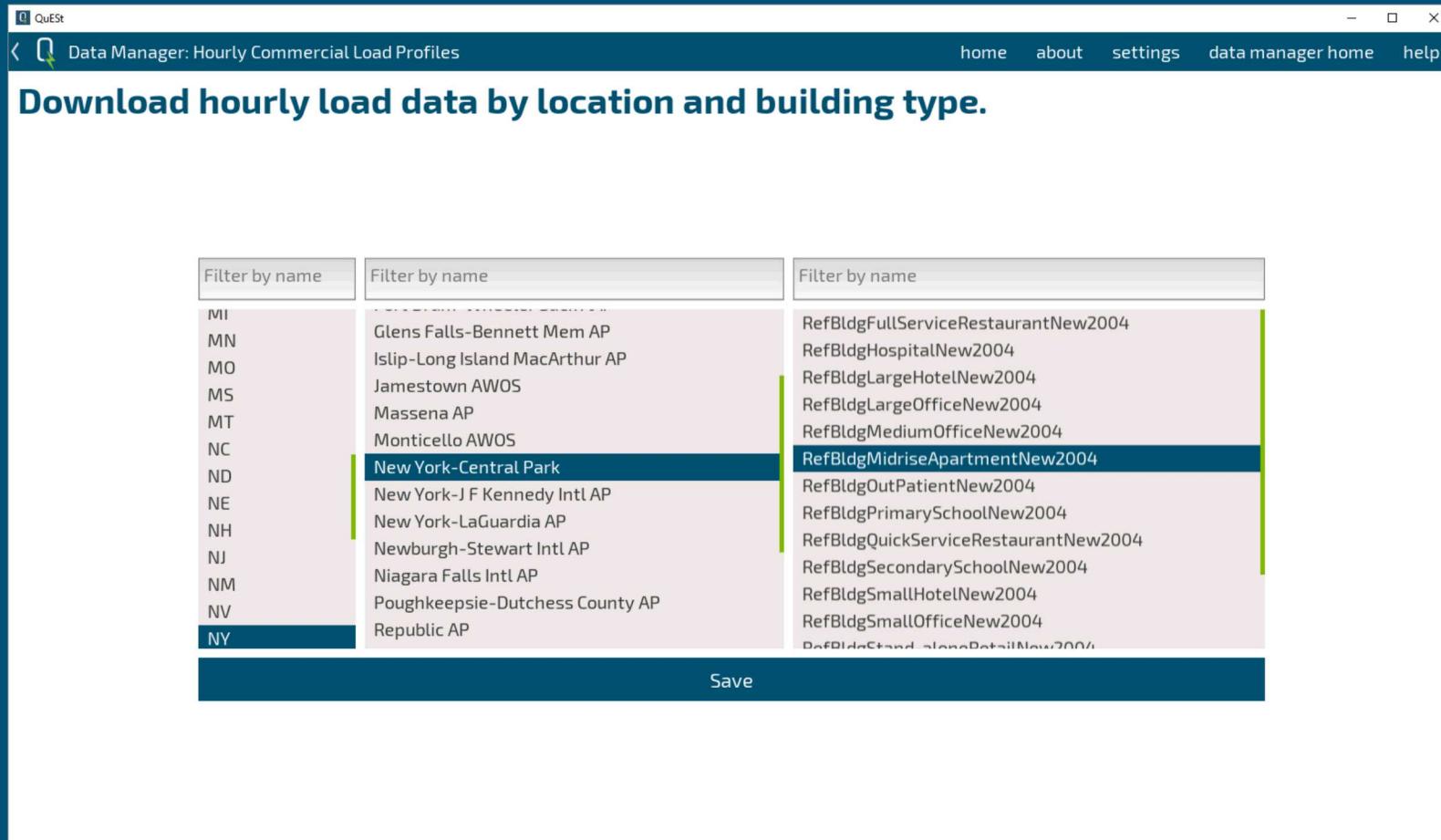
# QUEST DATA MANAGER



The screenshot shows the QuEST Data Manager interface for searching utility rate structures. The top navigation bar includes links for home, about, settings, data manager home, and help. A search bar at the top has a placeholder 'Data.gov API key' and a search button. Below the search bar are three buttons: 'by name', 'by zip', and 'by state'. The main search area has a text input with 'ny' and a 'Search' button. On the left, a sidebar titled 'Select a utility.' lists various utility companies, with 'Consolidated Edison Co-NY Inc' highlighted. On the right, a sidebar titled 'Select a rate structure.' shows a list of rate structures, with 'SC 8' selected. A detailed description of 'SC 8' is provided, mentioning it's for multiple dwellings, effective from 05/01/2015, and includes a TOD service for NYC. A 'Continue' button is at the bottom.

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

# QUEST DATA MANAGER

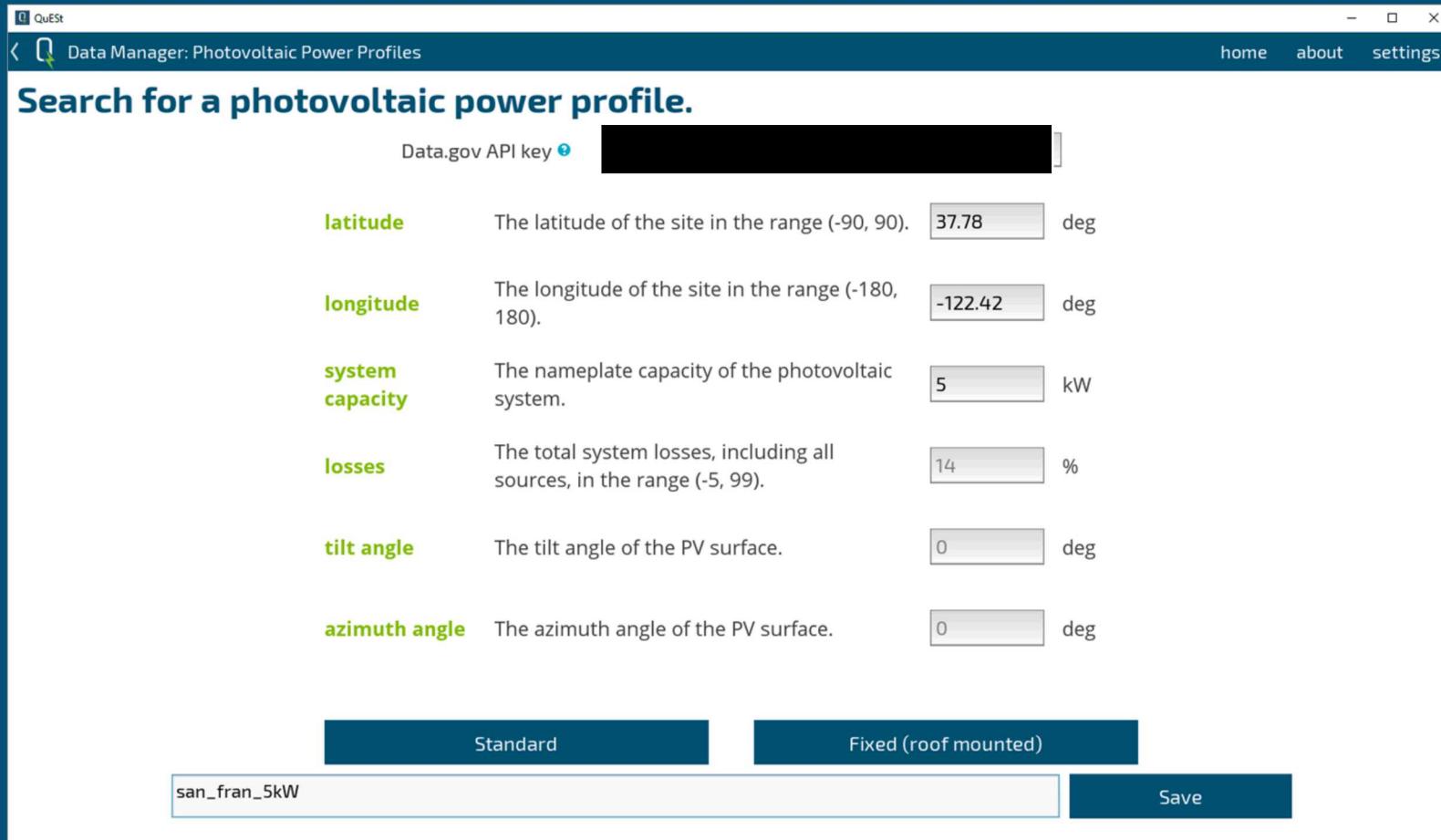


The screenshot shows a Windows application window titled "QuEST Data Manager: Hourly Commercial Load Profiles". The window has a menu bar with "home", "about", "settings", "data manager home", and "help". Below the menu is a sub-header "Data Manager: Hourly Commercial Load Profiles". The main content area contains three filter sections: "Filter by name" for states (MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, NM, NV, NY), "Filter by name" for locations (Glens Falls-Bennett Mem AP, Islip-Long Island MacArthur AP, Jamestown AWOS, Massena AP, Monticello AWOS, New York-Central Park, New York-J F Kennedy Intl AP, New York-LaGuardia AP, Newburgh-Stewart Intl AP, Niagara Falls Intl AP, Poughkeepsie-Dutchess County AP, Republic AP), and "Filter by name" for building types (RefBldgFullServiceRestaurantNew2004, RefBldgHospitalNew2004, RefBldgLargeHotelNew2004, RefBldgLargeOfficeNew2004, RefBldgMediumOfficeNew2004, RefBldgMidriseApartmentNew2004, RefBldgOutPatientNew2004, RefBldgPrimarySchoolNew2004, RefBldgQuickServiceRestaurantNew2004, RefBldgSecondarySchoolNew2004, RefBldgSmallHotelNew2004, RefBldgSmallOfficeNew2004, RefBldgStand-aloneRetailNew2004). A "Save" button is at the bottom.

<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 a 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 "QuEST Data Manager: Photovoltaic Power Profiles". The window has a header with "home", "about", and "settings" links. The main content area is titled "Search for a photovoltaic power profile." and includes a "Data.gov API key" input field. Below are six input fields for system parameters:

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

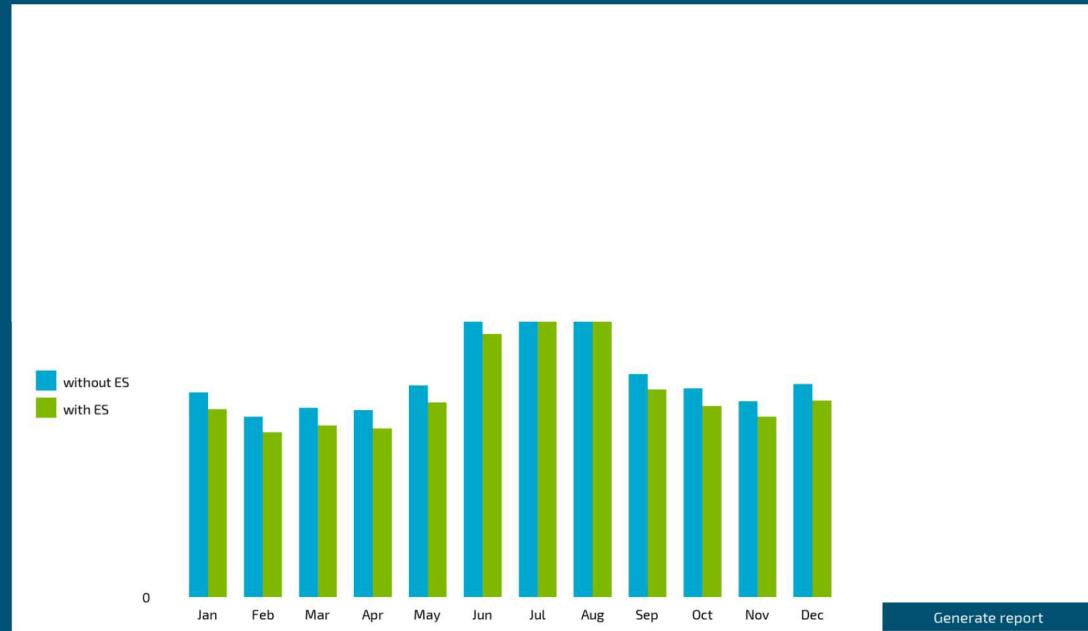
At the bottom, there are two buttons: "Standard" and "Fixed (roof mounted)", with "Fixed (roof mounted)" being the active tab. A text input field contains "san\_fran\_5kW" and a "Save" button is visible.

## PVWatts by NREL

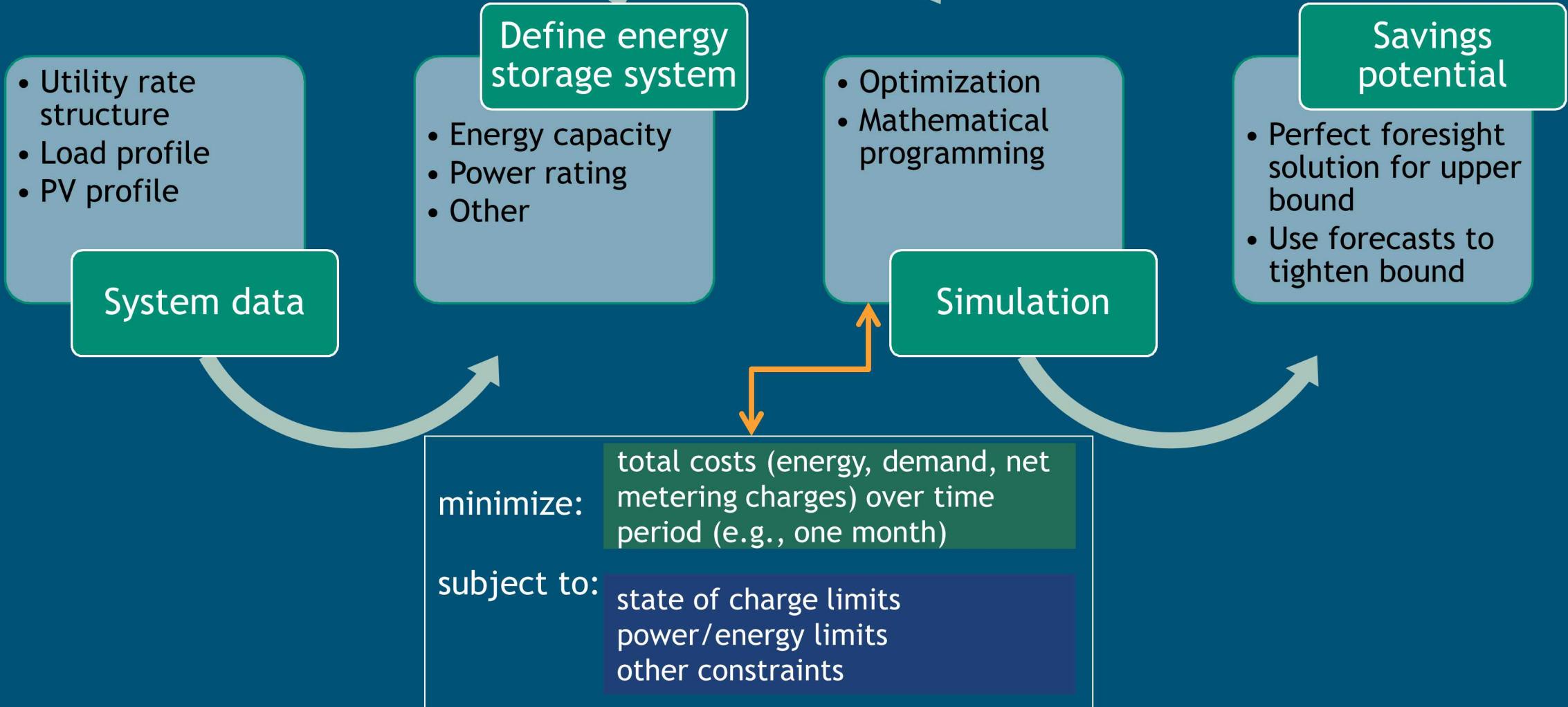
- Uses data from the National Solar Radiation Database and a solar panel system model to simulate hourly power output

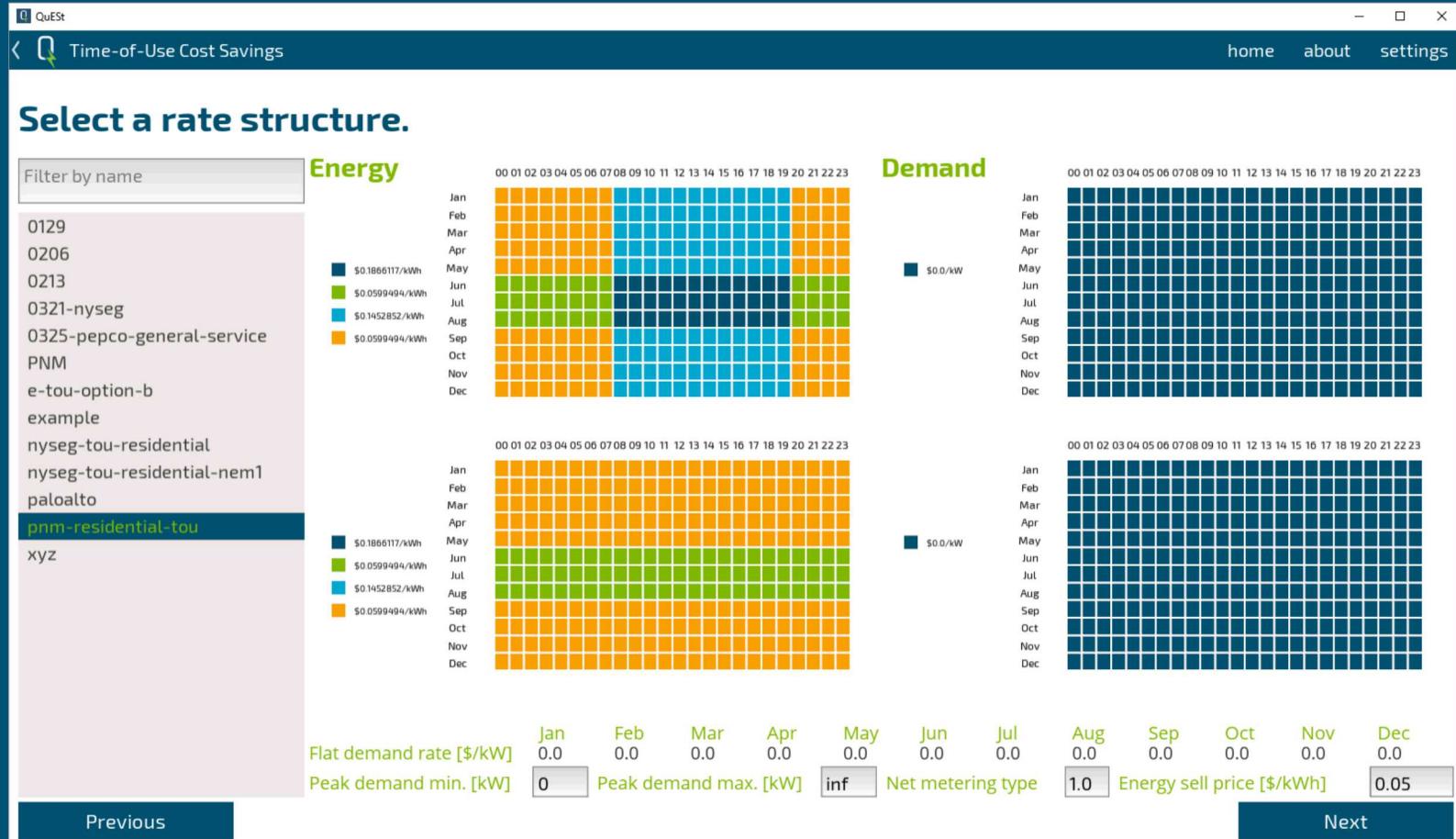
A collection of applications for behind-the-meter energy storage. The first application estimates cost savings for time-of-use and net energy metering customers.

- Incorporate specific utility rate structures (energy TOU schedule and rates, etc.)
- Use location-specific simulated load and photovoltaic power data or bring your own



Nguyen, T., and R. Byrne. "Maximizing the cost-savings for time-of-use and net-metering customers using behind-the-meter energy storage systems." *Proceedings of the 2017 North American Power Symposium (NAPS)*. 2017.





- 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

Time-of-Use Cost Savings

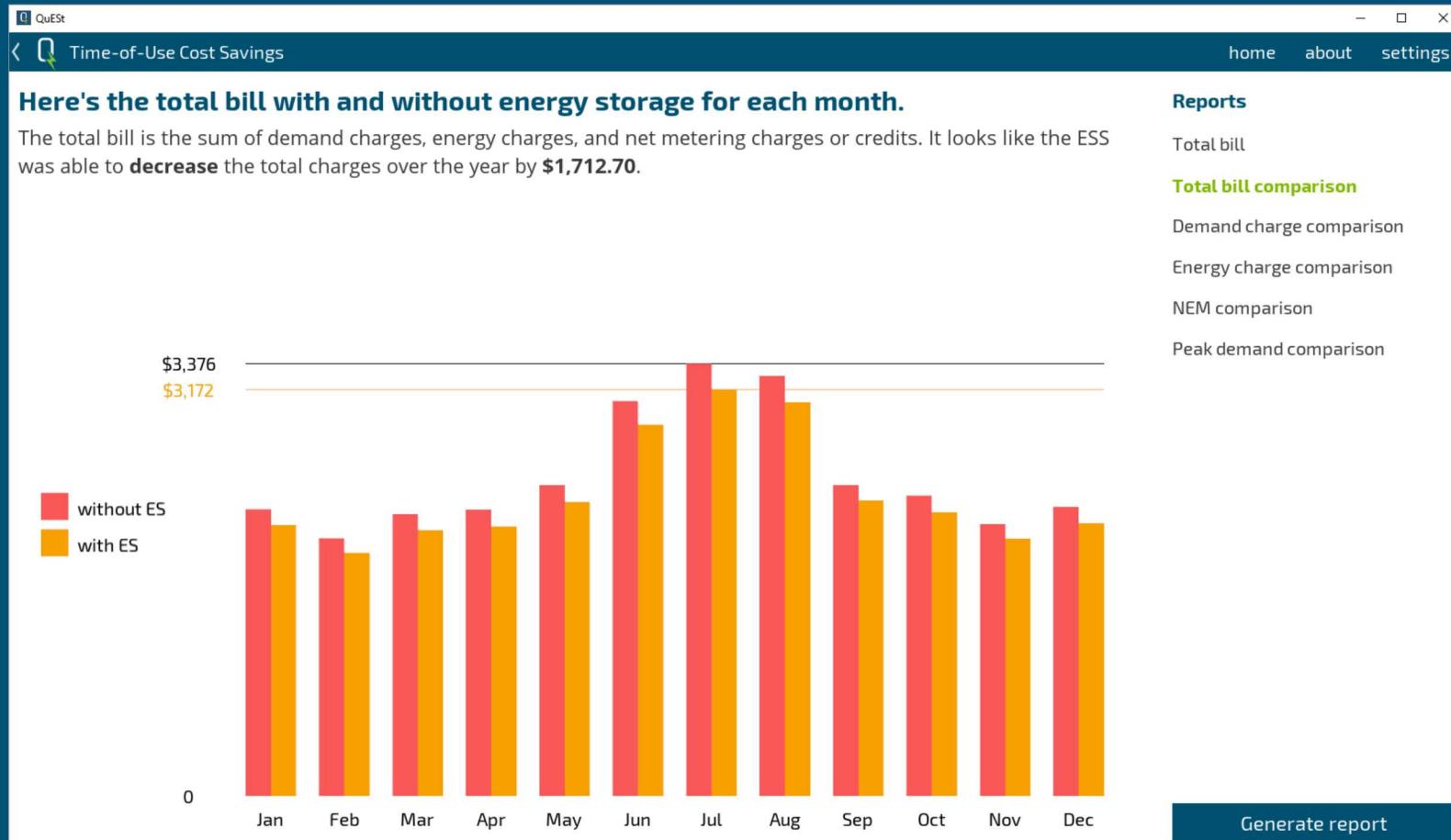
home about settings

**Specify the energy storage system parameters.**

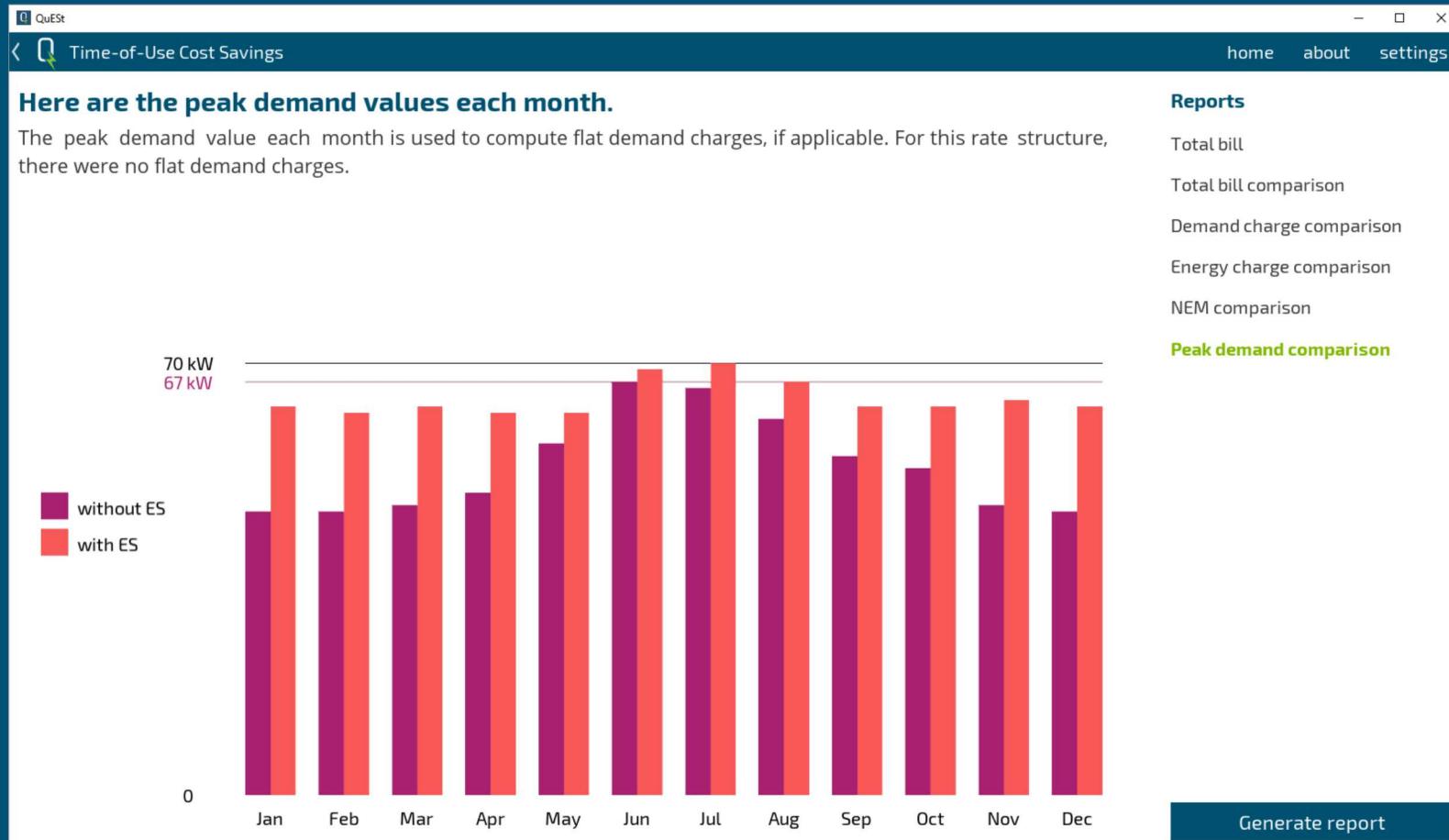
<b>energy capacity</b>	The maximum amount of energy that the ESS can store.	<input type="text" value="80"/> kWh
<b>power rating</b>	The maximum rate at which the ESS can charge or discharge energy.	<input type="text" value="20"/> kW
<b>transformer rating</b>	The maximum amount of power that can be exchanged.	<input type="text" value="1000000"/> kW
<b>self-discharge efficiency</b>	The percentage of stored energy that the ESS retains on an hourly basis.	<input type="text" value="100"/> %/h
<b>round trip efficiency</b>	The percentage of energy charged that the ESS actually retains.	<input type="text" value="85"/> %
<b>minimum state of charge</b>	The minimum ESS state of charge as a percentage of energy capacity.	<input type="text" value="0"/> %
<b>maximum state of charge</b>	The maximum ESS state of charge as a percentage of energy capacity.	<input type="text" value="100"/> %
<b>initial state of charge</b>	The percentage of energy capacity that the ESS begins with.	<input type="text" value="50"/> %

[Previous](#) [Next](#)

- 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



- 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



- 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



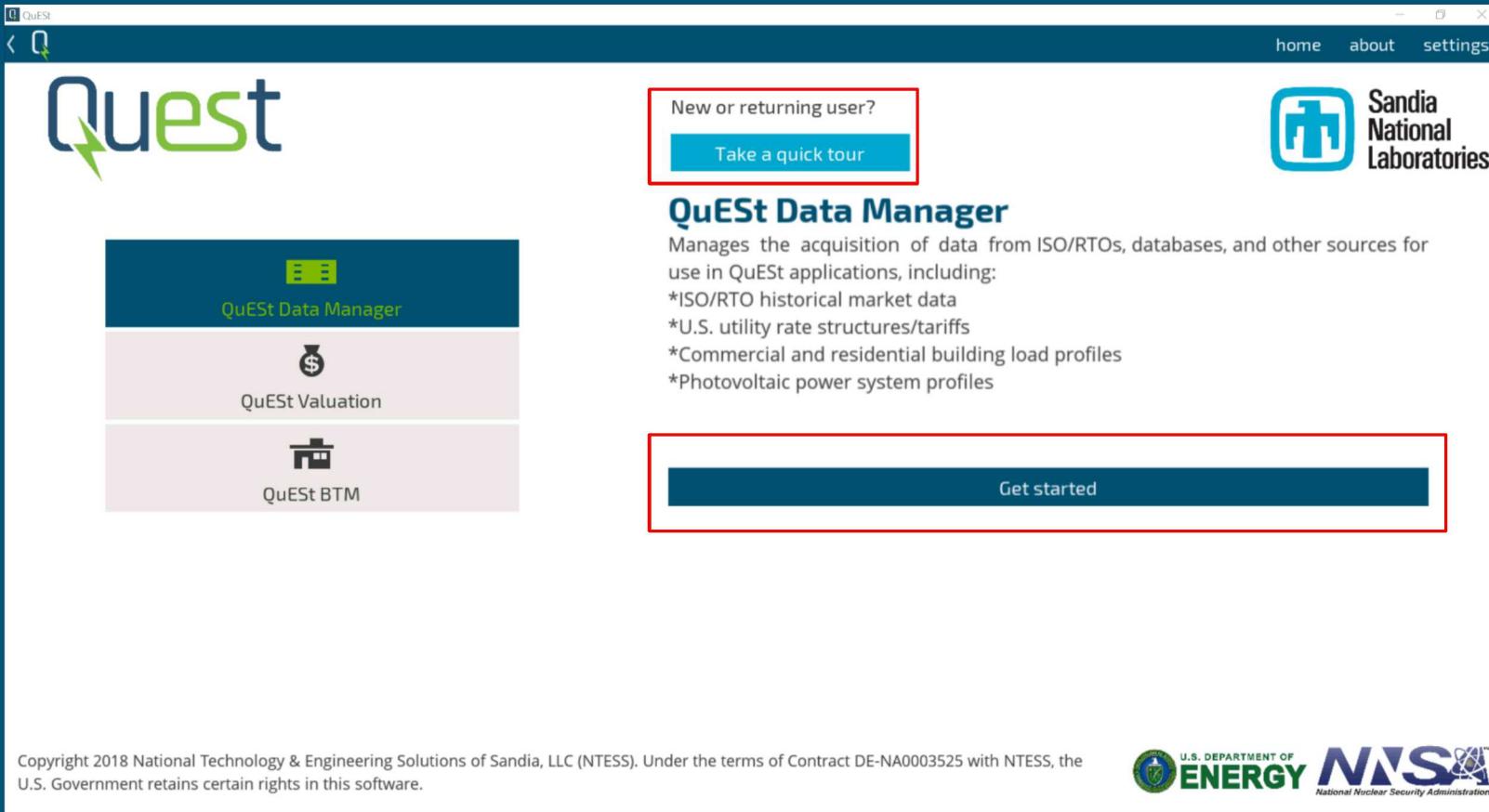
# CASE STUDY: A MID-SIZE OFFICE BUILDING WITH SOLAR + STORAGE IN RENO

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## CASE STUDY: MID-SIZE OFFICE BUILDING WITH PV+STORAGE

You are the operator of a mid-size office building with a 100 kW rooftop PV system in the Reno area. You're thinking about acquiring an energy storage system to better utilize your PV system and take advantage of time-of-use tariff to reduce the property's electricity bills. Would it be worth it?

# CASE STUDY: MID-SIZE OFFICE BUILDING WITH PV+STORAGE



QuEST

New or returning user?

Take a quick tour

home about settings

**QuEST Data Manager**

Manages the acquisition of data from ISO/RTOs, databases, and other sources for use in QuEST applications, including:

- \*ISO/RTO historical market data
- \*U.S. utility rate structures/tariffs
- \*Commercial and residential building load profiles
- \*Photovoltaic power system profiles

Get started

QuEST Data Manager

QuEST Valuation

QuEST BTM

home about settings

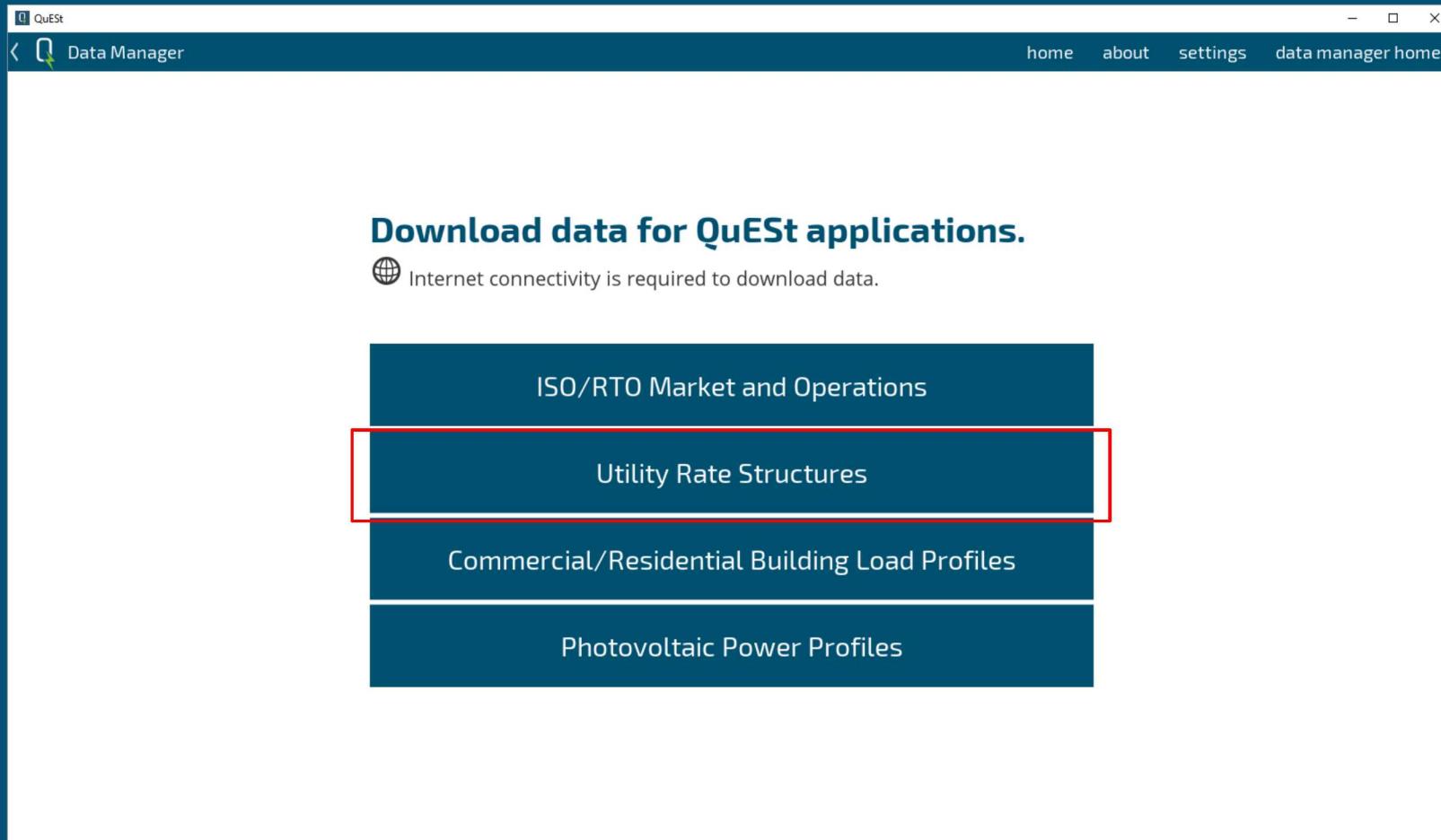
Sandia National Laboratories

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U.S. DEPARTMENT OF ENERGY NNSA  
National Nuclear Security Administration

- This is a behind-the-meter energy storage problem, so we will use QuEST BTM.
- For this analysis, we need:
  - Utility rate structure
  - Load profile for the property
  - PV power profile
- First, we head to QuEST Data Manager to get what we need.

# CASE STUDY: MID-SIZE OFFICE BUILDING WITH PV+STORAGE



- This is a behind-the-meter energy storage problem, so we will use QuEST BTM.
- For this analysis, we need:
  - Utility rate structure
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- First, we head to QuEST Data Manager to get what we need.

# CASE STUDY: MID-SIZE OFFICE BUILDING WITH PV+STORAGE

QuEST  
Data Manager: Utility Rate Structure Data

Search for a utility rate structure.

Data.gov API key: [REDACTED]

nv

Search

by name by zip by state

Select a utility.

Filter by name

- City of Boulder City - (NV)
- Harney Electric Coop, Inc
- Mt Wheeler Power, Inc
- Nevada Power Co
- Overton Power District No 5
- Plumas-Sierra Rural Elec Coop
- Raft River Rural Elec Coop Inc
- Sierra Pacific Power Co**
- Surprise Valley Electrification
- Valley Electric Assn, Inc
- Wells Rural Electric Co

Select a rate structure.

time of use

- OGS-1 TOU - Optional General Service Time of Use Experimental - Bundled (Effective Date : 07/02/2014)
- OGS-1 TOU - Optional General Service Time of Use Experimental - Bundled (Effective Date : 10/01/2013)
- OGS-1-EVRR-TOU - General Service Electric Vehicle Recharge Rider - Time of Use (Effective Date : 07/02/2014)
- OGS-2 TOU - Optional Medium General Service Time of Use - Secondary (Effective Date : 07/01/2019)**

Service under this schedule is available as an option to the regular, non-TOU service under Schedule No. GS-2. This schedule is available where another TaU schedule is not specifically available. This schedule is available to any service where, during any three or more billing periods in the preceding twelve (12) months, a) monthly metered maximum demand was greater than or equal to fifty (50) kilowatts or monthly metered energy usage was greater than or equal to 10,000 kilowatt hours, and b) monthly metered maximum demand was less than five

Continue

- Our building's utility is Sierra Pacific Power Co (NV Energy).
- The applicable rate structure for our property is "OGS-2 TOU - Optional Medium General Service Time of Use - Secondary".
- We'll need an API key for this tool and the PV profile downloader. There's a help prompt to get you started with that short process.

# CASE STUDY: MID-SIZE OFFICE BUILDING WITH PV+STORAGE

QuEST

Data Manager: Utility Rate Structure Data

home about settings data manager home help

Verify the energy rate structure.

Period	Rate [\$/kWh]
0	0.04565
1	0.05005
2	0.05583
3	0.05066
4	0.07635
5	0.11409

**Weekday**

	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Jan	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0	
Feb	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0	
Mar	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0	
Apr	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0	
May	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0	
Jun	3	3	3	3	3	3	3	3	3	4	4	4	5	5	5	5	5	4	4	4	3	3	3	
Jul	3	3	3	3	3	3	3	3	3	4	4	4	5	5	5	5	5	4	4	4	3	3	3	
Aug	3	3	3	3	3	3	3	3	3	4	4	4	5	5	5	5	5	4	4	4	3	3	3	
Sep	3	3	3	3	3	3	3	3	3	4	4	4	5	5	5	5	5	4	4	4	3	3	3	
Oct	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0	
Nov	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0	
Dec	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0	
	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23

**Weekend**

	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Jan	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0	
Feb	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0	
Mar	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0	
Apr	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0	
May	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0	
Jun	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
Jul	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
Aug	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
Sep	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
Oct	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0	
Nov	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0	
Dec	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0	
	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23

Previous Continue

- Verify that the energy and demand rate schedules are correct.

# CASE STUDY: MID-SIZE OFFICE BUILDING WITH PV+STORAGE

Verify the demand rate structure.

Period	Time-of-Use Rate [\$/kW]	
0	0	
1	0.92	
2	0.92	
3	2.21	
4	5.25	

**Weekday**

	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
Jan	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0
Feb	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0
Mar	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0
Apr	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0
May	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0
Jun	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0
Jul	0	0	0	0	0	0	0	0	0	3	3	3	3	4	4	4	4	4	3	3	3	3	0	0	0
Aug	0	0	0	0	0	0	0	0	0	3	3	3	3	4	4	4	4	4	3	3	3	3	0	0	0
Sep	0	0	0	0	0	0	0	0	0	3	3	3	3	4	4	4	4	4	3	3	3	3	0	0	0
Oct	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0
Nov	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0
Dec	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0

**Weekend**

	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
Jan	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0
Feb	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0
Mar	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0
Apr	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0
May	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0
Jun	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0
Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0
Nov	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0
Dec	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0

Previous Continue

- Verify that the energy and demand rate schedules are correct.

# CASE STUDY: MID-SIZE OFFICE BUILDING WITH PV+STORAGE

QuEST

Data Manager: Utility Rate Structure Data

home about settings data manager home help

**Finishing up.**

**Peak demand**

minimum [kW]  maximum [kW]

**Net (energy) metering**

Net metering 1.0 Net metering 2.0

Energy is sold at a fixed energy price. Energy is sold at the time-of-use energy price.

sell price [\$/kWh]

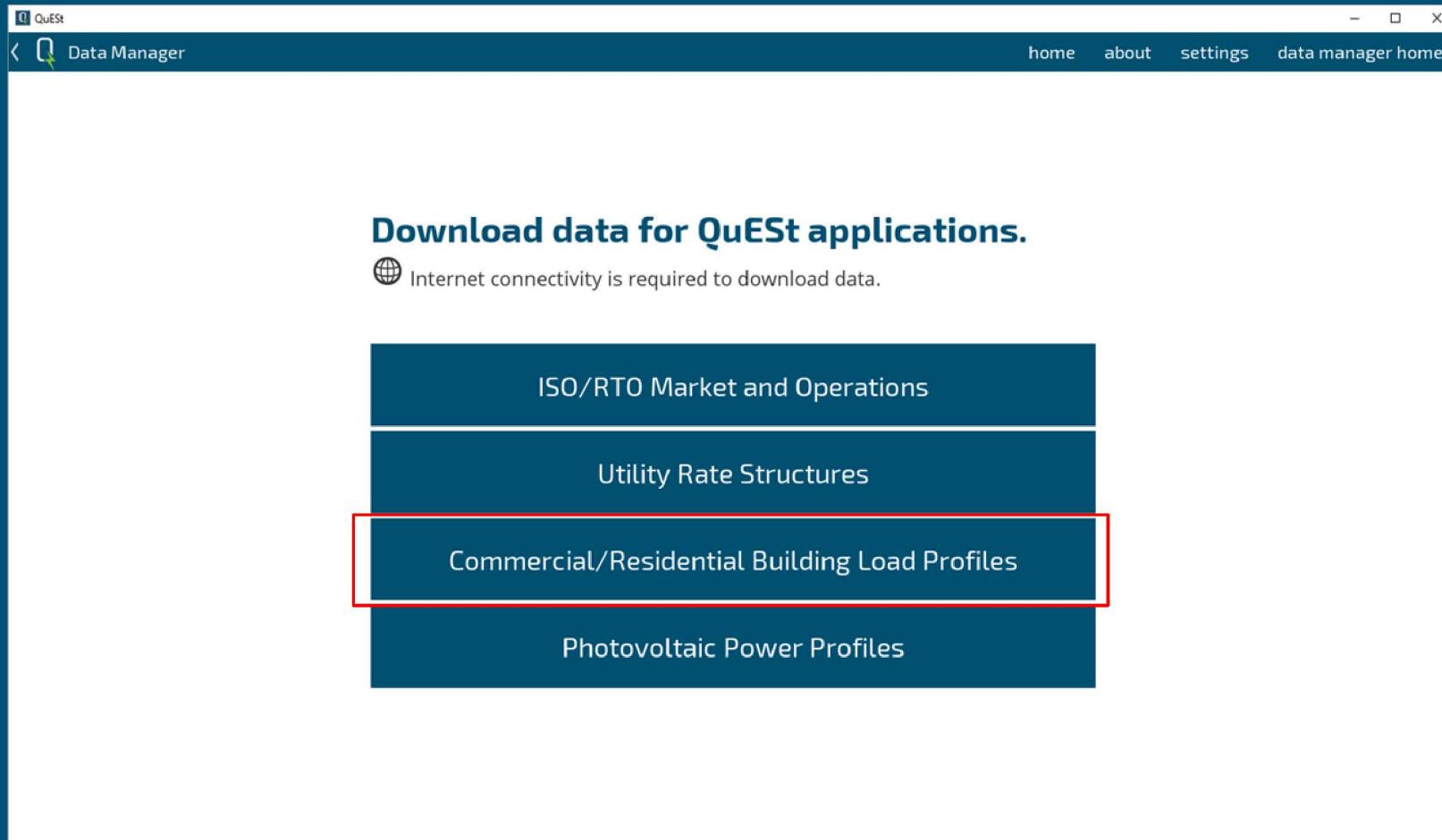
**Save rate structure**

sierra-pacific-ogs2-medium-secondary

Previous Start Over Data Manager Home

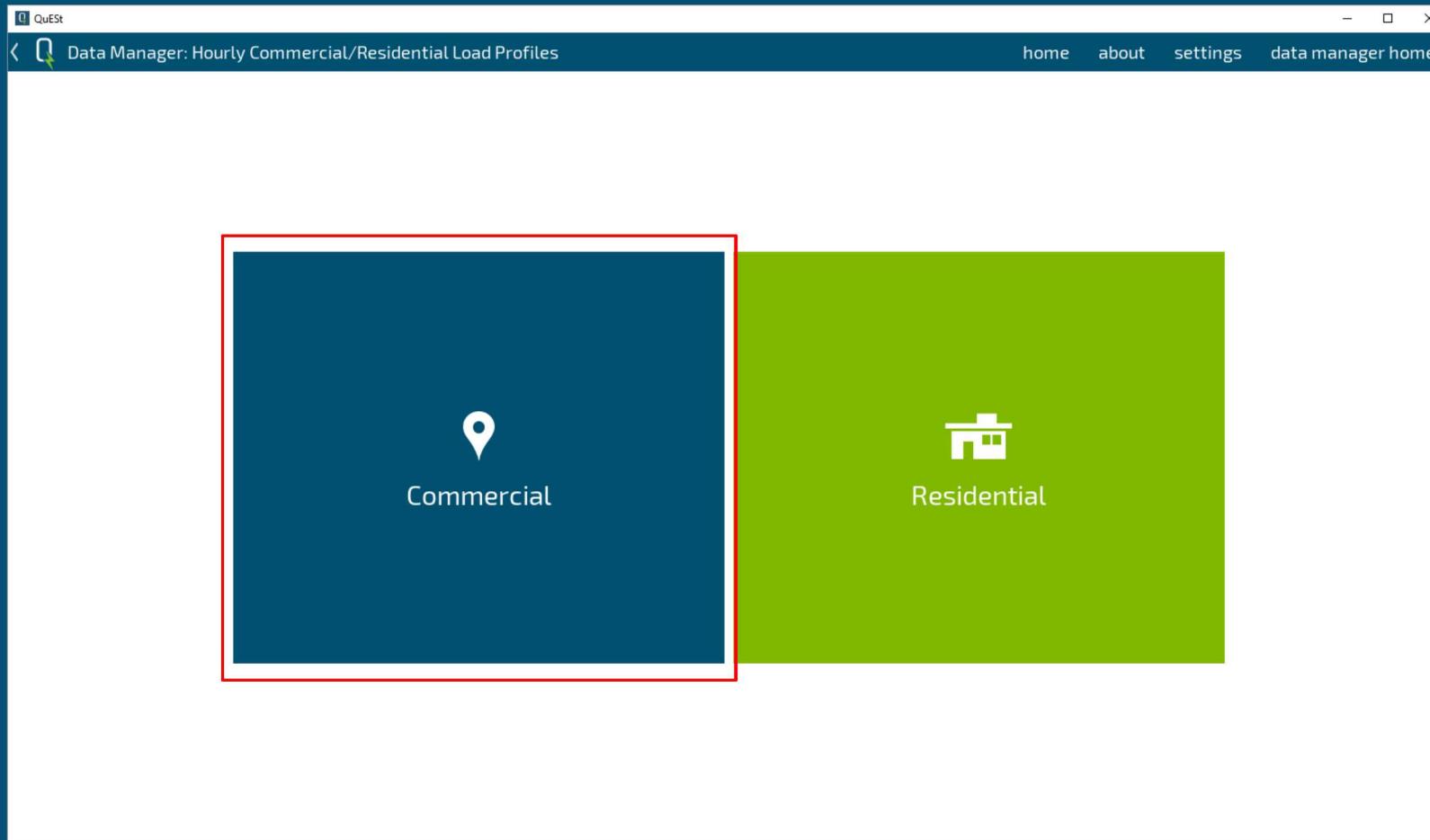
Save the rate structure for later.

# CASE STUDY: MID-SIZE OFFICE BUILDING WITH PV+STORAGE



Now we'll obtain the load profile for the building.

# CASE STUDY: MID-SIZE OFFICE BUILDING WITH PV+STORAGE



Now we'll obtain the load profile for the building.

# CASE STUDY: MID-SIZE OFFICE BUILDING WITH PV+STORAGE

QuEST

Data Manager: Hourly Commercial Load Profiles

home about settings data manager home help

Download hourly load data by location and building type.

Filter by name

ND  
NE  
NH  
NJ  
NM  
**NV**  
NY  
OH  
OK  
OR  
PA  
RI

Filter by name

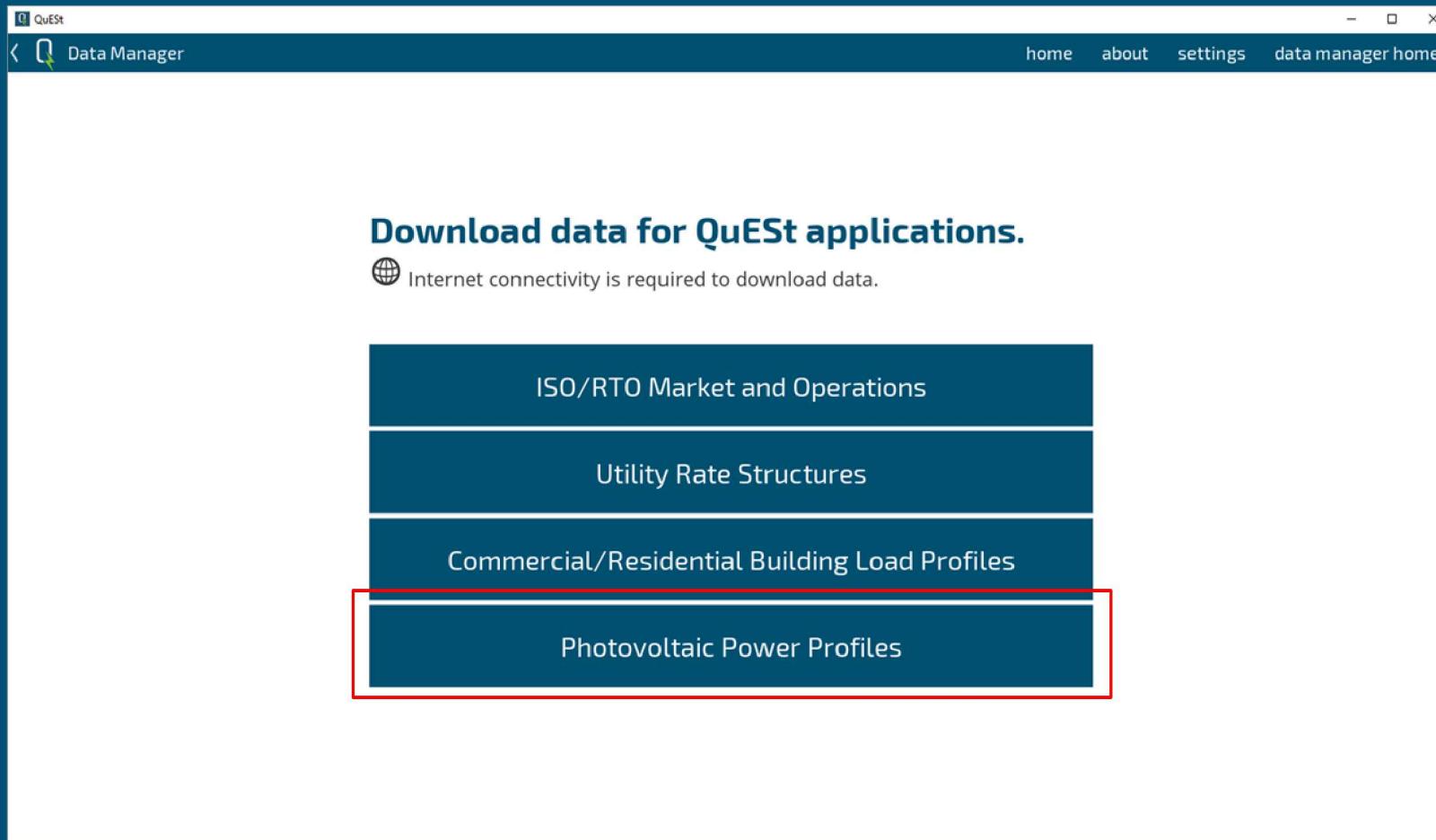
Elko Muni AP  
Ely-Yelland Field  
Fallon NAS  
Las Vegas-McCarren Intl AP  
Lovelock-Derby Field  
Mercury-Desert Rock AP  
Nellis AFB  
**Reno-Tahoe Intl AP**  
Tonopah AP  
Winnemucca Muni AP

Filter by name

RefBldgFullServiceRestaurantNew2004  
RefBldgHospitalNew2004  
RefBldgLargeHotelNew2004  
RefBldgLargeOfficeNew2004  
**RefBldgMediumOfficeNew2004**  
RefBldgMidriseApartmentNew2004  
RefBldgOutPatientNew2004  
RefBldgPrimarySchoolNew2004  
RefBldgQuickServiceRestaurantNew2004  
RefBldgSecondarySchoolNew2004  
RefBldgSmallHotelNew2004  
RefBldgSmallOfficeNew2004  
RefBldgStand-aloneRetailNew2004

Save

Now we'll obtain the load profile for the building.



Finally, we'll grab the PV power profile for our property.

# CASE STUDY: MID-SIZE OFFICE BUILDING WITH PV+STORAGE

QuEST

Data Manager: Photovoltaic Power Profiles

home about settings data manager home help

Search for a photovoltaic power profile.

Data.gov API key

**latitude** The latitude of the site in the range (-90, 90).  deg

**longitude** The longitude of the site in the range (-180, 180).  deg

**system capacity** The nameplate capacity of the photovoltaic system.  kW

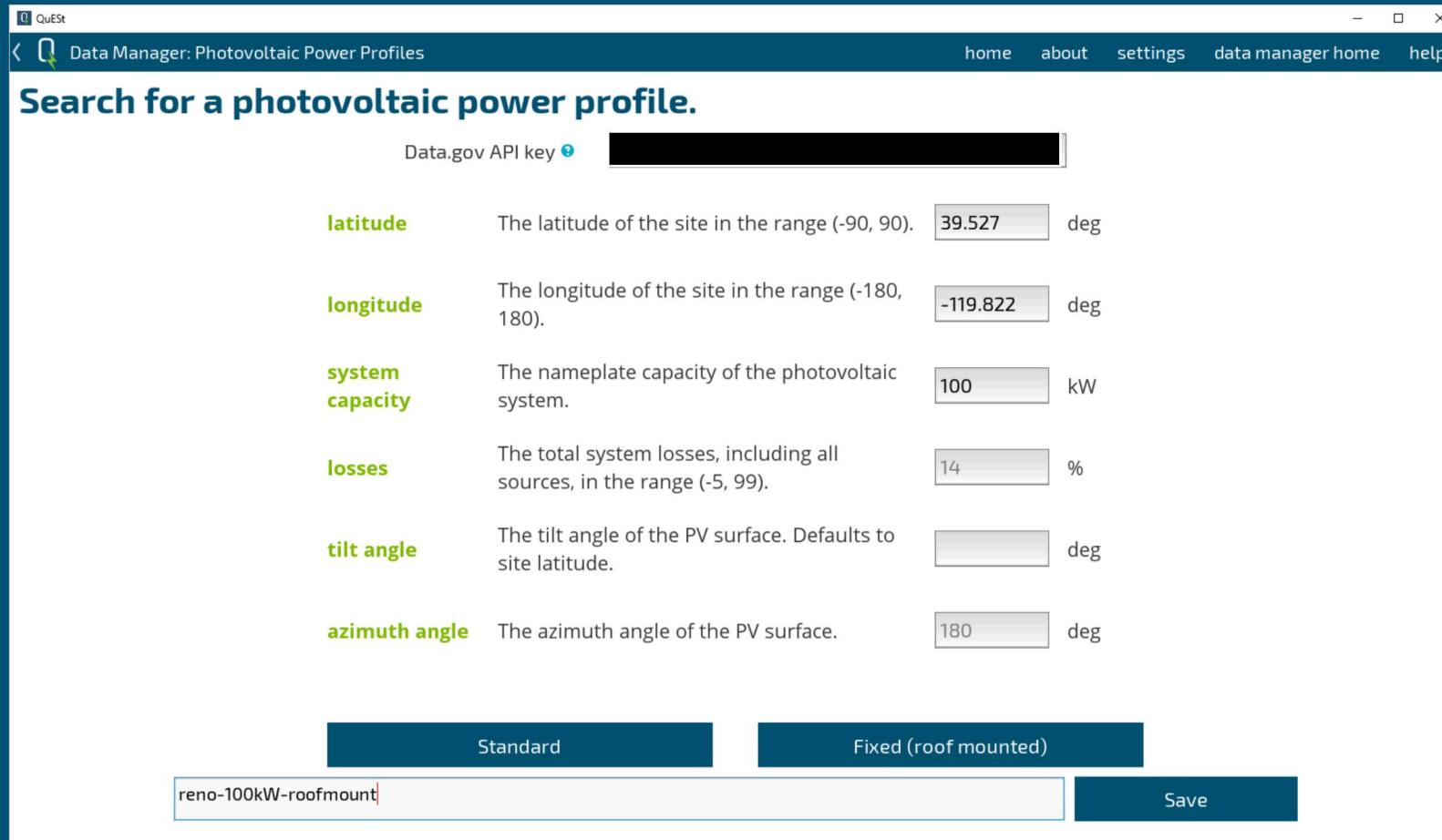
**losses** The total system losses, including all sources, in the range (-5, 99).  %

**tilt angle** The tilt angle of the PV surface. Defaults to site latitude.  deg

**azimuth angle** The azimuth angle of the PV surface.  deg

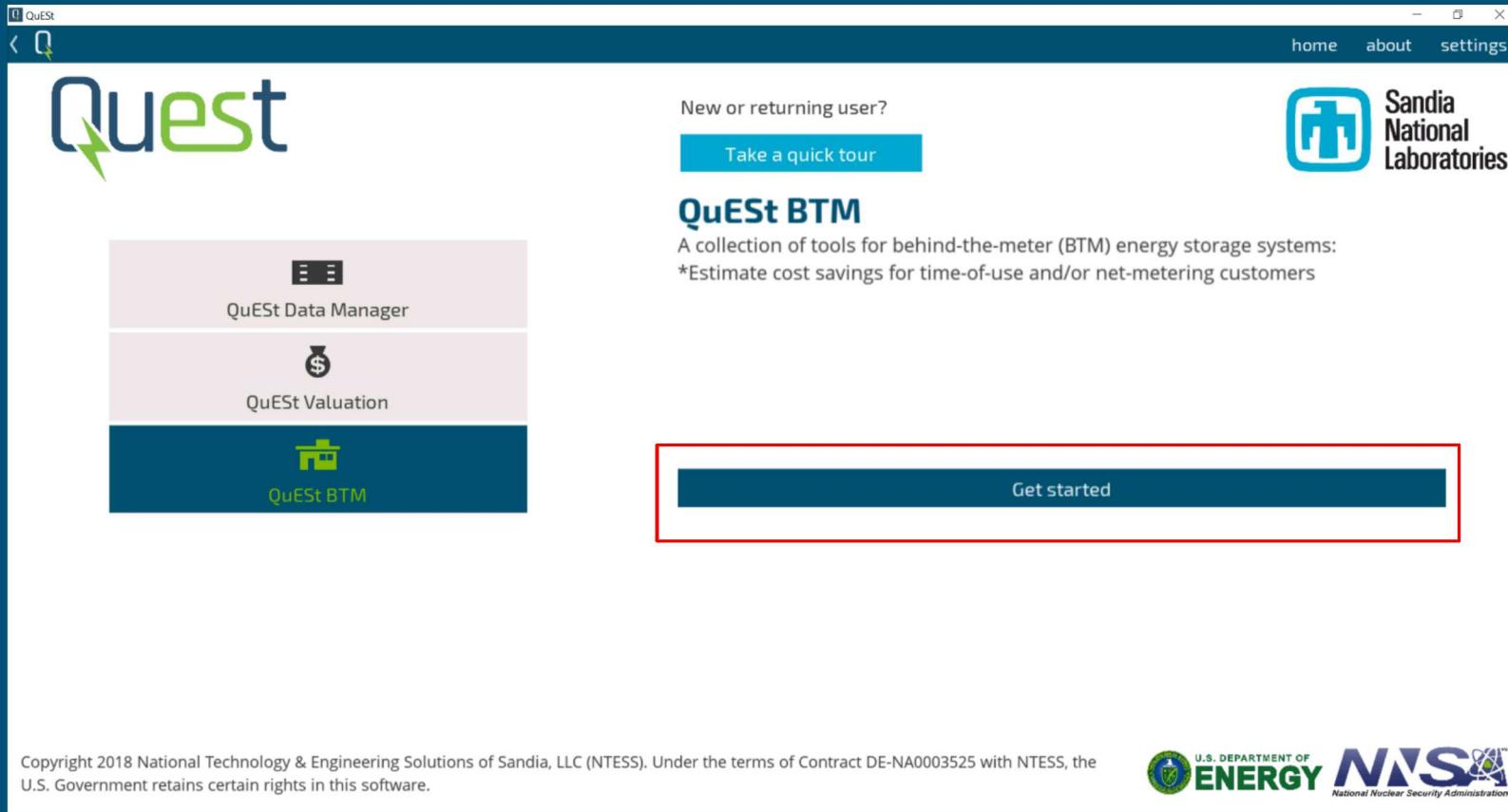
Standard Fixed (roof mounted)

Save



Finally, we'll grab the PV power profile for our property.

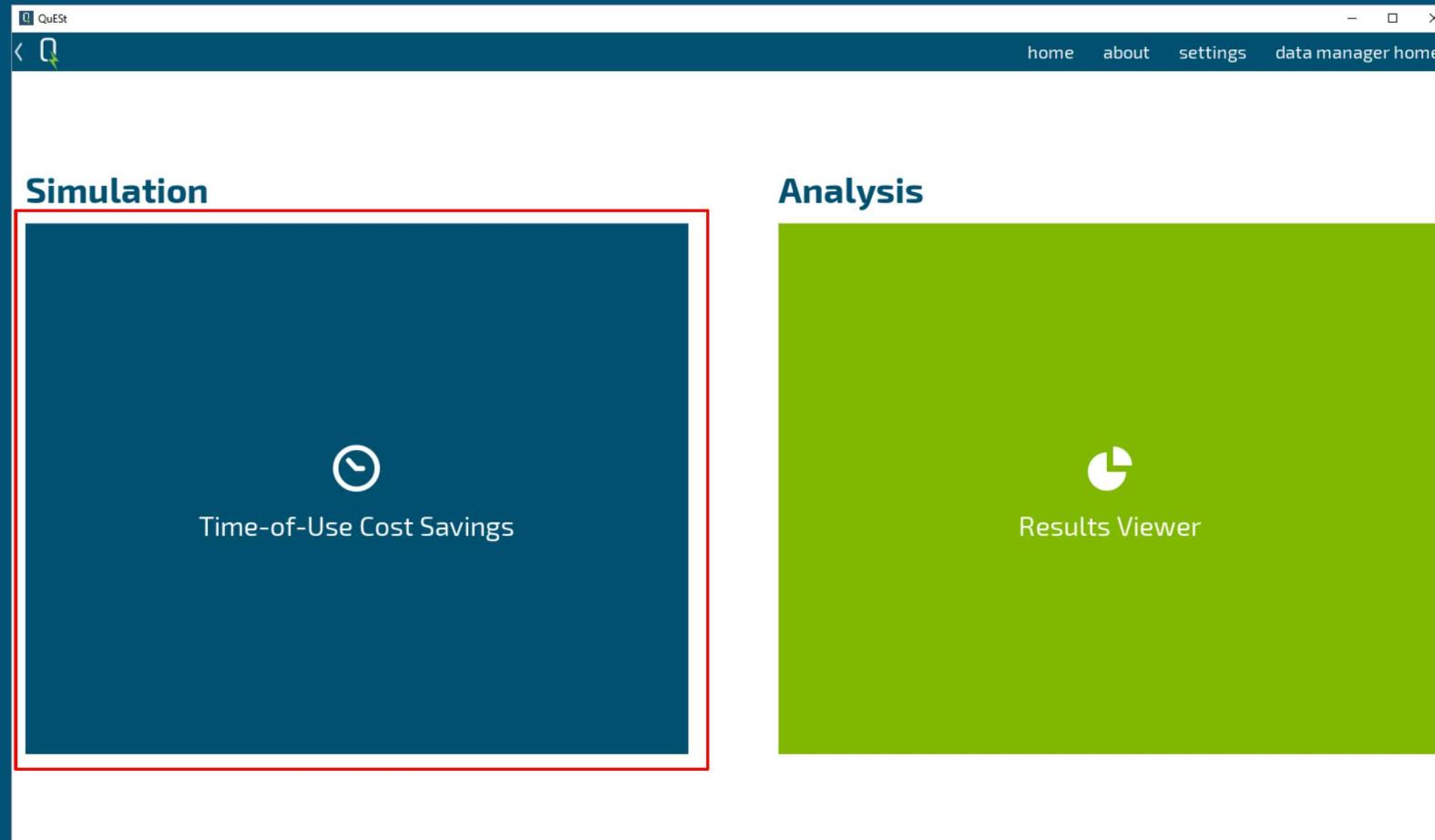
# CASE STUDY: MID-SIZE OFFICE BUILDING WITH PV+STORAGE



The screenshot shows the QuEST software interface. On the left, a sidebar menu includes 'QuEST Data Manager' (with a bar chart icon), 'QuEST Valuation' (with a dollar sign icon), and 'QuEST BTM' (with a house icon, highlighted in blue). The main content area is titled 'QuEST BTM' and describes it as a collection of tools for behind-the-meter (BTM) energy storage systems, including an estimate of cost savings for time-of-use and/or net-metering customers. It features a 'Get started' button. The top right of the main window shows the 'Sandia National Laboratories' logo. The top bar includes 'home', 'about', and 'settings' links. A copyright notice at the bottom states: 'Copyright 2018 National Technology & Engineering Solutions of Sandia, LLC (NTESS). Under the terms of Contract DE-NA0003525 with NTESS, the U.S. Government retains certain rights in this software.'

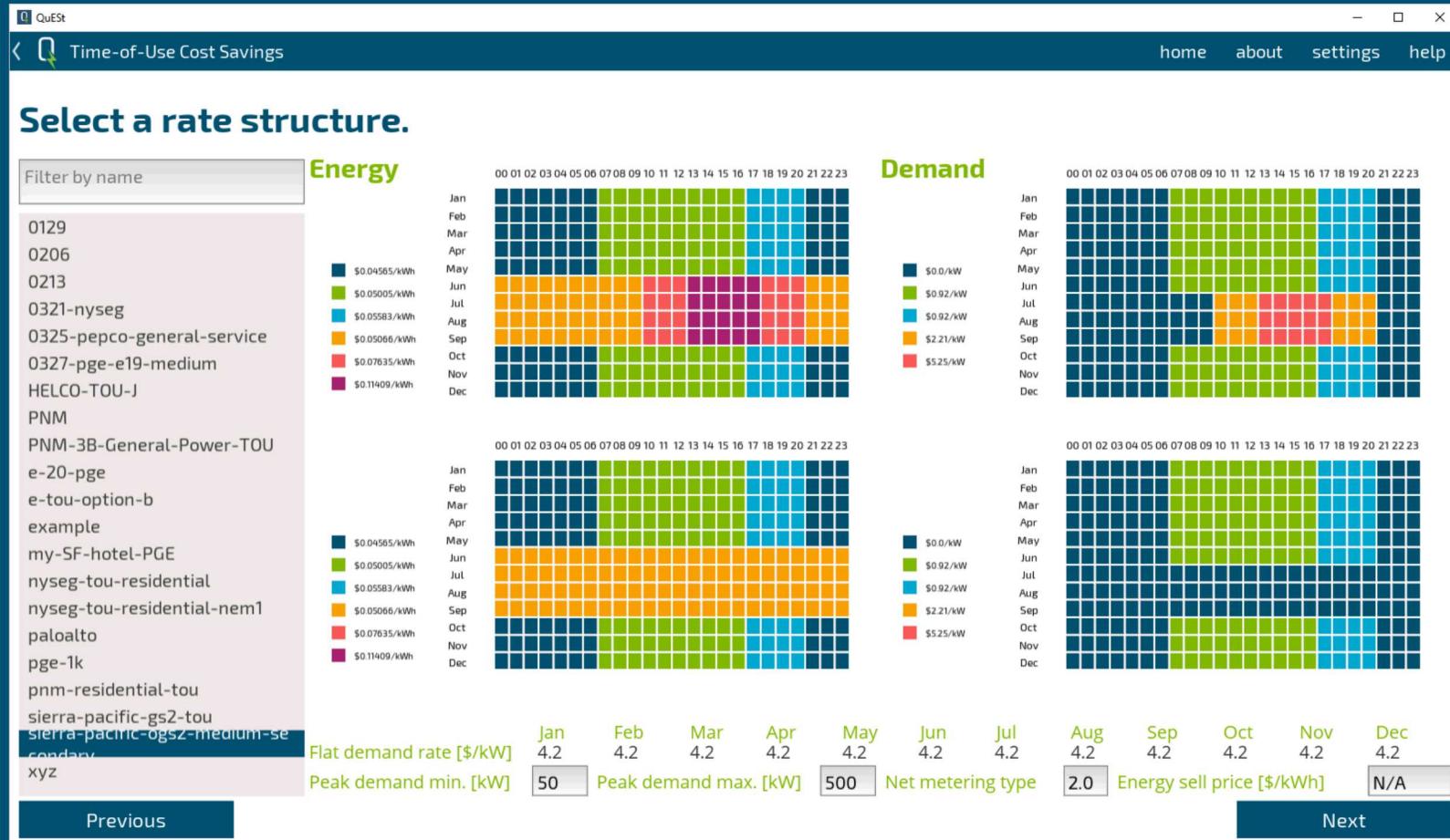
- Now that we have all the data that we need, we can return home and start using QuEST BTM for the analysis.
- We'll use the Time-of-Use Cost Savings wizard.

# CASE STUDY: MID-SIZE OFFICE BUILDING WITH PV+STORAGE



- Now that we have all the data that we need, we can return home and start using QuEST BTM for the analysis.
- We'll use the Time-of-Use Cost Savings wizard.

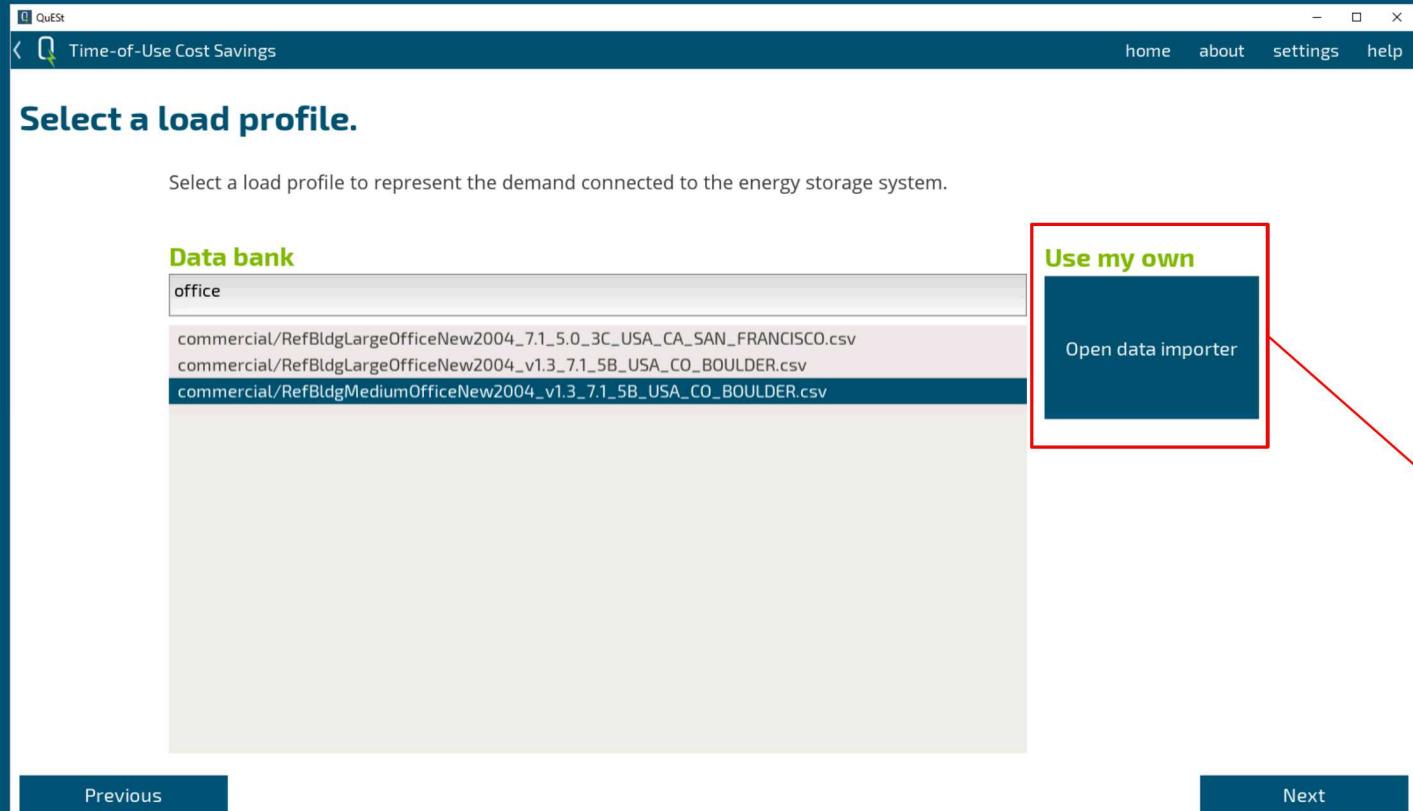
# CASE STUDY: MID-SIZE OFFICE BUILDING WITH PV+STORAGE



- Proceeding through the wizard, we select the data that we had just downloaded when prompted.

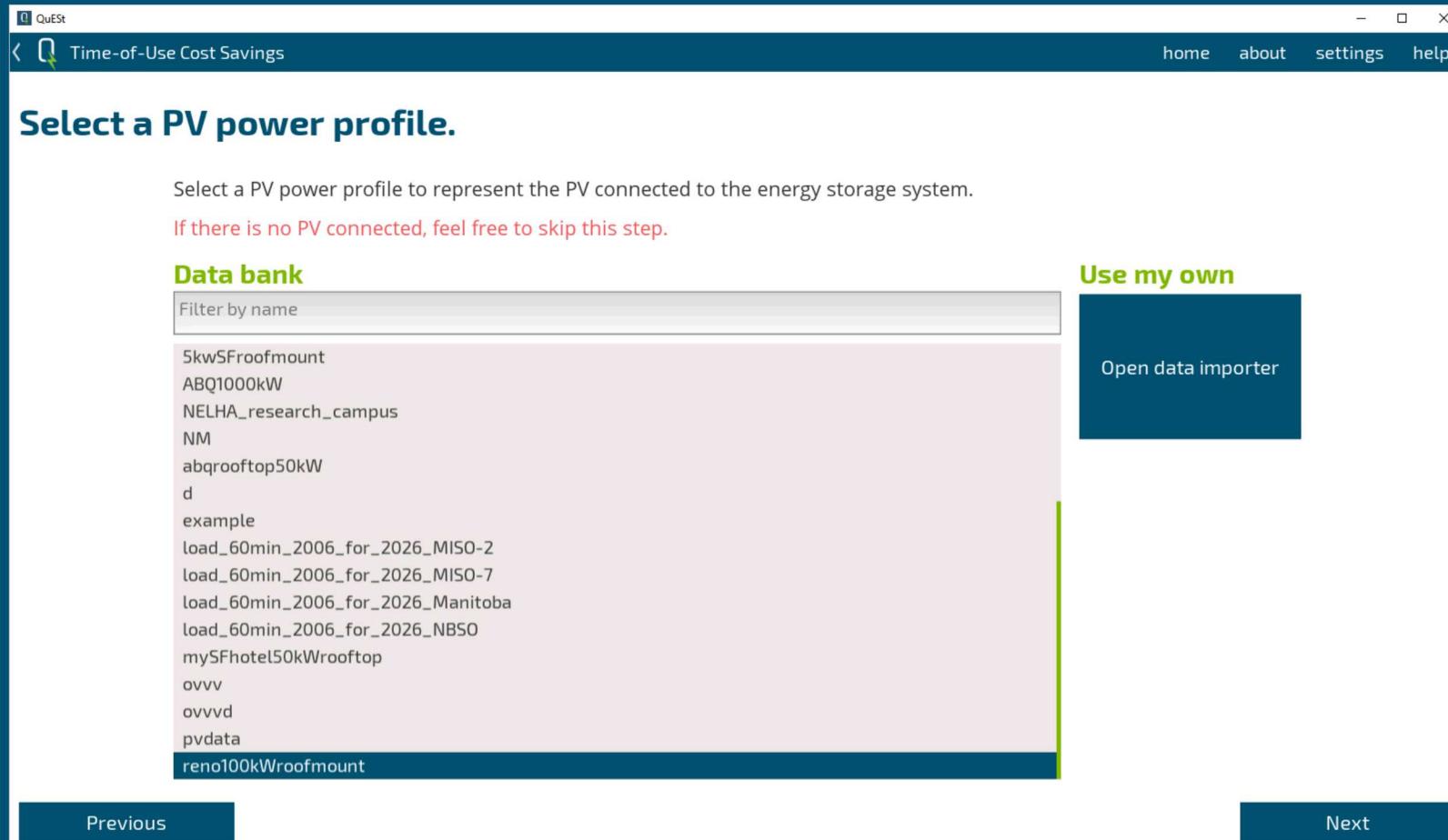
- Our proposed energy storage system is 320 kWh/80 kW, so we'll enter that in.

# CASE STUDY: MID-SIZE OFFICE BUILDING WITH PV+STORAGE



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# CASE STUDY: MID-SIZE OFFICE BUILDING WITH PV+STORAGE



- Proceeding through the wizard, we select the data that we had just downloaded when prompted.
- Our proposed energy storage system is 320 kWh/80 kW, so we'll enter that in.

QuEST

Time-of-Use Cost Savings

home about settings help

Specify the energy storage system parameters.

<b>energy capacity</b>	The maximum amount of energy that the ESS can store.	320	kWh
<b>power rating</b>	The maximum rate at which the ESS can charge or discharge energy.	80	kW
<b>transformer rating</b>	The maximum amount of power that can be exchanged.	1000000	kW
<b>self-discharge efficiency</b>	The percentage of stored energy that the ESS retains on an hourly basis.	100	%/h
<b>round trip efficiency</b>	The percentage of energy charged that the ESS actually retains.	85	%
<b>minimum state of charge</b>	The minimum ESS state of charge as a percentage of energy capacity.	0	%
<b>maximum state of charge</b>	The maximum ESS state of charge as a percentage of energy capacity.	100	%
<b>initial state of charge</b>	The percentage of energy capacity that the ESS begins with.	50	%

Previous

Next

- Proceeding through the wizard, we select the data that we had just downloaded when prompted.
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# CASE STUDY: MID-SIZE OFFICE BUILDING WITH PV+STORAGE

QuEST  
Time-of-Use Cost Savings

home about settings help

### Summary of selections.

**Rate Structure:**  
sierra-pacific-ogs2-medium-secondary  
Sierra Pacific Power Co  
OGS-2 TOU - Optional Medium General Service Time of Use - Secondary

**System Parameters:**  
initial state of charge: 50 %  
maximum state of charge: 100 %  
minimum state of charge: 0 %  
round trip efficiency: 85 %  
self-discharge efficiency: 100 %/h  
transformer rating: 1000000 kW  
power rating: 80 kW  
energy capacity: 320 kWh

**Load Profile:**  
commercial/RefBldgMediumOfficeNew2004\_v1.3\_7.1\_5B\_USA\_CO\_BOULDER.csv

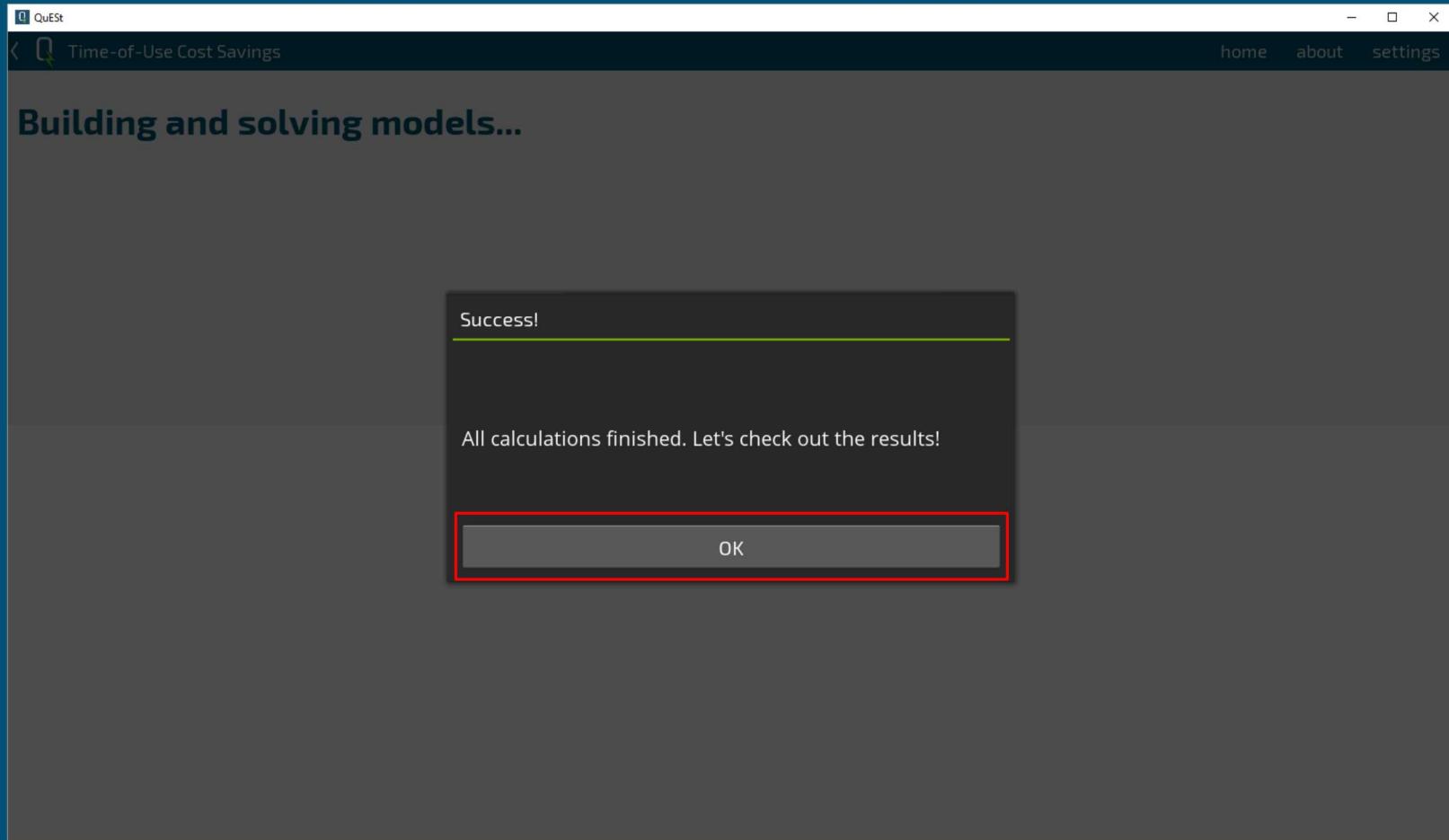
**PV Profile:**  
Location: 39.527, -119.822  
System Capacity: 100 kW  
Azimuth: 180 deg  
Tilt: 39.527 deg  
Array Type: Fixed (roof mounted)  
Module Type: Standard  
System Losses: 14%

Previous

Next

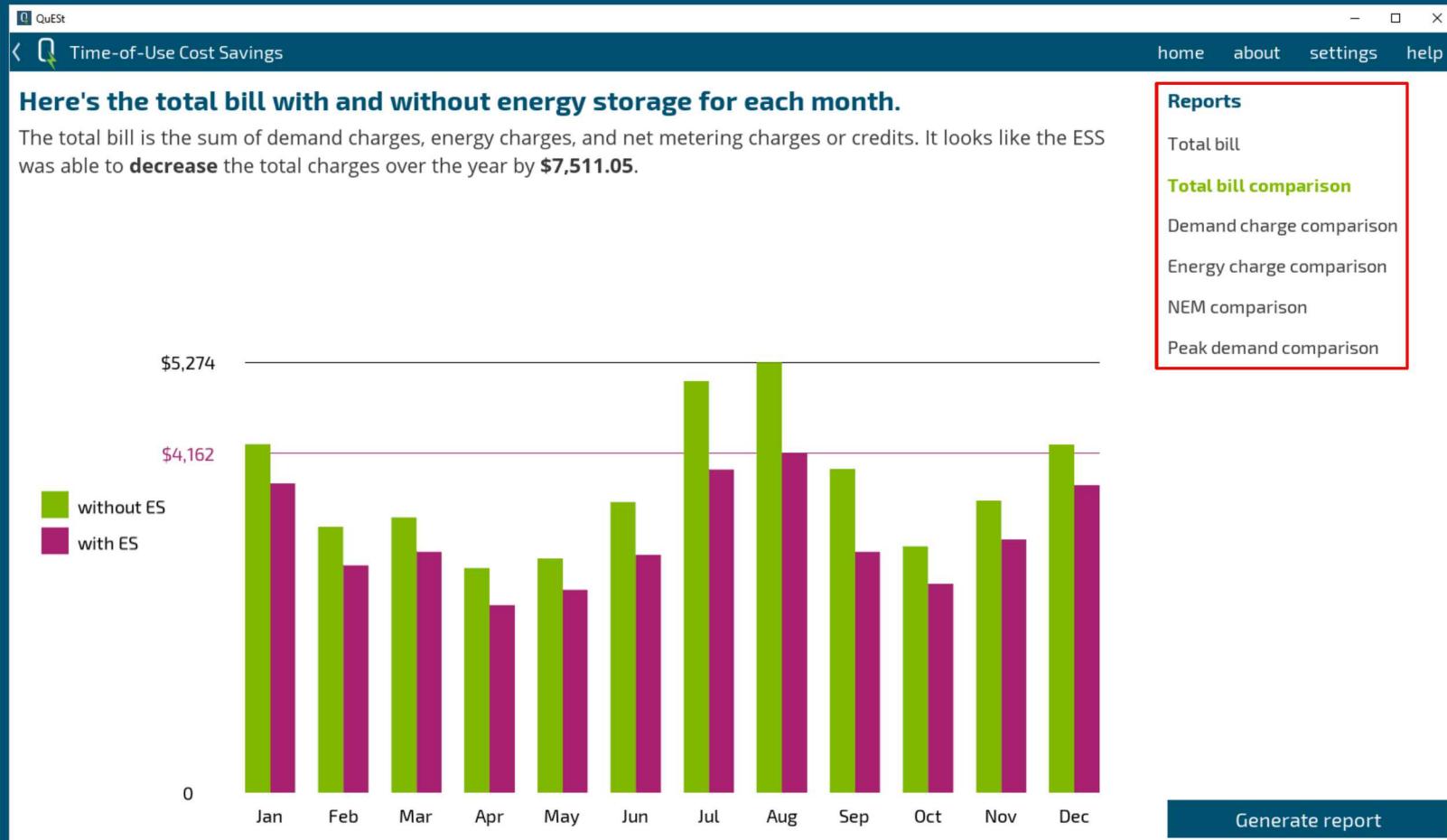
- Once everything's setup, we'll click "Next" to initiate the model building and solution process.
- In the background, the specified data is being loaded, the optimization models are being constructed, and the models are being solved.
- After a brief wait, a prompt will notify you that the computation is complete.

# CASE STUDY: MID-SIZE APARTMENT BUILDING WITH PV+STORAGE



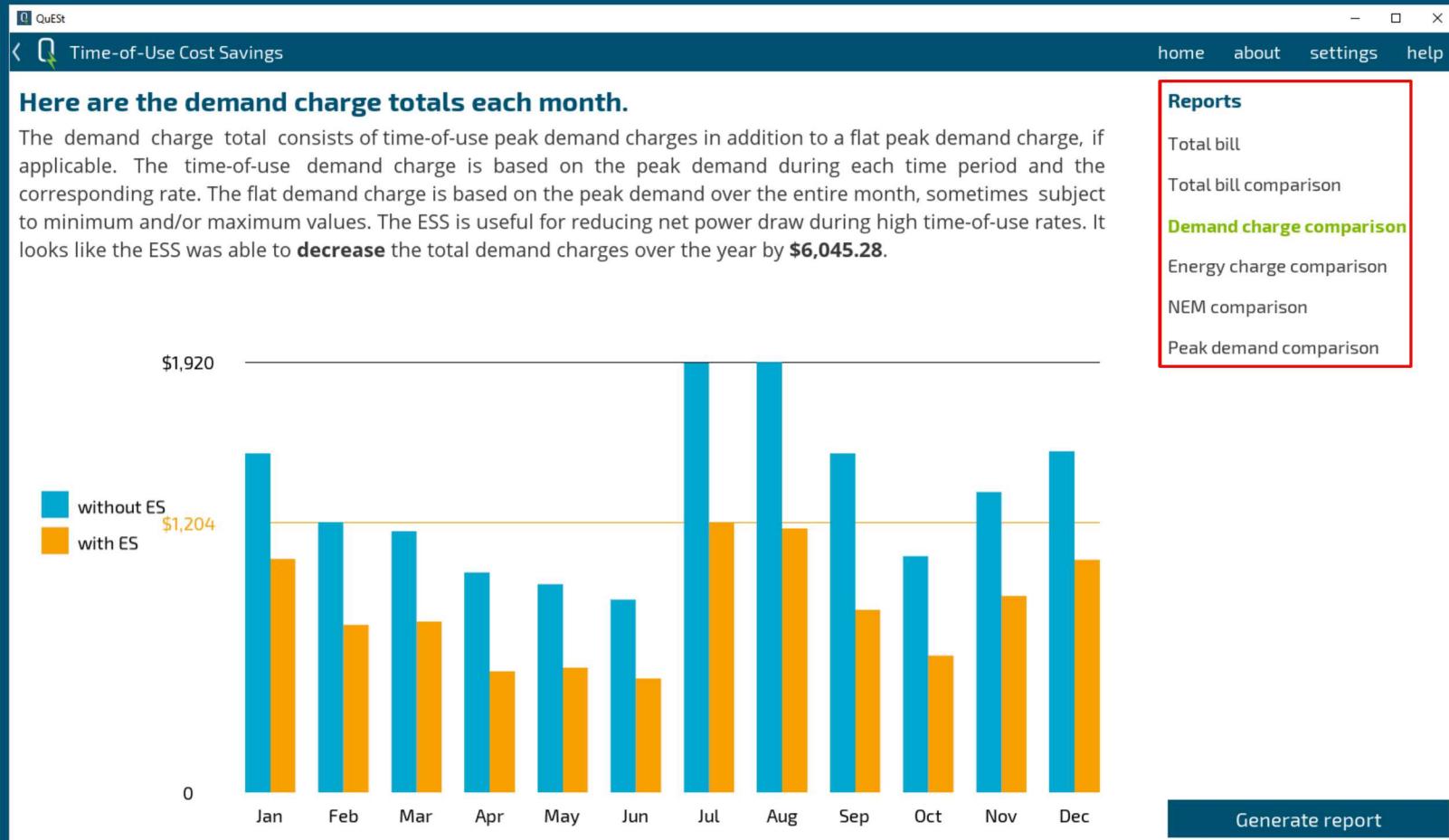
- Once everything's setup, we'll click "Next" to initiate the model building and solution process.
- In the background, the specified data is being loaded, the optimization models are being constructed, and the models are being solved.
- After a brief wait, a prompt will notify you that the computation is complete.

# CASE STUDY: MID-SIZE OFFICE BUILDING WITH PV+STORAGE



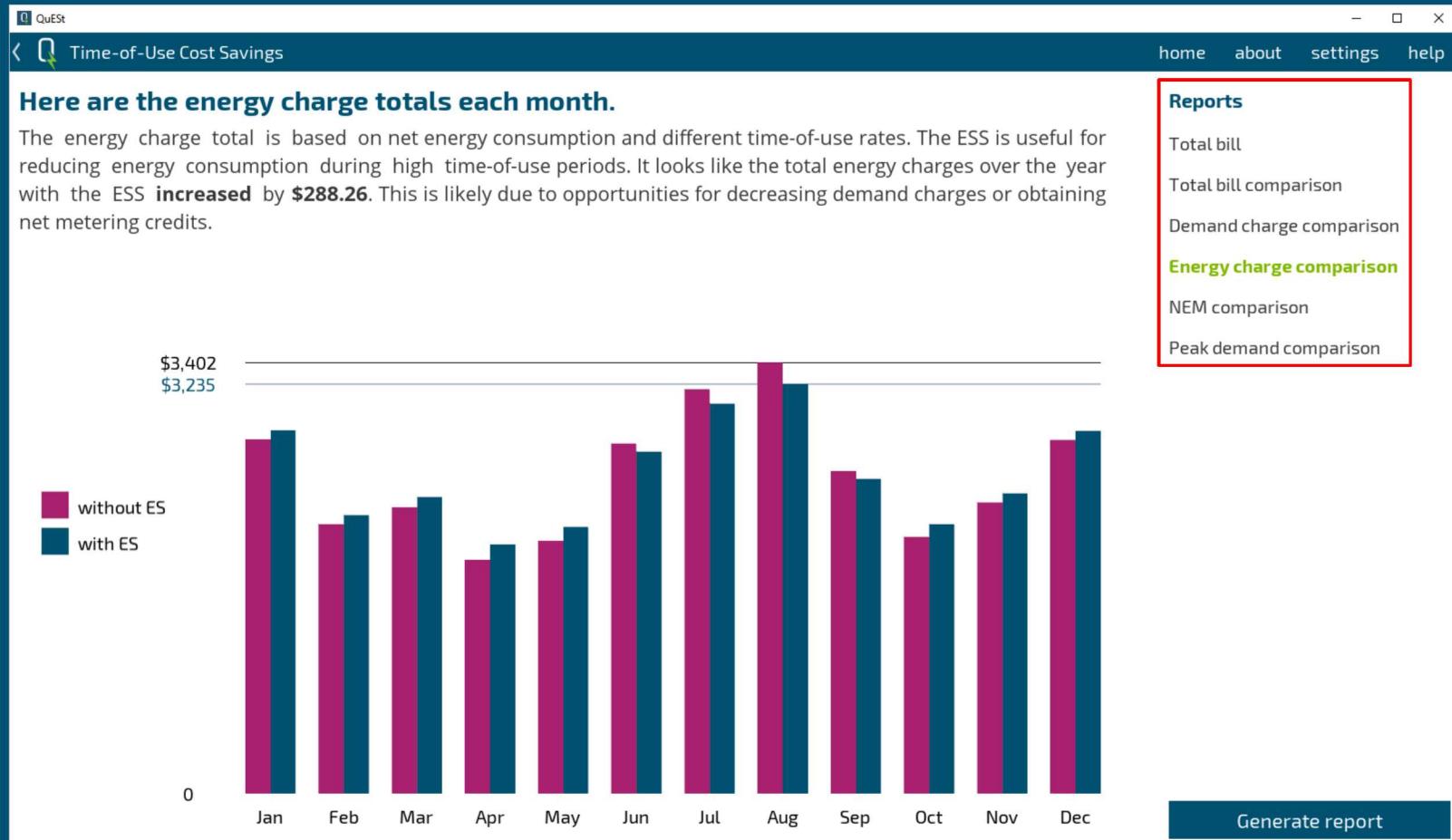
- We can now view the wizard's report of results and view several summary graphics.
- Based on the calculations, the addition of the energy storage system reduced annual charges by about \$7,511.
- This was mostly due to demand charge reduction.
- Peak demand each month was reduced by about 80 kW.

# CASE STUDY: MID-SIZE OFFICE BUILDING WITH PV+STORAGE



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# CASE STUDY: MID-SIZE OFFICE BUILDING WITH PV+STORAGE



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# CASE STUDY: MID-SIZE OFFICE BUILDING WITH PV+STORAGE



- We can also create a summary report that includes formulation details and the results.



**Quest**

Behind-the-Meter Energy Storage Cost Savings Report

Autogenerated using QuEST BTM

January 16, 2020

This report shows the results from optimizations performed by QuEST BTM.

**Scenario Summary**

**Utility:** Sierra Pacific Power Co

**Rate Structure:** OGS-2 TOU - Optional Medium General Service Time of Use - Secondary

**Load Profile:** commercial/RefBldgMediumOfficeNew2004\_v1.3\_7.1\_5B\_USA\_CO\_BOULDER.csv

**Photovoltaic Power Profile**

Location: 39.527, -119.822  
System Capacity: 100 kW  
Azimuth: 180 deg  
Tilt: 39.527 deg  
Array Type: Fixed (roof mounted)  
Module Type: Standard  
System Losses: 14%

**Energy Storage System Parameters**

Parameter	Value	Units
initial state of charge	50	%
maximum state of charge	100	%
minimum state of charge	0	%
round trip efficiency	85	%
self-discharge efficiency	100	%/h
transformer rating	1000000	kW
power rating	80	kW
energy capacity	320	kWh

Table 1: Energy Storage Device Characteristics

- We can also create a summary report that includes formulation details and the results.

## CASE STUDY: MID-SIZE APARTMENT BUILDING WITH PV+STORAGE

We can retry the wizard with different energy storage system parameters. Or we can try different PV/load profiles, rate structures, etc.

Is the energy storage system worth it? It will depend on the financials of acquiring and operating it... but we have an estimate on its performance value potential.



- Develop new applications and enhance existing ones
  - Integrated resource planning tools to meet RPS
  - Optimizing with costs
  - Implement different charging schemes to satisfy ITC requirements
  - Resilience applications
  - T&D deferral
  - More value streams
  - RFP templates
- Release API/Library
- Webinars, tutorials, workshops
- Integrate user feedback and requests



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<https://www.sandia.gov/ess-ssl/tools/quest/>

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### Follow us on GitHub:

[github.com/rconcep/snl-quest](https://github.com/rconcep/snl-quest)