

# Energy Storage Technology Advancement Partnership (ESTAP) Webinar

## QuEST: Optimizing Energy Storage Tool

*Hosted by*  
Seth Mullendore  
Clean Energy States Alliance

November 6, 2019



U.S. DEPARTMENT OF  
**ENERGY**

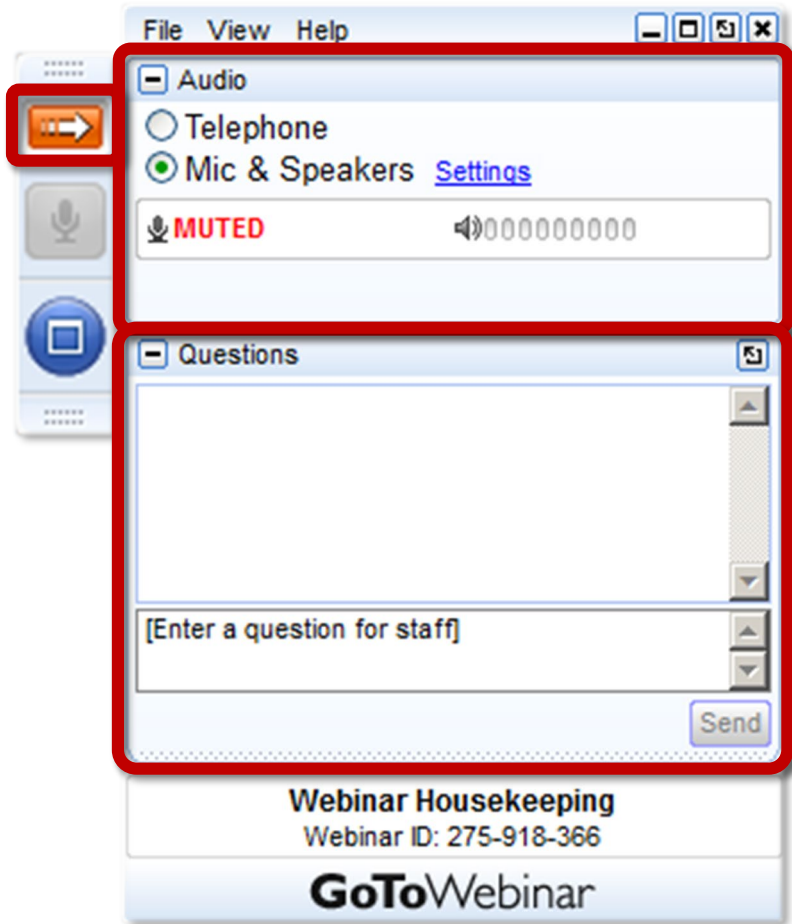


**CleanEnergy**  
States Alliance



**Sandia**  
National  
Laboratories

# Housekeeping



## Join audio

- Choose Mic & Speakers to use VoIP
- Choose Telephone and dial using the information provided

Click on the orange box with the arrow to open and close your control panel

Submit questions and comments via the Questions panel

This webinar is being recorded. We will email you a webinar recording within 48 hours. This webinar will be posted on CESA's website at [www.cesa.org/webinars](http://www.cesa.org/webinars)

# CleanEnergy States Alliance



# Energy Storage Technology Advancement Partnership (ESTAP) ([bit.ly/ESTAP](http://bit.ly/ESTAP))

ESTAP is supported by the U.S. Department of Energy Office of Electricity and Sandia National Laboratories, and is managed by CESA.

## ESTAP Key Activities:

### 1. Disseminate information to stakeholders

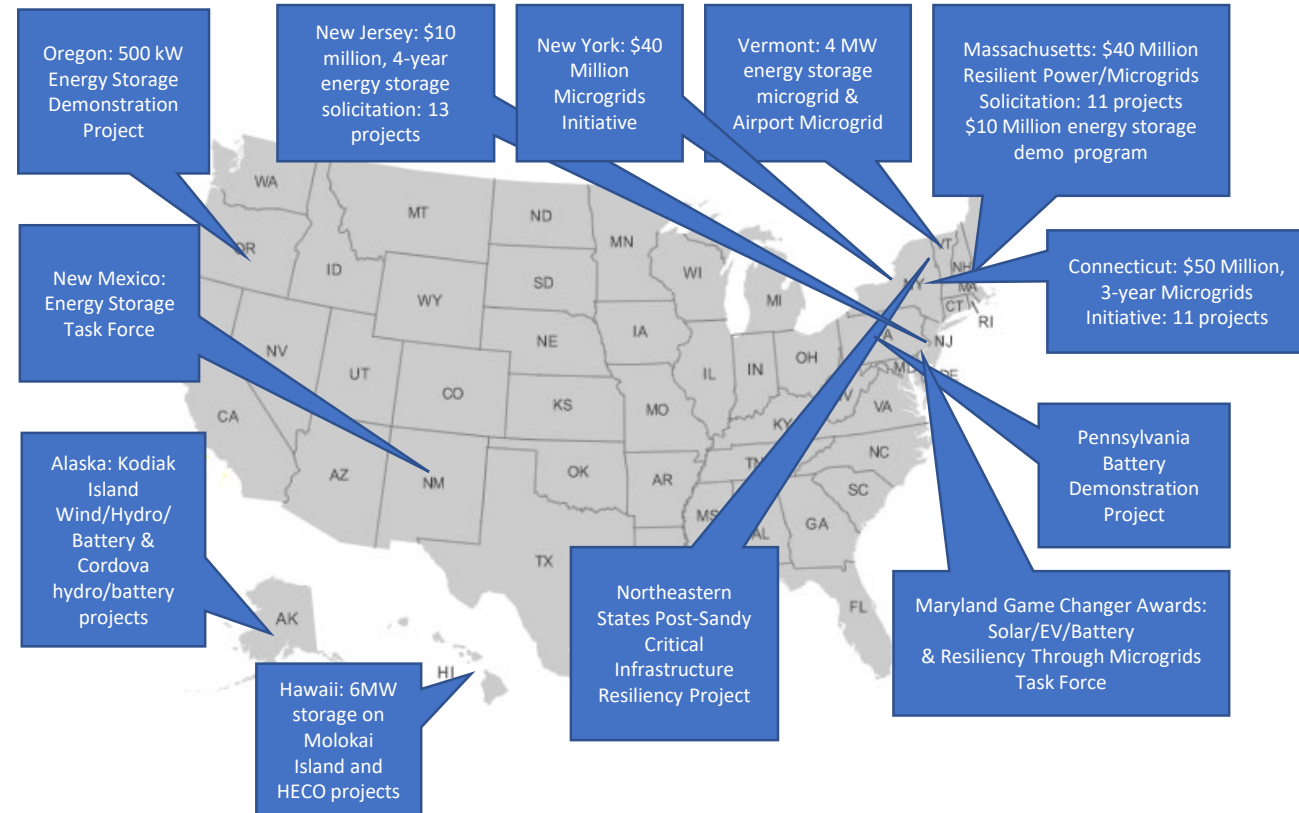
- ESTAP listserv >5,000 members
- Webinars, conferences, information updates, surveys.

### 2. Facilitate public/private partnerships to support joint federal/state energy storage demonstration project deployment

### 3. Support state energy storage efforts with technical, policy and program assistance



## ESTAP Project Locations:





# Webinar Speakers



**Ricky Concepcion**  
Sandia National  
Laboratories



**Tu Nguyen**  
Sandia National  
Laboratories



**Seth Mullendore**  
Clean Energy States  
Alliance (moderator)



# Thank you for attending our webinar

Seth Mullendore  
Project Director, CESA  
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Find us online:

[www.cesa.org](http://www.cesa.org)

[facebook.com/cleanenergystates](https://facebook.com/cleanenergystates)

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# Upcoming Webinar

## **Energy Storage 101: Part 3 – Applications and Economics**

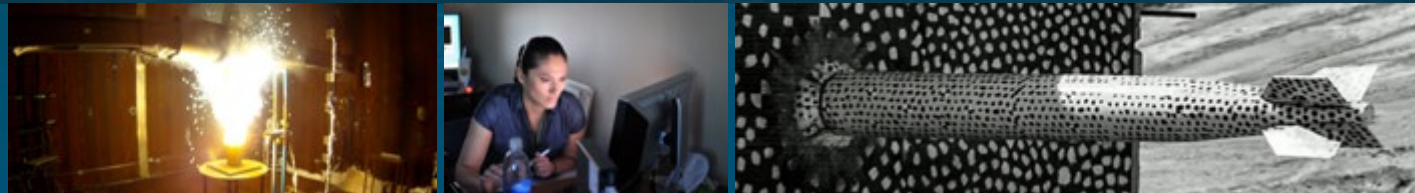
*Tuesday, November 19, 2019 at 1-2 pm ET*

This ESTAP webinar will look at when and where energy storage opportunities exist, which services can be effectively “stacked,” how revenue-generating opportunities are sometimes limited due to market rules or utility tariffs, and what future opportunities might arise with changes in market rules and regulations.

Learn more and register at: [www.cesa.org/webinars](http://www.cesa.org/webinars)

# Quest

## An Energy Storage Application Suite



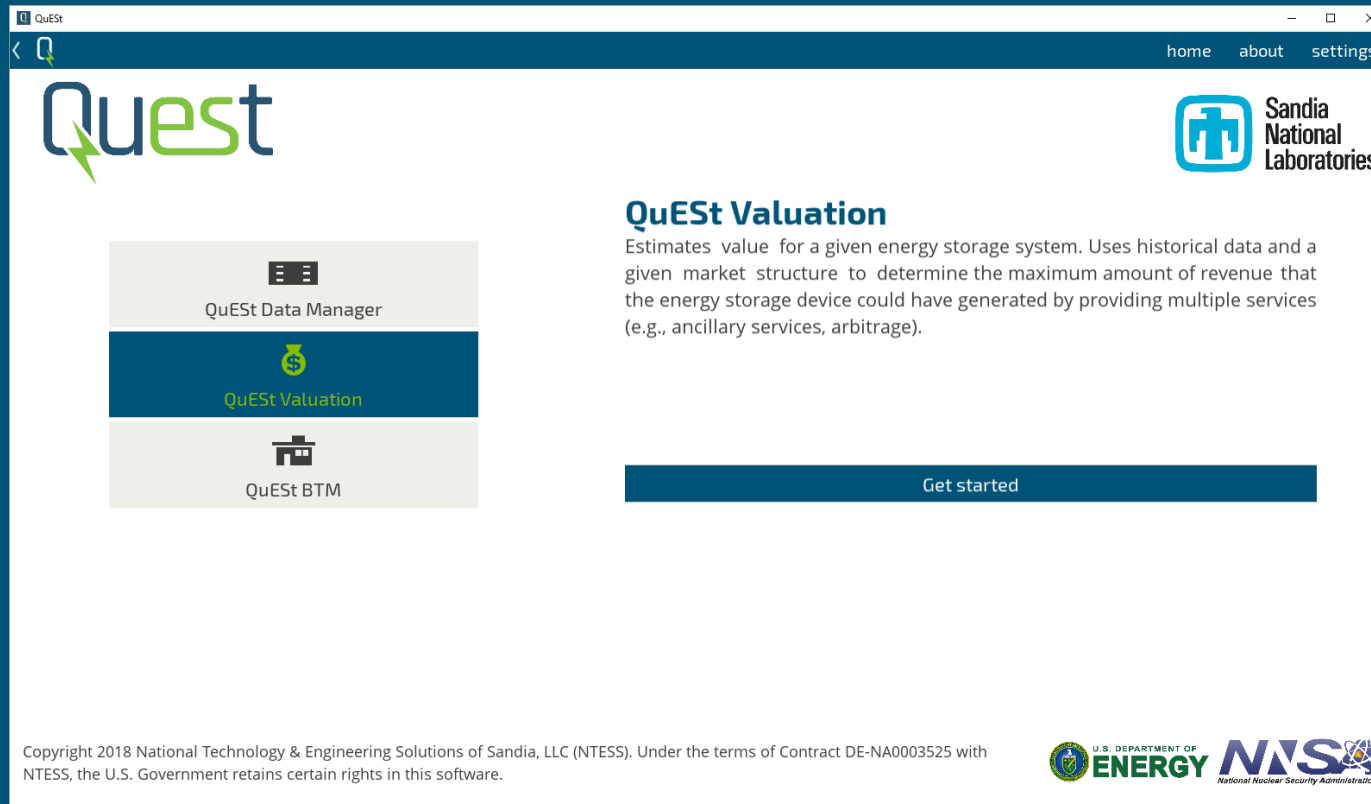
PRESENTED BY

Ricky Concepcion, Tu Nguyen





- QuEST overview
- How to obtain QuEST
- QuEST applications
  - QuEST Valuation
  - QuEST Data Manager
  - QuEST BTM
- Behind-the-meter energy storage systems
- Case study with QuEST: cost savings for large hotel with solar + storage
- Wrap-up and conclusions

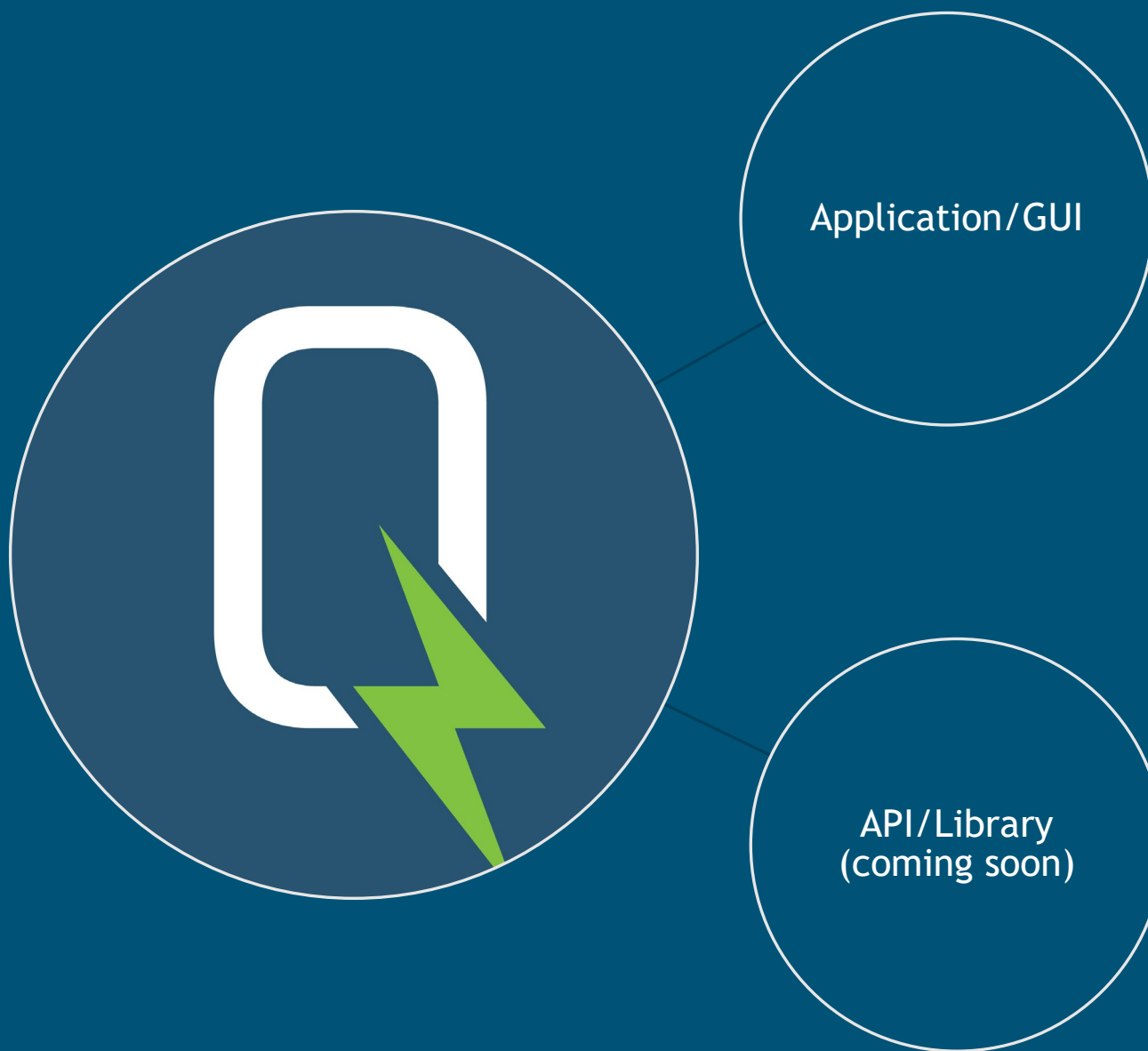


- Energy storage analysis software application suite
- Developed as a graphical user interface (GUI) for the optimization modeling capabilities of Sandia's energy storage analytics group
- Version 1.0 publicly released in September 2018
- Version 1.2 available on GitHub
  - [github.com/rconcep/snl-quest](https://github.com/rconcep/snl-quest) or [sandia.gov/ess](https://sandia.gov/ess) (tools)

## WHY QUEST?



- For energy storage project stakeholders
  - Accessible and easy-to-use software tool for energy storage valuation
- For engineers and software developers
  - Open source software project
  - GUI design, application design, Pyomo optimization modeling
  - Pyomo models and other code can be adjusted to fit specific needs
- 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





- 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

[Pull requests](#)
[Issues](#)
[Marketplace](#)
[Explore](#)

[rconcept / snl-quest](#)

[Unwatch](#)
6

[Star](#)
23

[Fork](#)
5

[Code](#)
[Issues 6](#)
[Pull requests 0](#)
[Projects 0](#)
[Wiki](#)
[Insights](#)
[Settings](#)

An open source, Python-based software application suite for energy storage simulation and analysis developed by Sandia National Laboratories.

[energy-storage](#)
[pyomo](#)
[kivy](#)
[sandia-national-laboratories](#)
[optimization](#)
[python](#)
[Manage topics](#)

100 commits
 2 branches
 5 releases
 2 contributors
 [View license](#)

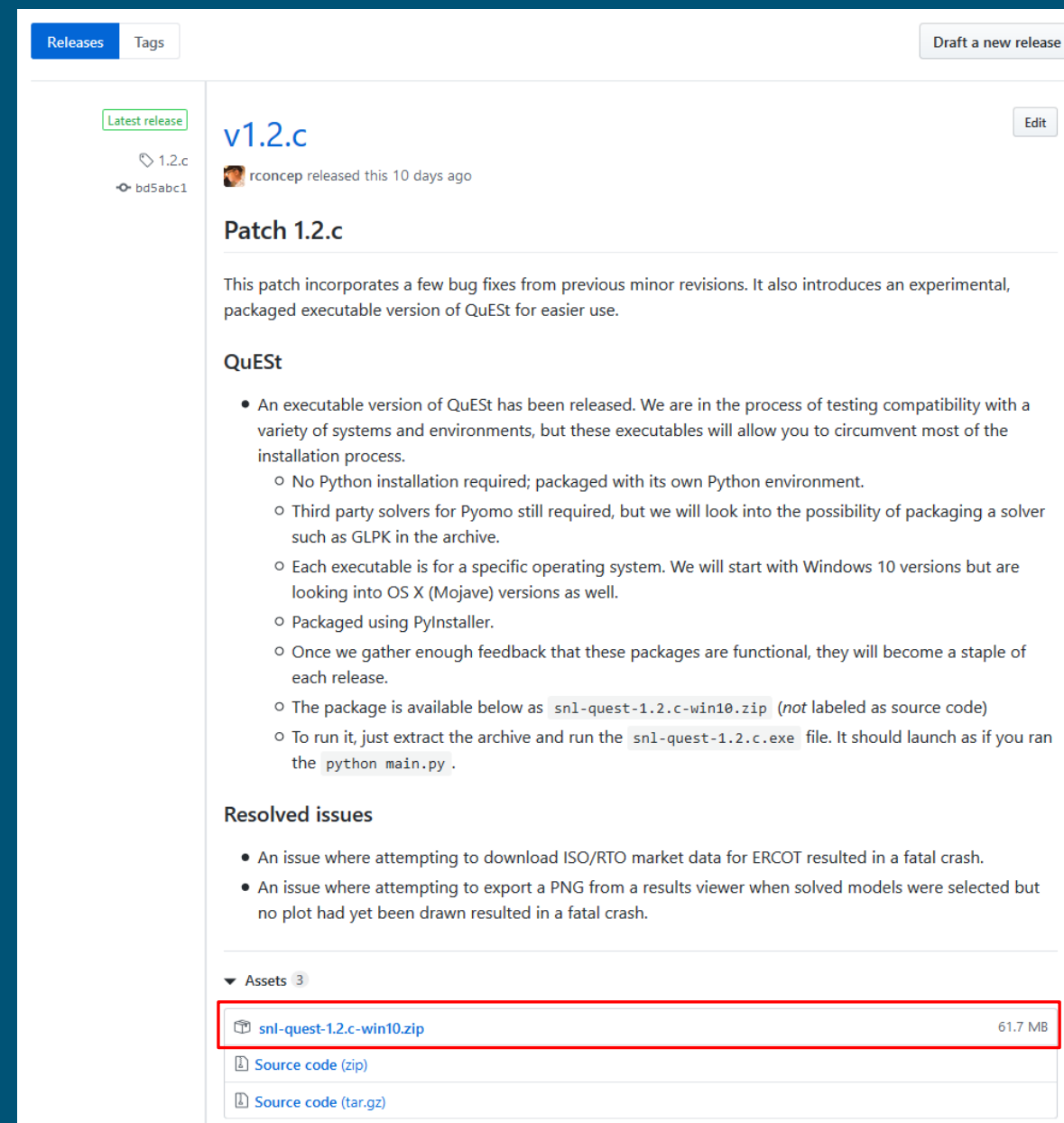
Branch: [master](#)
[New pull request](#)

[Create new file](#)
[Upload files](#)
[Find File](#)
[Clone or download](#)

rconcept Added notes to document typo fix and incremented patch number Latest commit bd5abc1 10 days ago		
docs/ValuationOptimizer	Updating ValOp docs and report templates notation	8 months ago
es_gui	Fixed a typo in the ERCOT data downloader routine	10 days ago
libs/garden/garden.matplotlib	Fixed kivy garden packaging	6 months ago
licenses	About and license for holidays package	3 months ago
patch_note_resources	Fixed results viewer export png fatal crash.	12 days ago
results	Saving chart figures for btm_cost_savings reports	3 months ago
.gitignore	Sorting results: rate structure period check bug	2 months ago
CHANGELOG.md	Added notes to document typo fix and incremented patch number	10 days ago
LICENSE	first commit	8 months ago
QuESt.kv	Reverted change to series.to_numpy() from series.values and updated i...	2 months ago
README.md	Added notes to document typo fix and incremented patch number	10 days ago
main.py	Added notes to document typo fix and incremented patch number	10 days ago
setup.py	Reverted change to series.to_numpy() from series.values and updated i...	2 months ago

# 7 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



The screenshot shows the GitHub release page for version v1.2.c of the QuEst project. The page is titled "v1.2.c" and indicates it was released 10 days ago by user rconcep. A "Patch 1.2.c" section describes the release, noting it includes bug fixes and an experimental packaged executable version. The "QuEst" section lists details about the executable version, including its compatibility with various systems and environments, and provides instructions on how to run it. The "Resolved issues" section lists two bugs that have been fixed. At the bottom, the "Assets" section lists three files: "snl-quest-1.2.c-win10.zip" (61.7 MB), "Source code (zip)", and "Source code (tar.gz)". The "snl-quest-1.2.c-win10.zip" file is highlighted with a red box.

Releases Tags Draft a new release

Latest release

1.2.c  
bd5abc1

v1.2.c

rconcep released this 10 days ago

Patch 1.2.c

This patch incorporates a few bug fixes from previous minor revisions. It also introduces an experimental, packaged executable version of QuEst for easier use.

QuEst

- An executable version of QuEst has been released. We are in the process of testing compatibility with a variety of systems and environments, but these executables will allow you to circumvent most of the installation process.
  - No Python installation required; packaged with its own Python environment.
  - Third party solvers for Pyomo still required, but we will look into the possibility of packaging a solver such as GLPK in the archive.
  - Each executable is for a specific operating system. We will start with Windows 10 versions but are looking into OS X (Mojave) versions as well.
  - Packaged using PyInstaller.
  - Once we gather enough feedback that these packages are functional, they will become a staple of each release.
  - The package is available below as `snl-quest-1.2.c-win10.zip` (not labeled as source code)
  - To run it, just extract the archive and run the `snl-quest-1.2.c.exe` file. It should launch as if you ran the `python main.py`.

Resolved issues

- An issue where attempting to download ISO/RTO market data for ERCOT resulted in a fatal crash.
- An issue where attempting to export a PNG from a results viewer when solved models were selected but no plot had yet been drawn resulted in a fatal crash.

Assets 3

snl-quest-1.2.c-win10.zip 61.7 MB

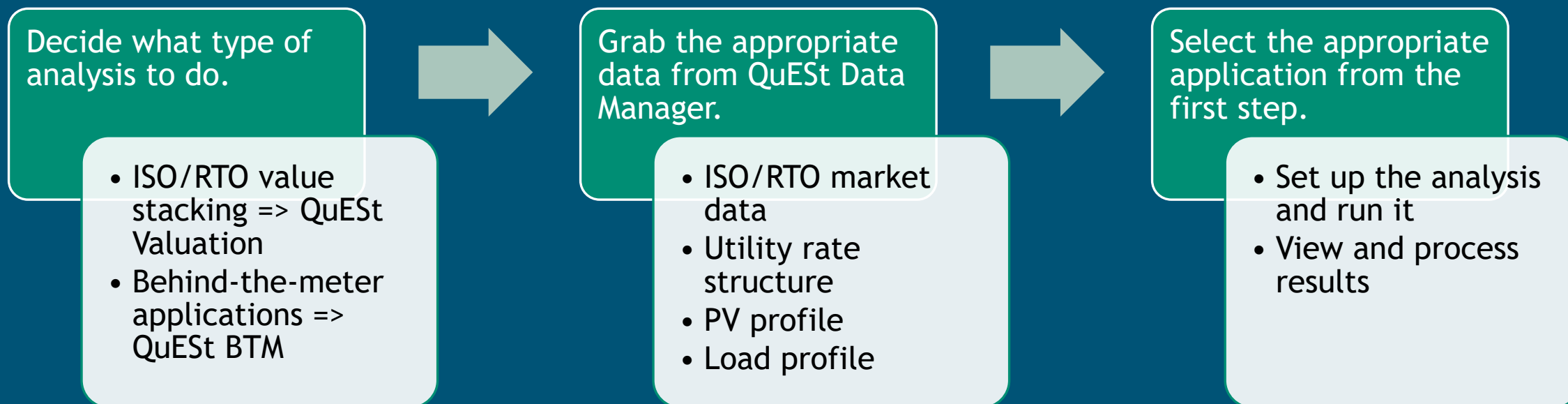
Source code (zip)

Source code (tar.gz)



# QUEST APPLICATIONS OVERVIEW

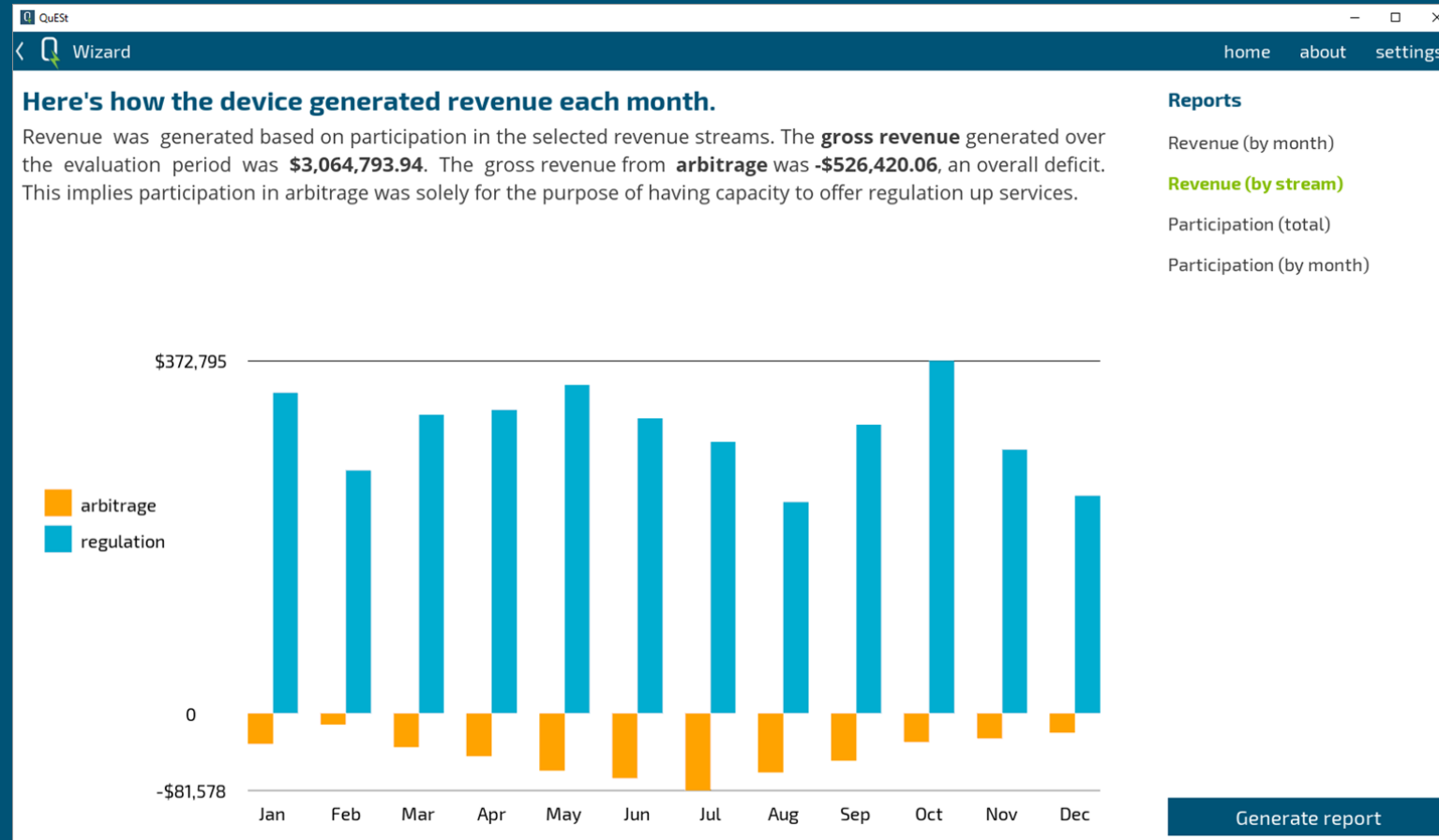
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Given an energy storage device, an electricity market with a certain payment structure, and market data, how would the device maximize the revenue generated and provide value?



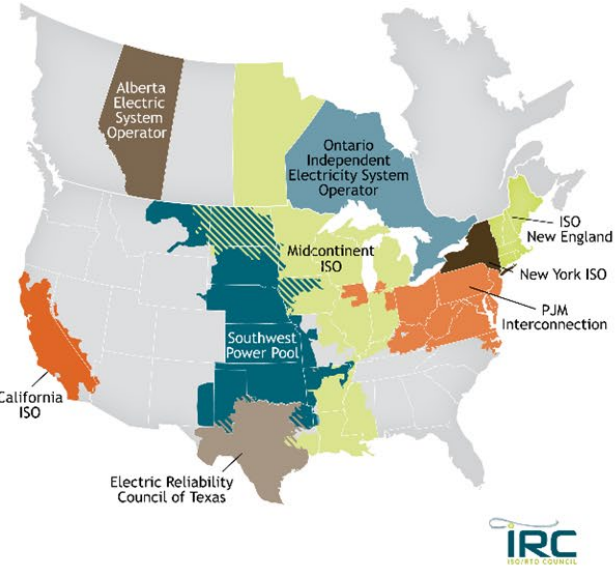
Byrne, Raymond H., et al. "Energy management and optimization methods for grid energy storage systems." *IEEE Access* 6 (2018): 13231-13260.

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

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)

100.0

90.0

24.0

36.0

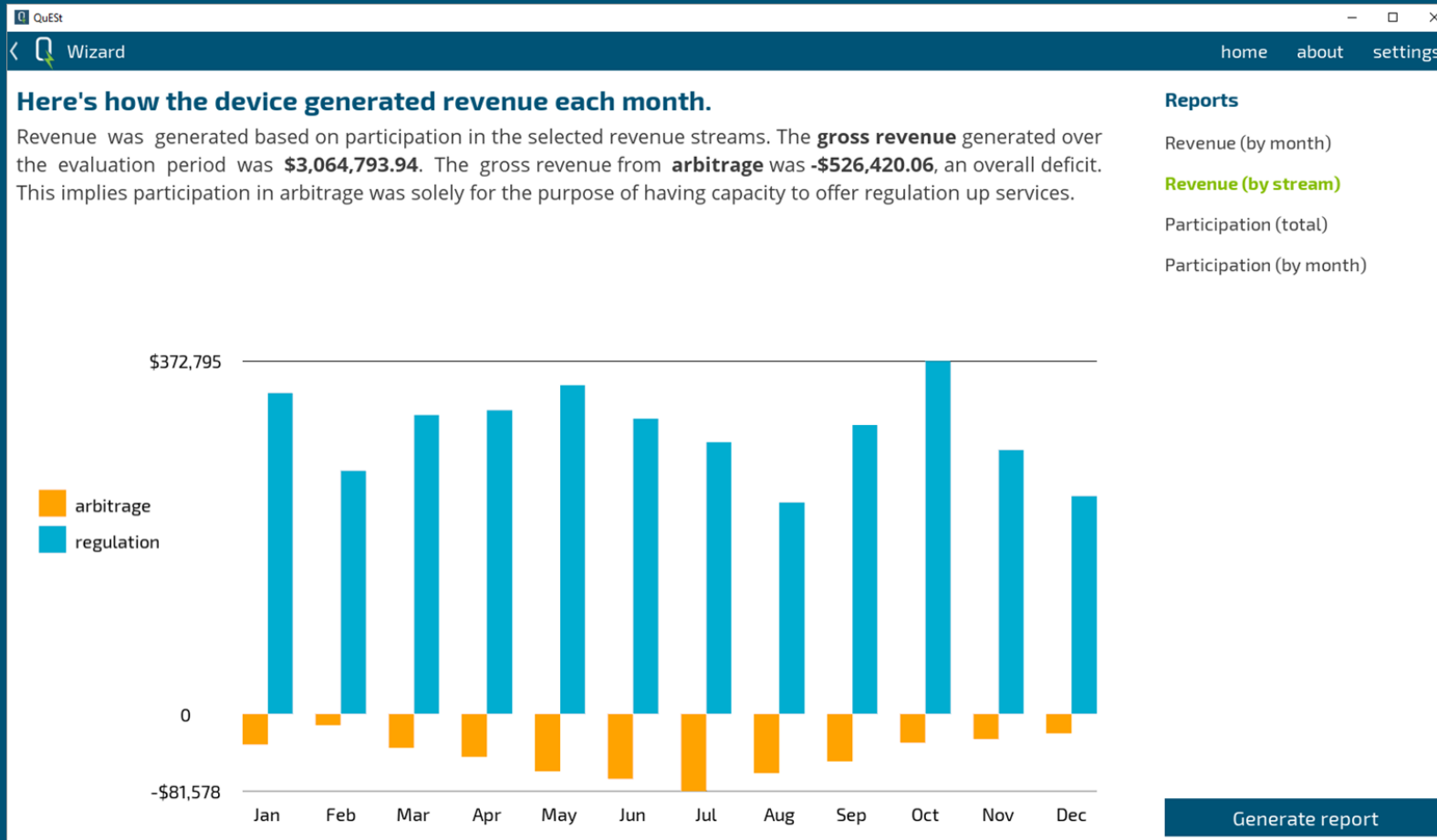
**Li-ion Battery**

Modeled after the Notrees Battery Storage Project in western TX.

Previous

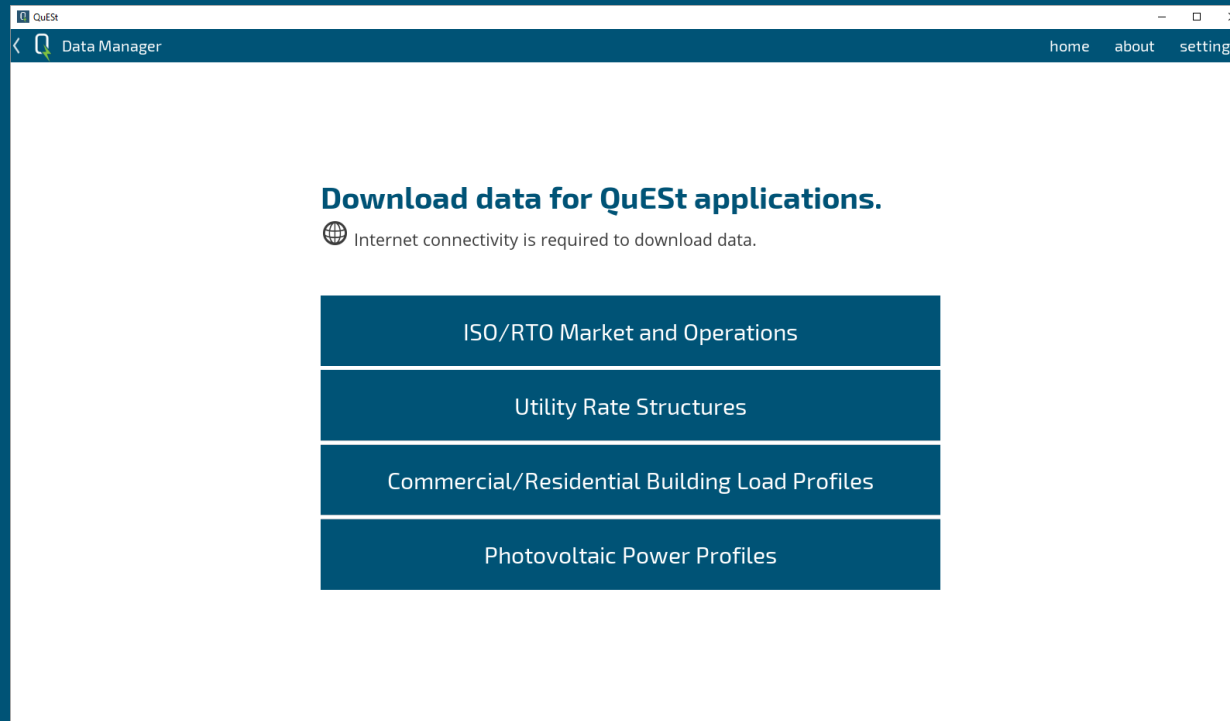
Next

- 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





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: ISO/RTO Market and Operations Data

home about settings

### Download ISO/RTO market and operations data.

SPP PJM NYISO MISO **ISO-NE** ERCOT CAISO

**ISO-NE**

Enter ISO-NE ISO Express credentials. ⓘ

Username

Password

Specify the range of months.

Start:

End:

Pricing node ID and/or types of nodes

☐ Internal Hub ☐ Zones

- LMPs, frequency regulation performance/capacity clearing prices, etc. posted by ISOs/RTOs
- Use operator-provided APIs
- Use web crawling libraries to parse marketplace data portals





QuEst

Data Manager: Utility Rate Structure Data

home about settings

### Search for a utility rate structure.

Data.gov API key  

#### Select a utility.

Filter by name

- PUD No 2 of Pacific County
- PacifiCorp
- PacifiCorp
- PacifiCorp
- PacifiCorp
- PacifiCorp
- Pacific Gas & Electric Co.**
- Sierra Pacific Power Co

#### Select a rate structure.

- E-TOU Option B - Residential Time of Use Service (All Baseline Regions) (Effective Date : 03/23/2016)
- E-TOU Option B - Residential Time of Use Service (All Baseline Regions) (Effective Date : 10/22/2017)**
- E-TOU Option B - Residential Time of Use Service (All Baseline Regions) (Effective Date : 12/30/2016)

- 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: Hourly Commercial Load Profiles

home about settings

### Download hourly load data by location and building type.

Filter by name	Filter by name	Filter by name
MI	Albuquerque Intl AP	RefBldgLargeOfficeNew2004
MN	Carlsbad Cavern City Air Terminal	RefBldgMediumOfficeNew2004
MO	Clayton Muni AP	RefBldgMidriseApartmentNew2004
MS	Clovis Muni AWOS	RefBldgOutPatientNew2004
MT	Clovis-Cannon AFB	RefBldgPrimarySchoolNew2004
NC	Deming Muni AP	RefBldgQuickServiceRestaurantNew2004
ND	Farmington-Four Corners Rgnl AP	RefBldgSecondarySchoolNew2004
NE	Gallup-Sen Clarke Field	RefBldgSmallHotelNew2004
NH	Holloman AFB	RefBldgSmallOfficeNew2004
NJ	Las Cruces Intl AP	RefBldgStand-aloneRetailNew2004
NM	Roswell Industrial Air Park	RefBldgStripMallNew2004
NV	Ruidoso-Sierra Blanca Rgnl AP	RefBldgSuperMarketNew2004
	Santa Fe County Muni AP	RefBldgWarehouseNew2004

Save

- OpenEI.org also hosts simulated hourly load profiles for a 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: Photovoltaic Power Profiles

home about settings

### Search for a photovoltaic power profile.

Data.gov API key 

latitude	The latitude of the site in the range (-90, 90).	<input type="text" value="37.78"/>	deg
longitude	The longitude of the site in the range (-180, 180).	<input type="text" value="-122.42"/>	deg
system capacity	The nameplate capacity of the photovoltaic system.	<input type="text" value="5"/>	kW
losses	The total system losses, including all sources, in the range (-5, 99).	<input type="text" value="14"/>	%
tilt angle	The tilt angle of the PV surface.	<input type="text" value="0"/>	deg
azimuth angle	The azimuth angle of the PV surface.	<input type="text" value="0"/>	deg

Standard

Fixed (roof mounted)

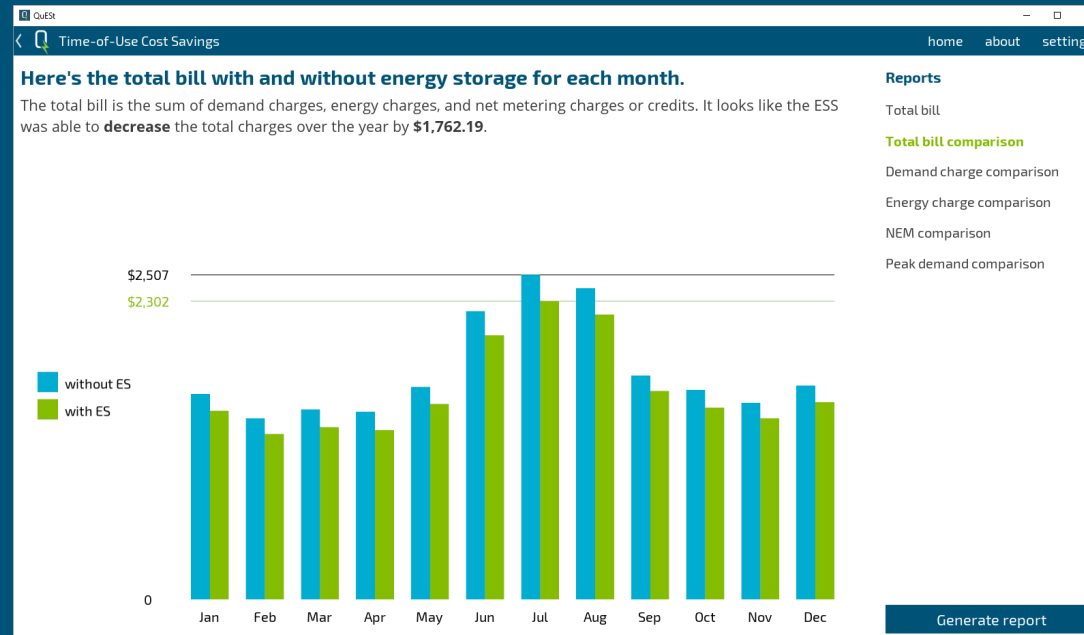
## ■ PVWatts by NREL

- 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](https://pvwatts.nrel.gov/version_6.php)

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



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.



QUEST

Time-of-Use Cost Savings

home about settings

### Select a rate structure.

Filter by name

- 0129
- 0206
- 0213
- 0321-nyseg
- 0325-pepco-general-service
- PNM
- e-tou-option-b
- example
- nyseg-tou-residential
- nyseg-tou-residential-nem1
- paloalto
- pnm-residential-tou**
- xyz

**Energy**

☐ \$0.1866117/kWh  
☐ \$0.0599494/kWh  
☐ \$0.1452852/kWh  
☐ \$0.0599494/kWh

**Demand**

☐ \$0.0/kW

Flat demand rate [\$/kW] Jan 0.0 Feb 0.0 Mar 0.0 Apr 0.0 May 0.0 Jun 0.0 Jul 0.0 Aug 0.0 Sep 0.0 Oct 0.0 Nov 0.0 Dec 0.0  
 Peak demand min. [kW]  Peak demand max. [kW]  Net metering type  Energy sell price [\$/kWh]

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



QUEST

Time-of-Use Cost Savings

home about settings

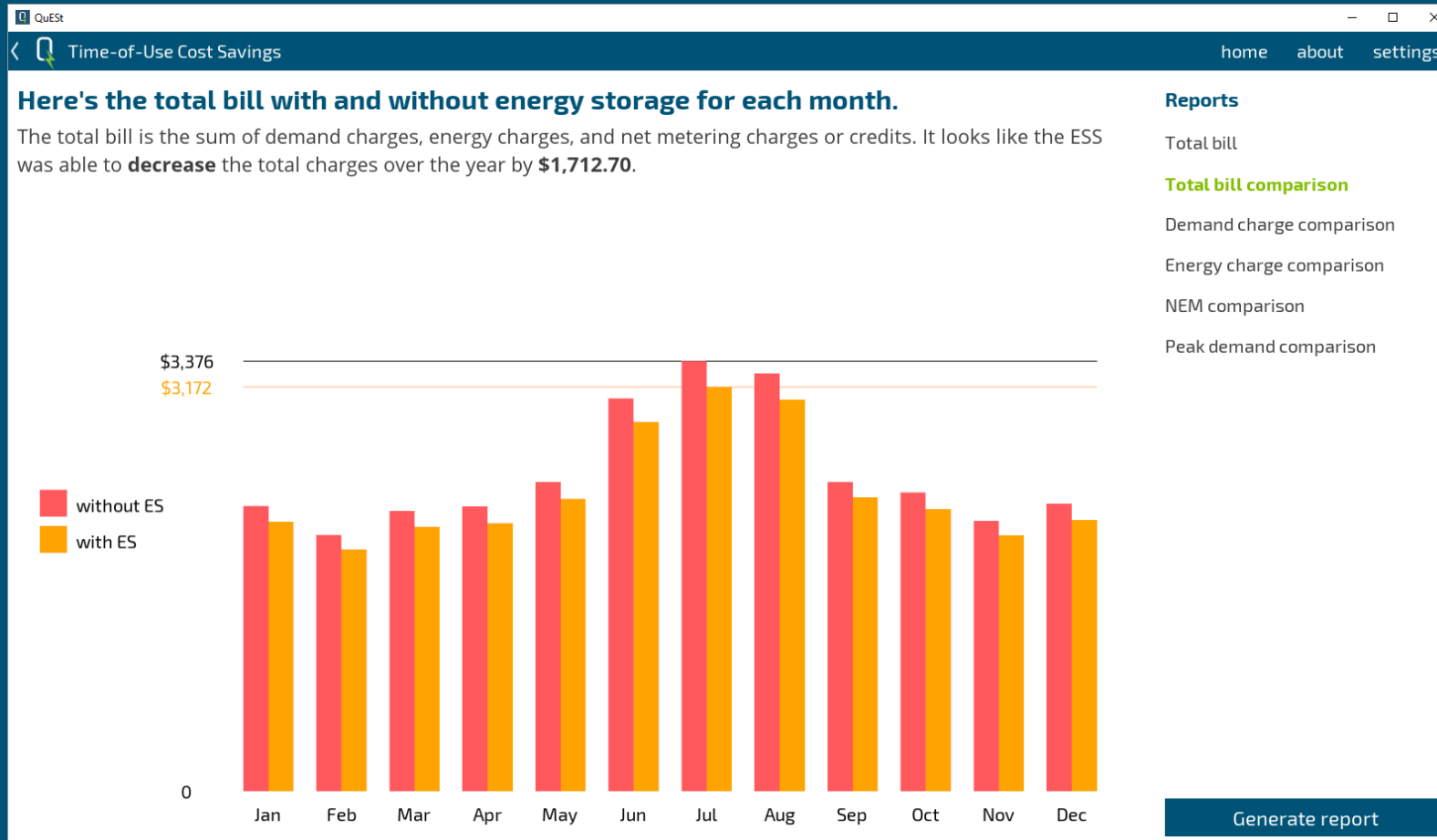
### Specify the energy storage system parameters.

<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 that 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"/>	%

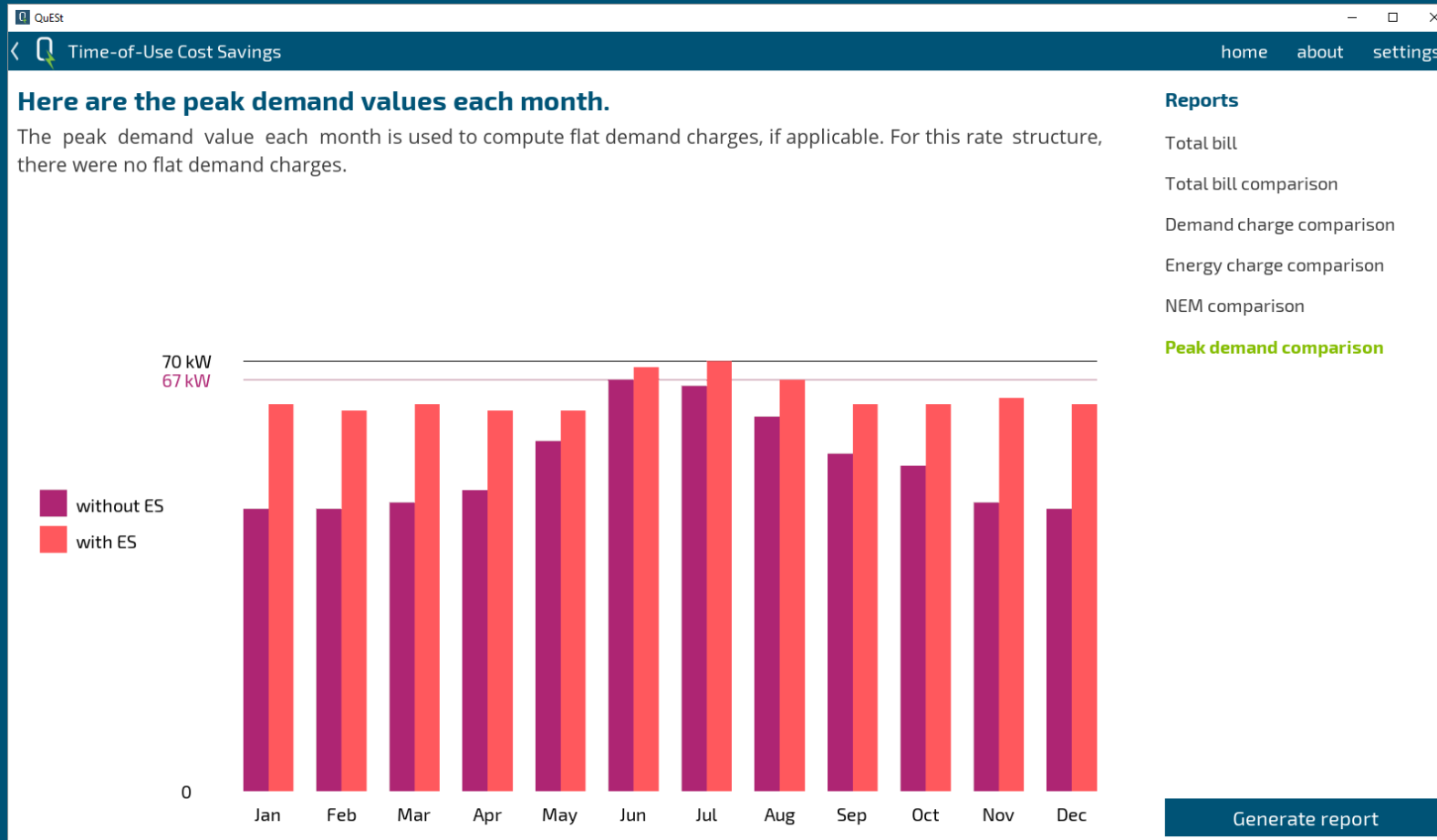
Previous

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





# BEHIND-THE-METER ENERGY STORAGE SYSTEMS OVERVIEW AND CASE STUDY



# FRONT-OF-METER VS. BEHIND-THE-METER

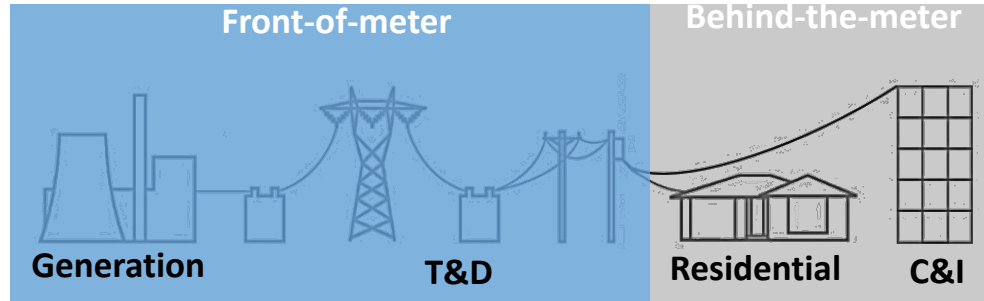
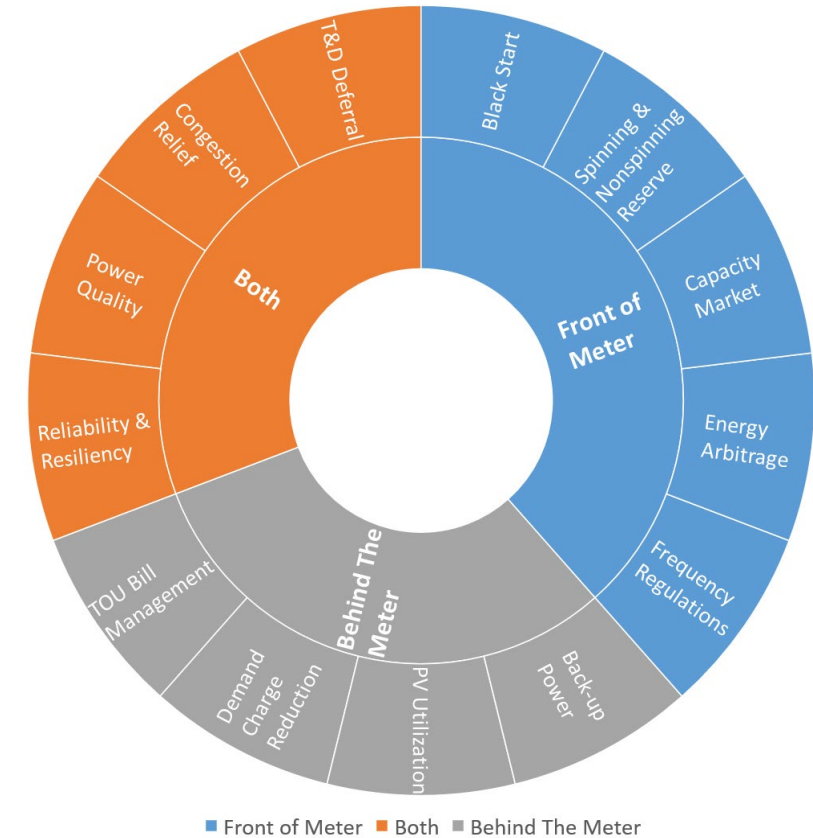
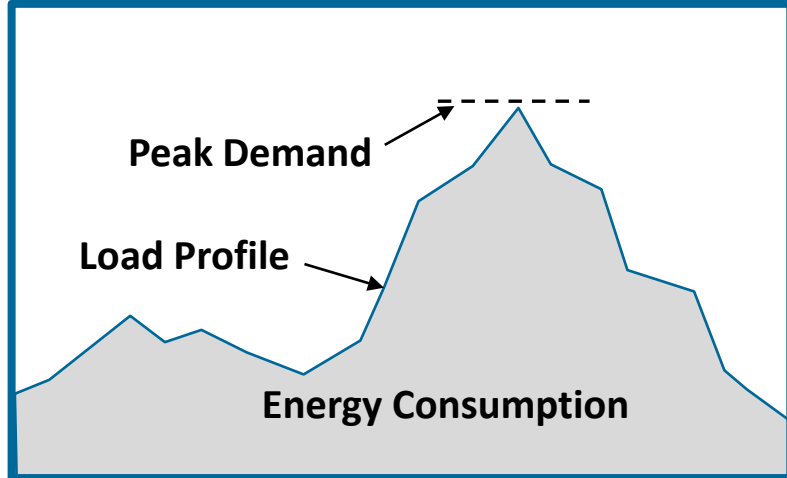


Image Credit: Navigant

- **Behind-the-meter** refers to the systems that are located at the customers' sites (homes, commercial and industrial facilities). BTM systems are usually owned by customers and intended for customers' use.



- **Energy Charge:** a charge to customers for the amount of energy consumed, \$/kWh.
- **Demand Charge:** a charge to customers for their peak power, \$/kW.
- **Other Charges:** meter and basic customer fees are independent of consumption, \$/month.



	Energy Charge	Demand Charge	Other Charges
Residential Customers	Yes	Yes/No*	Yes
Commercial Customers	Yes	Yes/No*	Yes
Industrial Customers	Yes	Yes	Yes

\* Demand charge is often applied to large commercial customers

## UTILITY RATE STRUCTURES – FIXED RATE

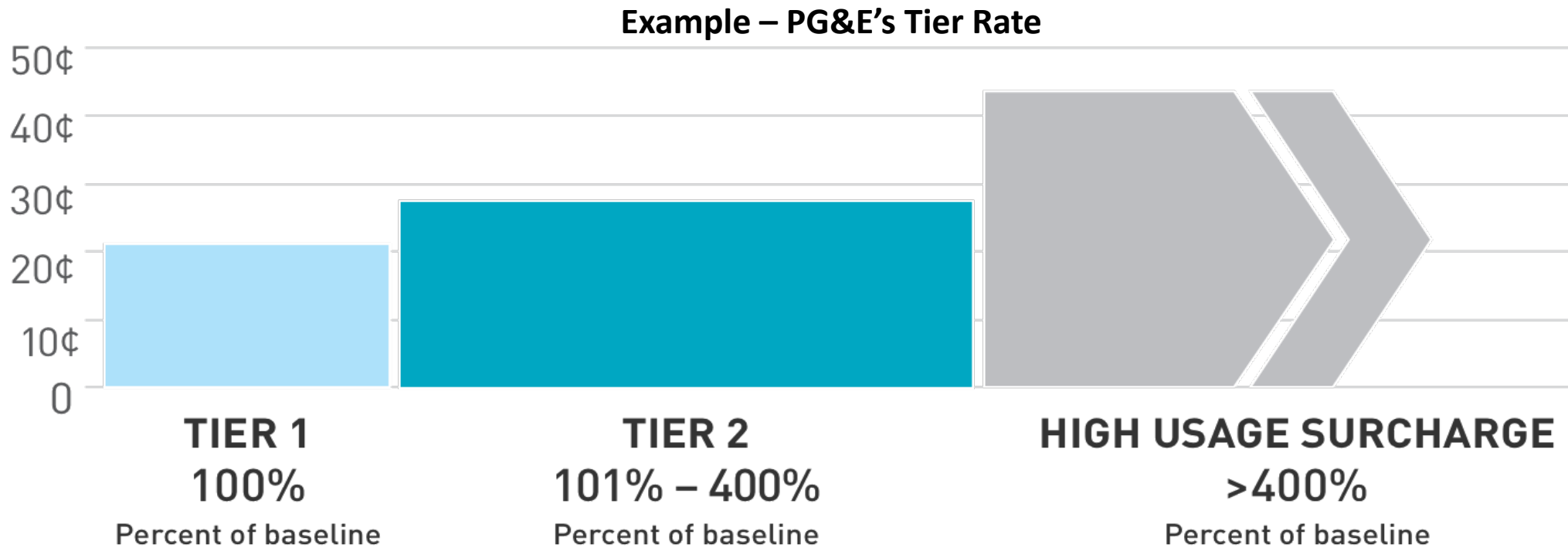


Image Credit: PG&E

- **Fixed rate:** or often called tiered rate is the rate structure where a constant price is applied to each tier of energy consumption.

- **Dynamic rate:** includes the rate structures where energy and demand prices are time dependent.
- **Utilities' motivations for dynamic-price rate:**
  - Increase customer satisfaction with options to reduce energy bill.
  - Encourage load growth.
  - Reduce peak demand by load shifting.
  - Comply with statutory or regulatory mandate

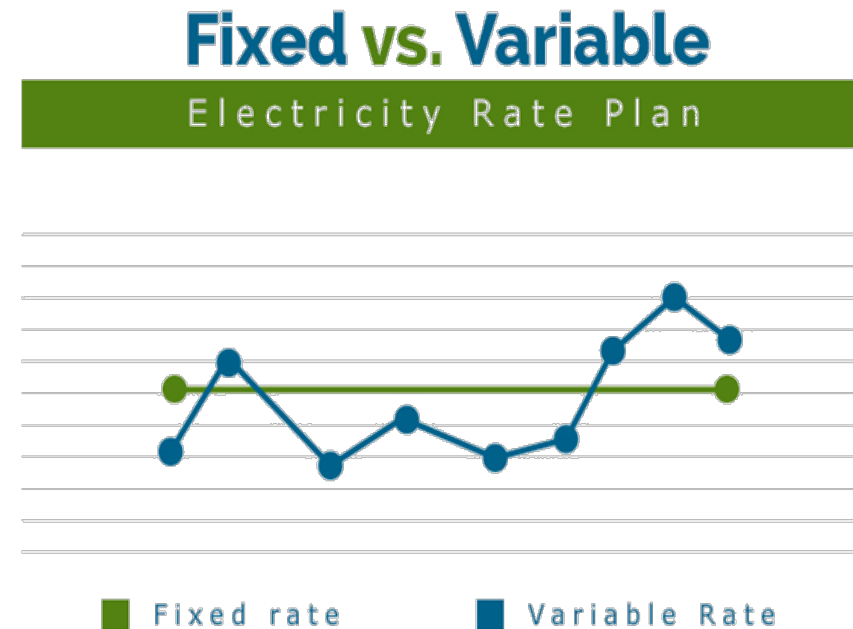
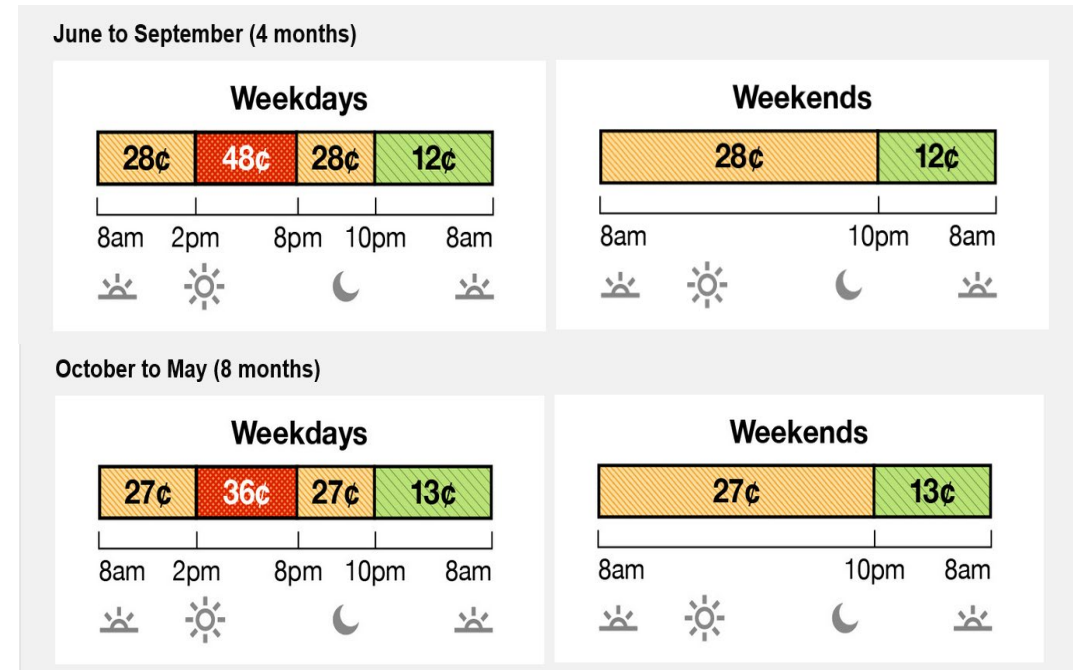


Image Credit: smartenergy.com



- In TOU pricing, energy and demand prices are set in advance for different time periods.
- Time schedules for TOU:
  - Hour: peak, part-peak, and off- peak hours.
  - Day: weekdays, weekends, and holidays.
  - Month: summer and winter



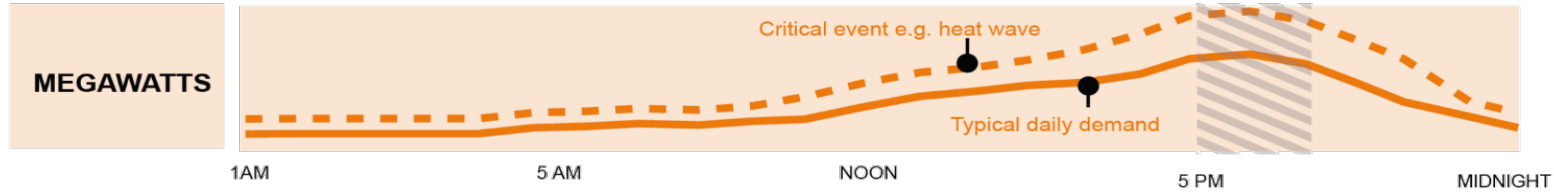
**Southern California Edison – Schedule TOU-D-A**



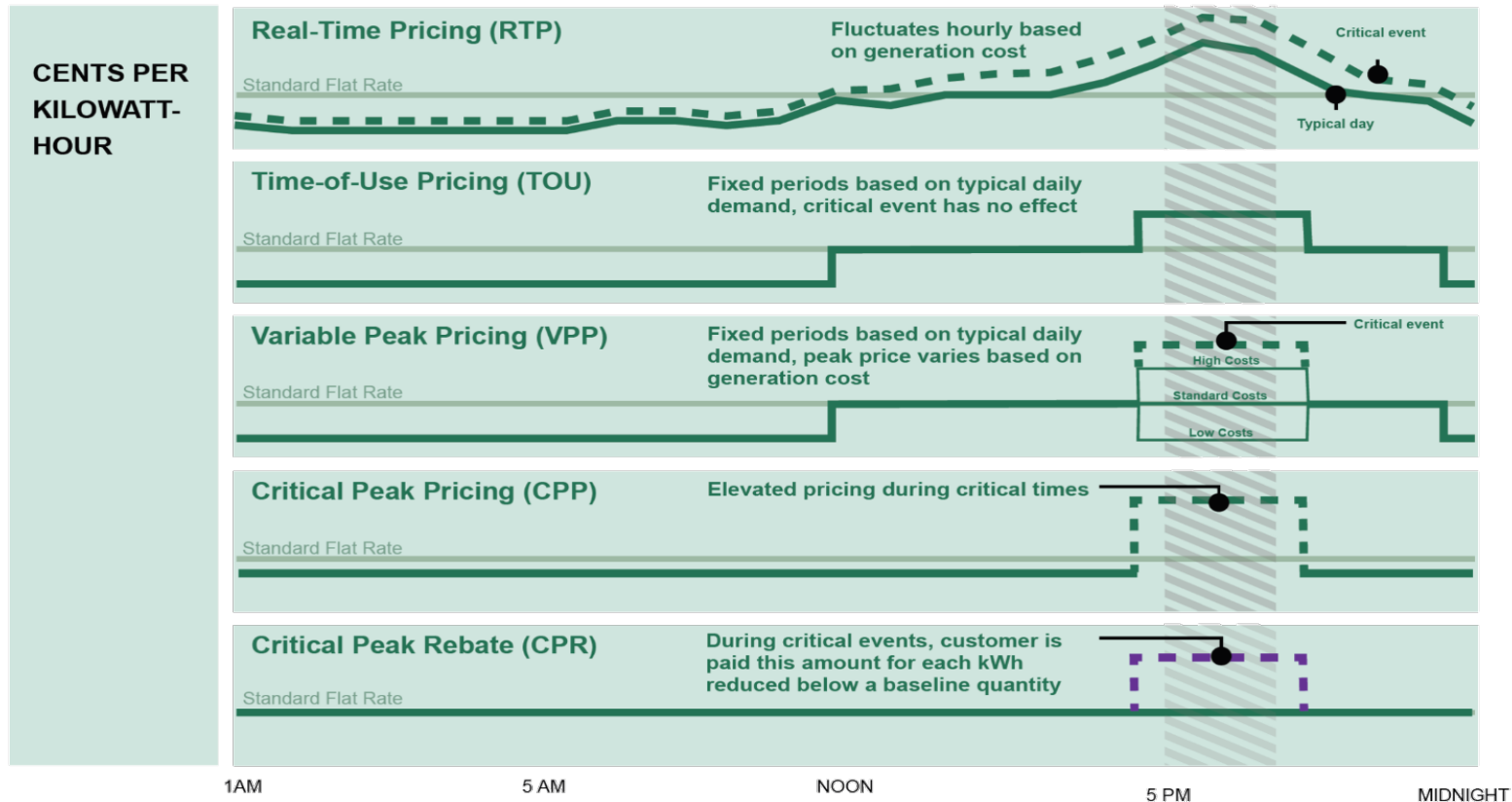
# UTILITY RATE STRUCTURES – DYNAMIC RATE



## ENERGY DEMAND



## PRICING OPTIONS



Source: Environmental Defense Fund (EDF)

# UTILITY RATE STRUCTURES – NET METERING PROGRAM



- Net metering (NEM) programs allow customers who own renewable energy systems to export their excess energy to the grid.
- The net energy exported to the grid will be used to offset the customers' consumption. At the end of the true-up period, the customers will be charged/credited for the net energy usage/surplus.

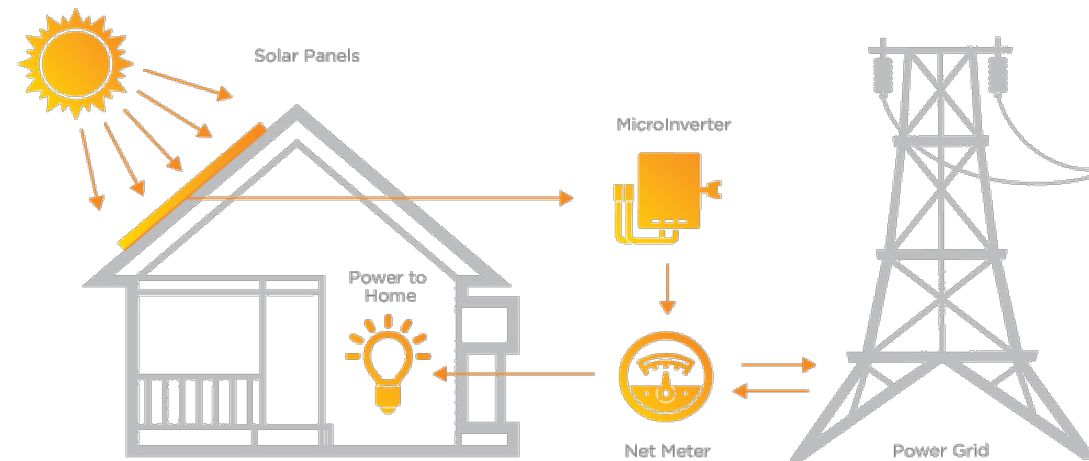
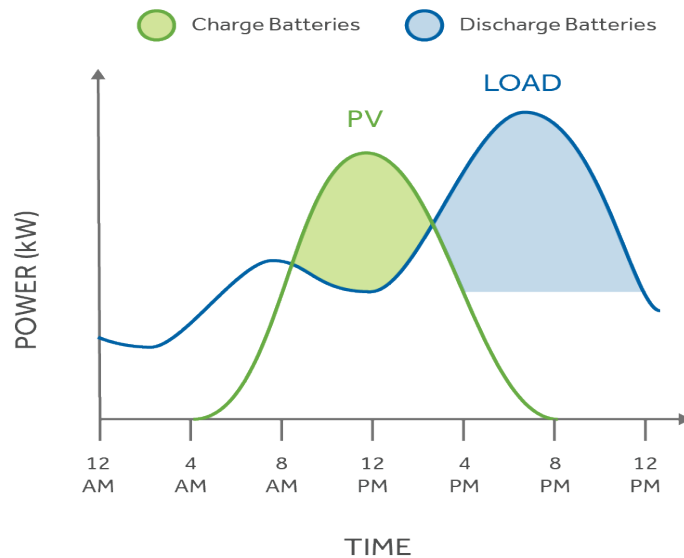


Image Credit - Lowcountry Solar

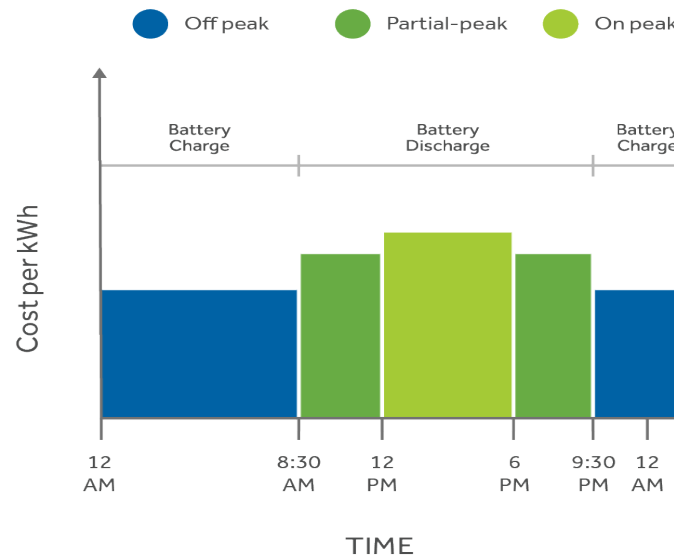
# HOW CAN UTILITY CUSTOMERS BENEFIT?



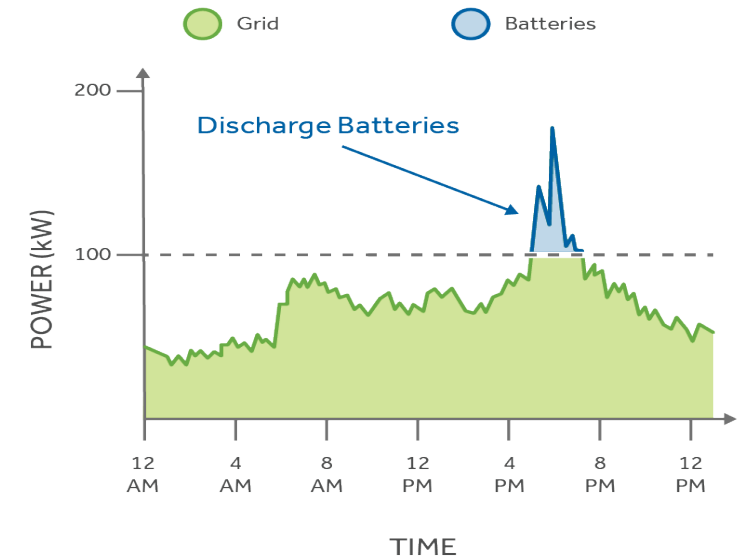
- To benefit from dynamic rate structures, the customers must be able to change their loads in a manner that lowers their electricity bills without interrupting their operations (commercial and industrial customers) or sacrificing their conveniences (residential customers).



**Renewable Time Shift**



**Time-of-use Management**



**Demand Charge Reduction**



- The objective is to minimize the electricity bill such that the physical limits of energy storage device and the inverter are satisfied.

$$\min\{C_E^m + C_N^m + C_D^m\}$$

*s.t. energy storage and inverter constraints*

$C_E^m$  is the energy charge of period  $m$

$C_D^m$  is the demand charge of period  $m$

$C_N^m$  ( $\leq 0$ ) is the net metering charge of period  $m$ .

- The decision variables are the charge and discharge power of the energy storage device at each hour

# CASE STUDY: LARGE HOTEL WITH SOLAR + STORAGE



The screenshot shows the QuEST Data Manager web application. The header includes the QuEST logo, the Sandia National Laboratories logo, and navigation links for home, about, and settings. The main content area features three large buttons: 'QuEST Data Manager' (highlighted with a red border), 'QuEST Valuation', and 'QuEST BTM'. To the right of these buttons, the 'QuEST Data Manager' section provides a description of its function and lists the types of data it manages. A 'Get started' button is also present, also highlighted with a red border. The footer contains copyright information and logos for the U.S. Department of Energy and the National Nuclear Security Administration.

QuEST

home about settings

Sandia National Laboratories

**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

QuEST Data Manager

QuEST Valuation

QuEST BTM

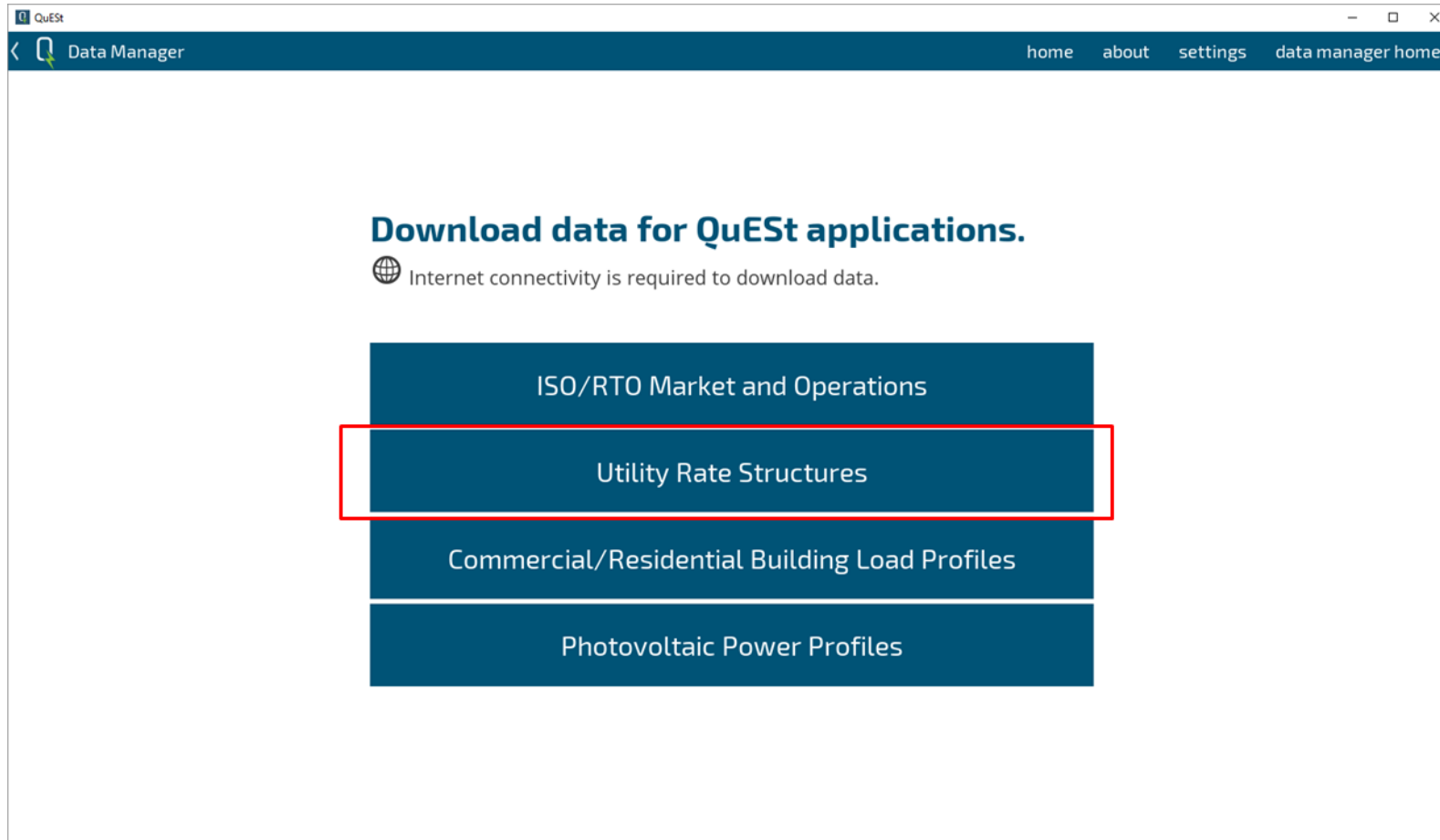
Get started

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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.
- First, we head to QuEST Data Manager to get what we need.

# CASE STUDY: LARGE HOTEL WITH SOLAR + STORAGE



- For this analysis, we need:
  - Utility rate structure
  - Load profile for the property
  - PV power profile



# CASE STUDY: LARGE HOTEL WITH SOLAR + STORAGE



QuEST

Data Manager: Utility Rate Structure Data

home about settings data manager home

## Search for a utility rate structure.

Data.gov API key

### Select a utility.

Filter by name

- PUD No 2 of Pacific County
- PacifiCorp
- PacifiCorp
- PacifiCorp
- PacifiCorp
- PacifiCorp
- PacifiCorp
- Pacific Gas & Electric Co.**
- Sierra Pacific Power Co

### Select a rate structure.

- E-19 Medium General Demand TOU (Secondary) (Effective Date : 03/01/2017)
- E-19 Medium General Demand TOU (Secondary) (Effective Date : 01/01/2017)
- E-19 Medium General Demand TOU (Secondary) (Effective Date : 03/24/2016)
- E-19 Medium General Demand TOU (Secondary, Voluntary) (Effective Date : 03/01/2018)**
- E-19 Medium General Demand TOU (Secondary, Voluntary) (Effective Date : 01/01/2018)

This schedule is available on a voluntary basis for customers with maximum billing demands less than 500 kW. Customers voluntarily taking service on this schedule are subject to all the terms and conditions below, unless otherwise specified in Section 14.

Ongoing daily Time-of-Use (TOU) meter charges applicable to customers taking voluntary TOU service under this rate schedule will no longer be applied if the customer has a SmartMeter™ installed.

- Our hotel's utility is Pacific Gas & Electric.
- The applicable rate structure for our property is "E-19 Medium General Demand TOU (Secondary, Voluntary)".
- 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: LARGE HOTEL WITH SOLAR + STORAGE



QuEST

Data Manager: Utility Rate Structure Data

home about settings data manager home

## Verify the energy rate structure.

Period	Rate [\$/kWh]
0	0.09401
1	0.11004
2	0.08671
3	0.11613
4	0.16055

**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	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
Feb	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
Mar	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
Apr	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
May	2	2	2	2	2	2	2	2	3	3	3	3	4	4	4	4	4	4	3	3	3	2	2	2
Jun	2	2	2	2	2	2	2	2	3	3	3	3	4	4	4	4	4	4	3	3	3	2	2	2
Jul	2	2	2	2	2	2	2	2	3	3	3	3	4	4	4	4	4	4	3	3	3	2	2	2
Aug	2	2	2	2	2	2	2	2	3	3	3	3	4	4	4	4	4	4	3	3	3	2	2	2
Sep	2	2	2	2	2	2	2	2	3	3	3	3	4	4	4	4	4	4	3	3	3	2	2	2
Oct	2	2	2	2	2	2	2	2	3	3	3	3	4	4	4	4	4	4	3	3	3	2	2	2
Nov	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
Dec	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Jun	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Jul	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Aug	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Sep	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Oct	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Previous Continue

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

# CASE STUDY: LARGE HOTEL WITH SOLAR + STORAGE



QuEST

Data Manager: Utility Rate Structure Data

home about settings data manager home

## Verify the demand rate structure.

**Period**

0

1

2

3

**Time-of-Use Rate [\$ /kW]**

0

0.12

5.4

19.65

**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 0 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0

Feb 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0

Mar 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0

Apr 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0

May 0 0 0 0 0 0 0 0 2 2 2 2 3 3 3 3 3 3 2 2 0 0 0

Jun 0 0 0 0 0 0 0 0 2 2 2 2 3 3 3 3 3 3 2 2 0 0 0

Jul 0 0 0 0 0 0 0 0 2 2 2 2 3 3 3 3 3 3 2 2 0 0 0

Aug 0 0 0 0 0 0 0 0 2 2 2 2 3 3 3 3 3 3 2 2 0 0 0

Sep 0 0 0 0 0 0 0 0 2 2 2 2 3 3 3 3 3 3 2 2 0 0 0

Oct 0 0 0 0 0 0 0 0 2 2 2 2 3 3 3 3 3 3 2 2 0 0 0

Nov 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0

Dec 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0

**Month**

Jan

Feb

Mar

Apr

May

Jun

Jul

Aug

Sep

Oct

Nov

Dec

**Flat Rate [\$ /kW]**

17.74

17.74

17.74

17.74

17.74

17.74

17.74

17.74

17.74

17.74

17.74

17.74

**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

Feb 0

Mar 0

Apr 0

May 0

Jun 0

Jul 0

Aug 0

Sep 0

Oct 0

Nov 0

Dec 0

Previous Continue

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

# CASE STUDY: LARGE HOTEL WITH SOLAR + STORAGE



QuEST

Data Manager: Utility Rate Structure Data

home about settings data manager home

## Finishing up.

### Peak demand

minimum [kW]  maximum [kW]

### Net (energy) metering

☐ Net metering 1.0 ☒ Net metering 2.0

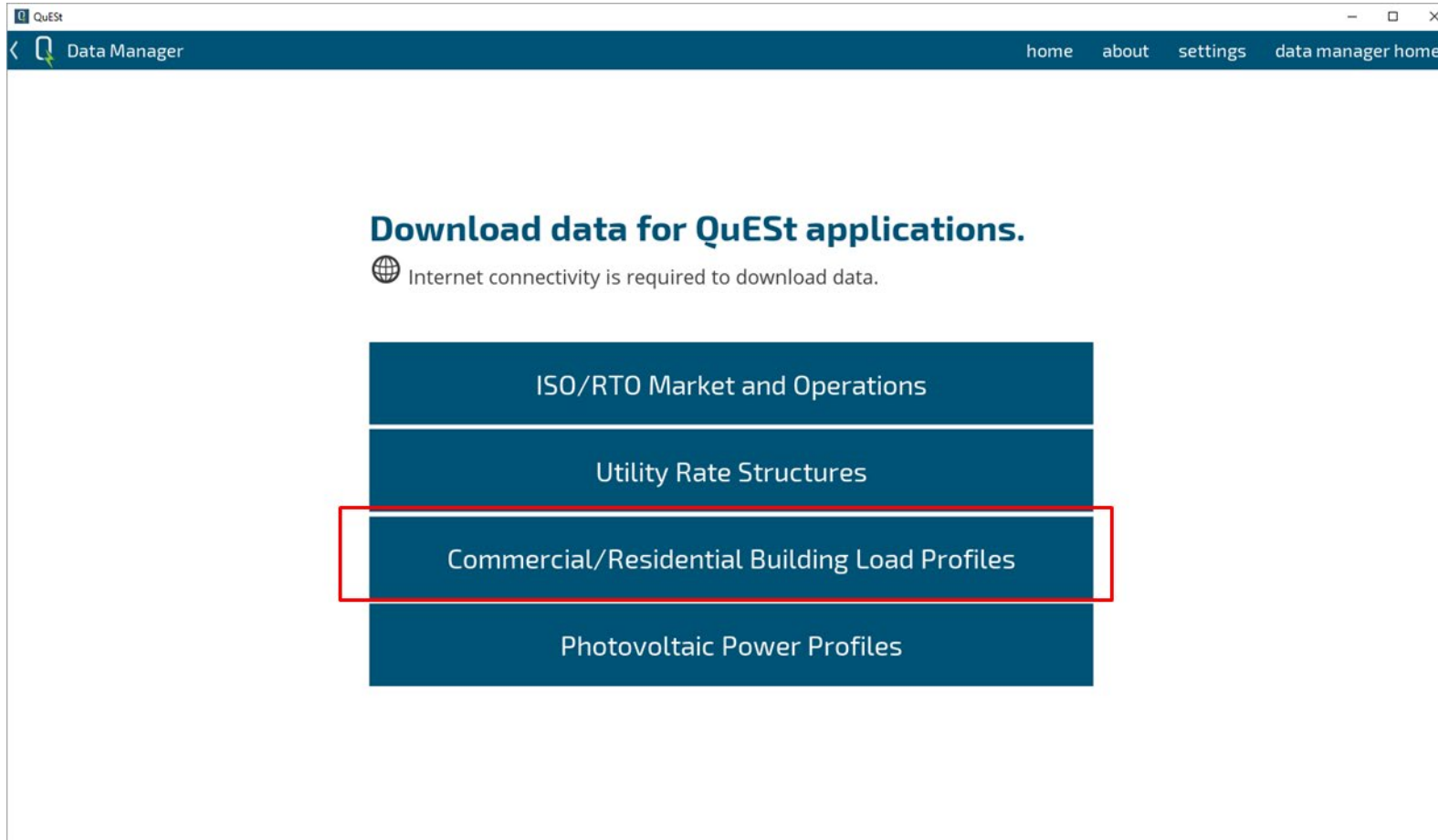
Energy is sold at a fixed energy price.

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

### Save rate structure

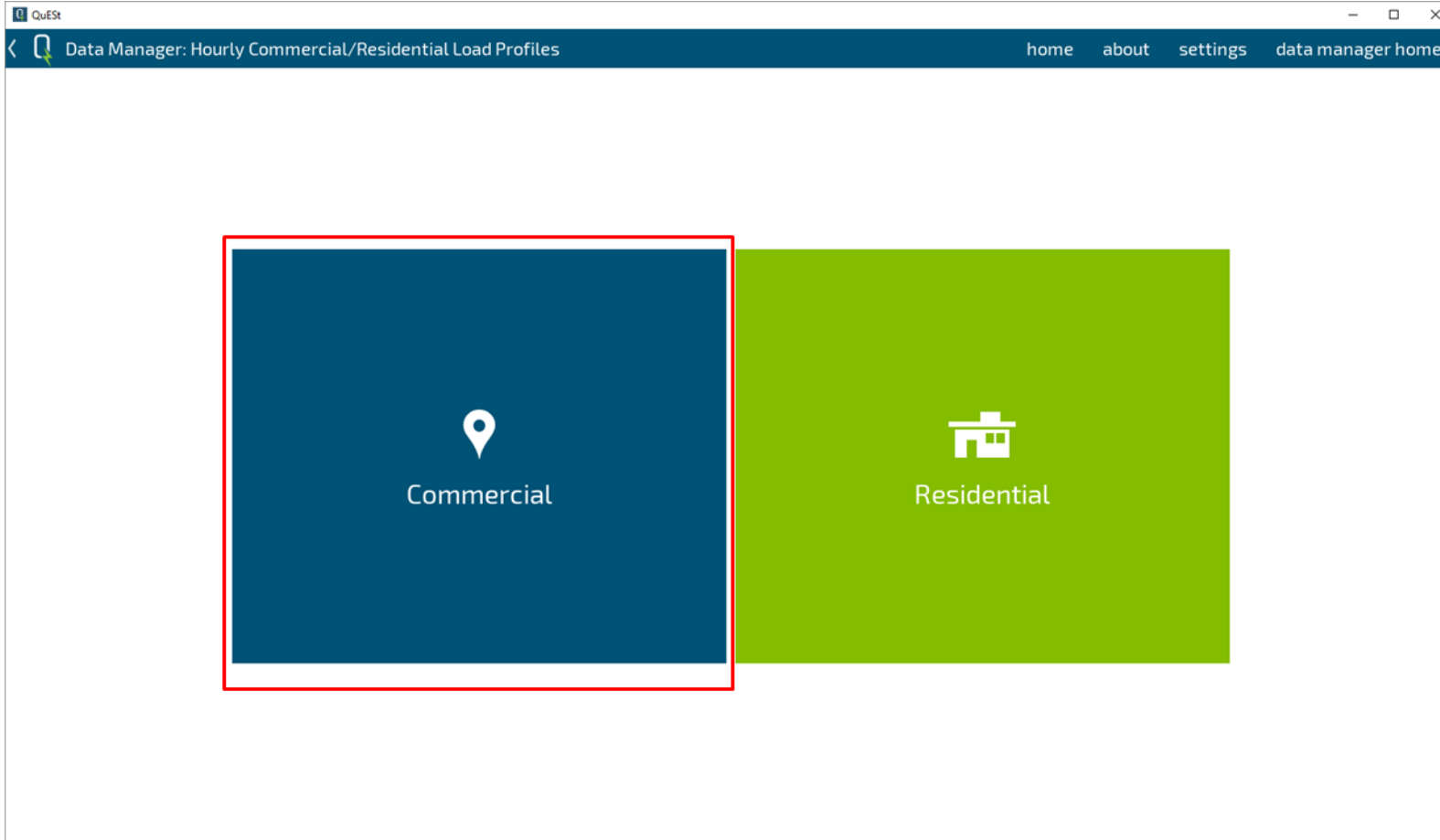
- Save the rate structure for later.

# CASE STUDY: LARGE HOTEL WITH SOLAR + STORAGE



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

# CASE STUDY: LARGE HOTEL WITH SOLAR + STORAGE



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

# CASE STUDY: LARGE HOTEL WITH SOLAR + STORAGE



QuEST

Data Manager: Hourly Commercial Load Profiles

home about settings data manager home

### Download hourly load data by location and building type.

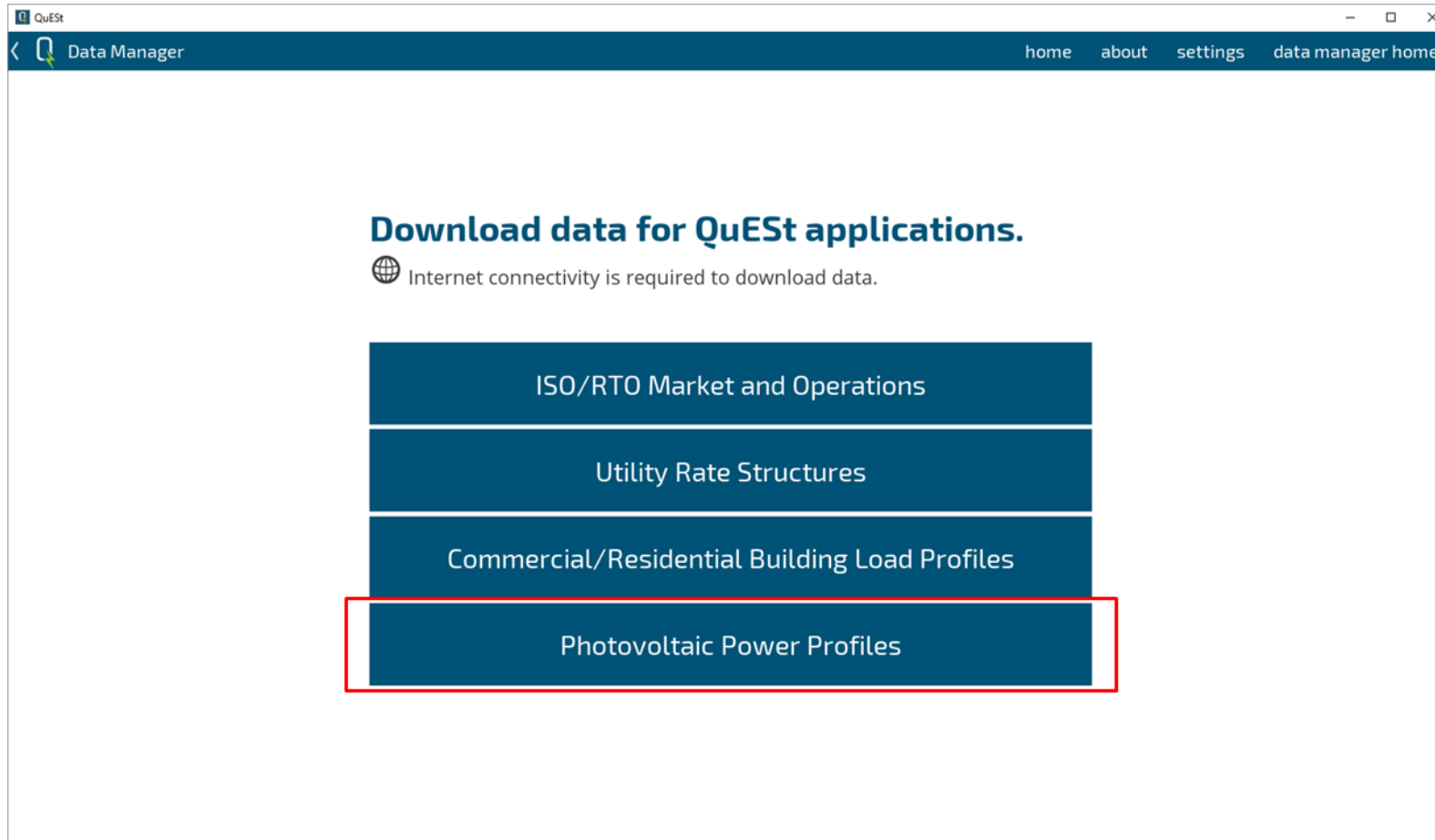
Filter by name	san	Filter by name
AK	San Diego-Lindbergh Field	RefBldgFullServiceRestaurantNew2004
AL	San Diego-Miramar NAS	RefBldgHospitalNew2004
AR	San Diego-Montgomery Field	<b>RefBldgLargeHotelNew2004</b>
AZ	San Diego-North Island NAS	RefBldgLargeOfficeNew2004
<b>CA</b>	<b>San Francisco Intl AP</b>	RefBldgMediumOfficeNew2004
CO	San Jose Intl AP	RefBldgMidriseApartmentNew2004
CT	San Luis Obispo AP	RefBldgOutPatientNew2004
DE	Sandberg	RefBldgPrimarySchoolNew2004
FL	Santa Ana-John Wayne AP	RefBldgQuickServiceRestaurantNew2004
GA	Santa Barbara Muni AP	RefBldgSecondarySchoolNew2004
HI	Santa Maria Public AP	RefBldgSmallHotelNew2004
IA	Santa Monica Muni AP	RefBldgSmallOfficeNew2004
IN	Santa Rosa AWOS	RefBldgStand-aloneRetailNew2004

Save

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



# CASE STUDY: LARGE HOTEL WITH SOLAR + STORAGE



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

# CASE STUDY: LARGE HOTEL WITH SOLAR + STORAGE



QuEST

Data Manager: Photovoltaic Power Profiles

home about settings data manager home

### Search for a photovoltaic power profile.

Data.gov API key AHKRnsqzqRbhOZ9XU2C63gwFEsPASXtQlL3b1Pd0

<b>latitude</b>	The latitude of the site in the range (-90, 90).	<input type="text" value="37.78"/>	deg
<b>longitude</b>	The longitude of the site in the range (-180, 180).	<input type="text" value="-122.42"/>	deg
<b>system capacity</b>	The nameplate capacity of the photovoltaic system.	<input type="text" value="50"/>	kW
<b>losses</b>	The total system losses, including all sources, in the range (-5, 99).	<input type="text" value="14"/>	%
<b>tilt angle</b>	The tilt angle of the PV surface. Defaults to site latitude.	<input type="text"/>	deg
<b>azimuth angle</b>	The azimuth angle of the PV surface.	<input type="text" value="180"/>	deg

Standard

Fixed (roof mounted)

Save

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

# CASE STUDY: LARGE HOTEL WITH SOLAR + STORAGE



The screenshot shows the QuEST web application interface. At the top, there is a navigation bar with a back arrow, a search icon, and links for 'home', 'about', and 'settings'. The main header features the 'Quest' logo on the left and the 'Sandia National Laboratories' logo on the right. Below the header, there is a sidebar on the left with three menu items: 'QuEST Data Manager' (with a list icon), 'QuEST Valuation' (with a dollar sign icon), and 'QuEST BTM' (with a house icon and highlighted in blue). The main content area on the right is titled 'QuEST BTM' and includes a subtitle: 'A collection of tools for behind-the-meter (BTM) energy storage systems: \*Estimate cost savings for time-of-use and/or net-metering customers'. Below this text is a large blue button labeled 'Get started', which is highlighted with a red rectangular border. At the bottom of the page, there is a copyright notice: '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.' and logos for the 'U.S. DEPARTMENT OF ENERGY' and 'NNSA National Nuclear Security Administration'.

QuEST

home about settings

Quest

Sandia National Laboratories

QuEST BTM

A collection of tools for behind-the-meter (BTM) energy storage systems:  
\*Estimate cost savings for time-of-use and/or net-metering customers

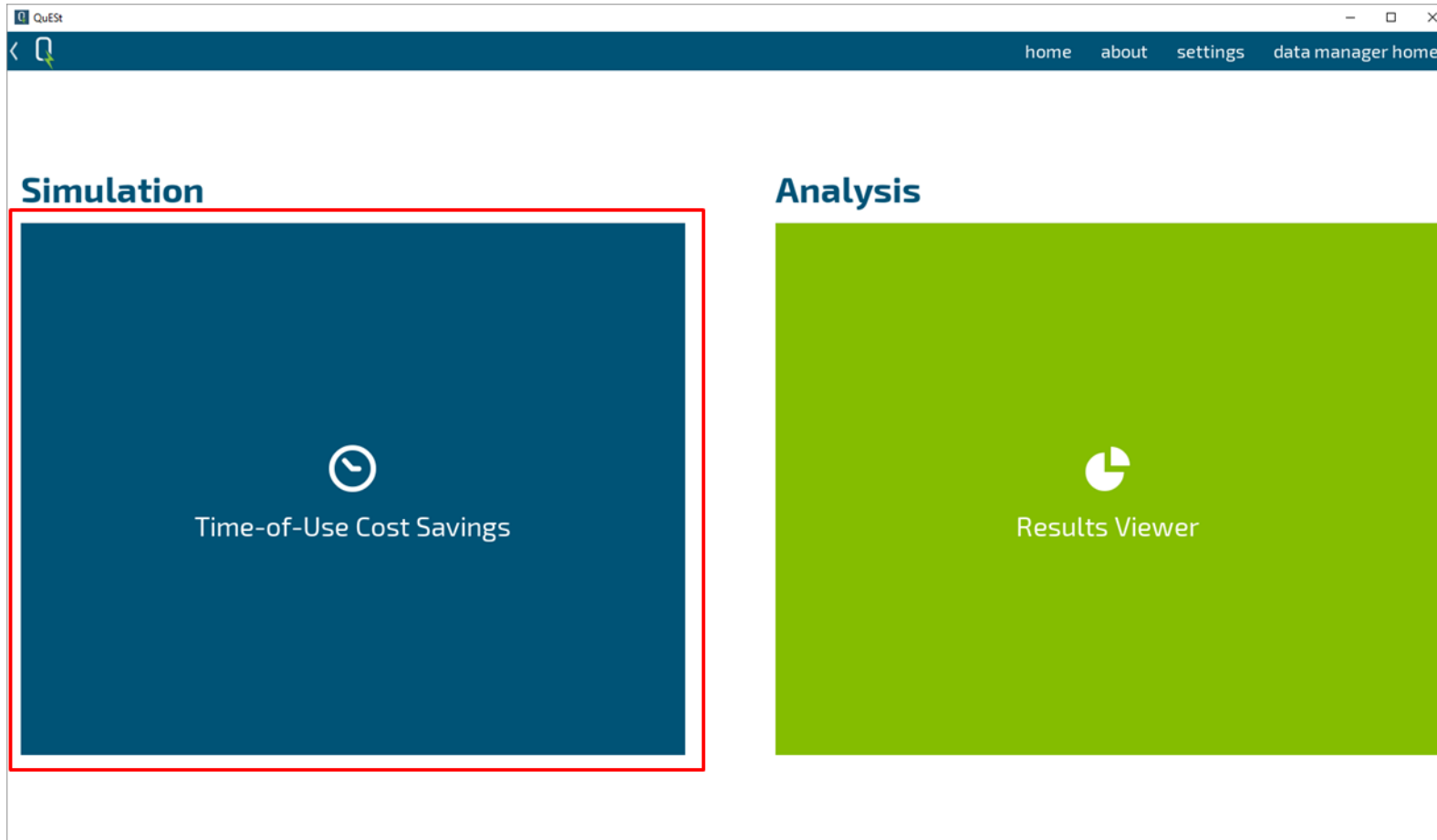
Get started

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

- 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: LARGE HOTEL WITH SOLAR + 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: LARGE HOTEL WITH SOLAR + STORAGE



QuEST

Time-of-Use Cost Savings

home about settings

## Select a rate structure.

Filter by name

- 0129
- 0206
- 0213
- 0321-nyseg
- 0325-pepco-general-service
- 0327-pge-e19-medium
- PNM
- e-tou-option-b
- example
- my-SF-hotel-PGE**
- nyseg-tou-residential
- nyseg-tou-residential-nem1
- paloalto
- pnm-residential-tou
- xyz

**Energy**

☐ \$0.09401/kWh  
☐ \$0.11004/kWh  
☐ \$0.08671/kWh  
☐ \$0.11613/kWh  
☐ \$0.16055/kWh

☐ \$0.09401/kWh  
☐ \$0.11004/kWh  
☐ \$0.08671/kWh  
☐ \$0.11613/kWh  
☐ \$0.16055/kWh

**Demand**

☐ \$0.0/kW  
☐ \$0.12/kW  
☐ \$5.4/kW  
☐ \$19.65/kW

☐ \$0.0/kW  
☐ \$0.12/kW  
☐ \$5.4/kW  
☐ \$19.65/kW

Flat demand rate [\$/kW] Jan 17.74 Feb 17.74 Mar 17.74 Apr 17.74 May 17.74 Jun 17.74 Jul 17.74 Aug 17.74 Sep 17.74 Oct 17.74 Nov 17.74 Dec 17.74

Peak demand min. [kW]  Peak demand max. [kW]  Net metering type  Energy sell price [\$/kWh]

Previous Next

- Proceeding through the wizard, we select the data that we had just downloaded when prompted.
- Our proposed energy storage system is 400 kWh/100 kW, so we'll enter that in.

# CASE STUDY: LARGE HOTEL WITH SOLAR + STORAGE



QuEST

Time-of-Use Cost Savings

home about settings

## Select a load profile.

Select a load profile to represent the demand connected to the energy storage system.

Filter by name

commercial/RefBldgFullServiceRestaurantNew2004\_v1.3\_7.1\_4B\_USA\_NM\_ALBUQUERQUE.csv

commercial/RefBldgFullServiceRestaurantNew2004\_v1.3\_7.1\_8A\_USA\_AK\_FAIRBANKS.csv

**commercial/RefBldgLargeHotelNew2004\_7.1\_5.0\_3C\_USA\_CA\_SAN\_FRANCISCO.csv**

commercial/RefBldgLargeHotelNew2004\_v1.3\_7.1\_4A\_USA\_MD\_BALTIMORE.csv

commercial/RefBldgLargeOfficeNew2004\_7.1\_5.0\_3C\_USA\_CA\_SAN\_FRANCISCO.csv

commercial/RefBldgMidriseApartmentNew2004\_v1.3\_7.1\_4A\_USA\_MD\_BALTIMORE.csv

commercial/RefBldgPrimarySchoolNew2004\_v1.3\_7.1\_5B\_USA\_CO\_BOULDER.csv

commercial/RefBldgQuickServiceRestaurantNew2004\_v1.3\_7.1\_2A\_USA\_TX\_HOUSTON.csv

commercial/RefBldgSecondarySchoolNew2004\_v1.3\_7.1\_4A\_USA\_MD\_BALTIMORE.csv

commercial/RefBldgSuperMarketNew2004\_v1.3\_7.1\_5B\_USA\_CO\_BOULDER.csv

residential/USA\_AK\_Anchorage.Intl.AP.702730\_TMY3\_BASE.csv

residential/USA\_CA\_Mountain.View-Moffett.Field.NAS.745090\_TMY3\_LOW.csv

residential/USA\_CA\_San.Francisco.Intl.AP.724940\_TMY3\_BASE.csv

residential/USA\_CA\_San.Francisco.Intl.AP.724940\_TMY3\_LOW.csv

residential/USA\_DE\_Dover.AFB.724088\_TMY3\_HIGH.csv

residential/USA\_KY\_Fort.Knox-Godman.AAF.724240\_TMY3\_HIGH.csv

residential/USA\_NM\_Albuquerque.Intl.AP.723650\_TMY3\_BASE.csv

residential/USA\_NY\_Elmira.RgnL.AP.725156\_TMY3\_HIGH.csv

Previous

Next

- Proceeding through the wizard, we select the data that we had just downloaded when prompted.
- Our proposed energy storage system is 400 kWh/100 kW, so we'll enter that in.

# CASE STUDY: LARGE HOTEL WITH SOLAR + STORAGE



QuEST

Time-of-Use Cost Savings

home about settings

## Select a PV power profile.

Select a PV power profile to represent the PV connected to the energy storage system.

If there is no PV connected, feel free to skip this step.

Filter by name

- 00
- 030419
- 03215kWABQ
- 0325abq10kw
- 1000kWABQ
- 500kw
- 50kWSF
- 5kW5Froofmount
- abqrooftop50kW
- d
- example
- mySFHotel50kWrooftop**
- ovvv
- ovvvd
- pvddata

Previous Next

- Proceeding through the wizard, we select the data that we had just downloaded when prompted.
- Our proposed energy storage system is 400 kWh/100 kW, so we'll enter that in.

# CASE STUDY: LARGE HOTEL WITH SOLAR + STORAGE



QueST

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="400"/>	kWh
<b>power rating</b>	The maximum rate that at which the ESS can charge or discharge energy.	<input type="text" value="100"/>	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

- Proceeding through the wizard, we select the data that we had just downloaded when prompted.
- Our proposed energy storage system is 400 kWh/100 kW, so we'll enter that in.



# CASE STUDY: LARGE HOTEL WITH SOLAR + STORAGE



QuEST

Time-of-Use Cost Savings

home about settings

## Summary of selections.

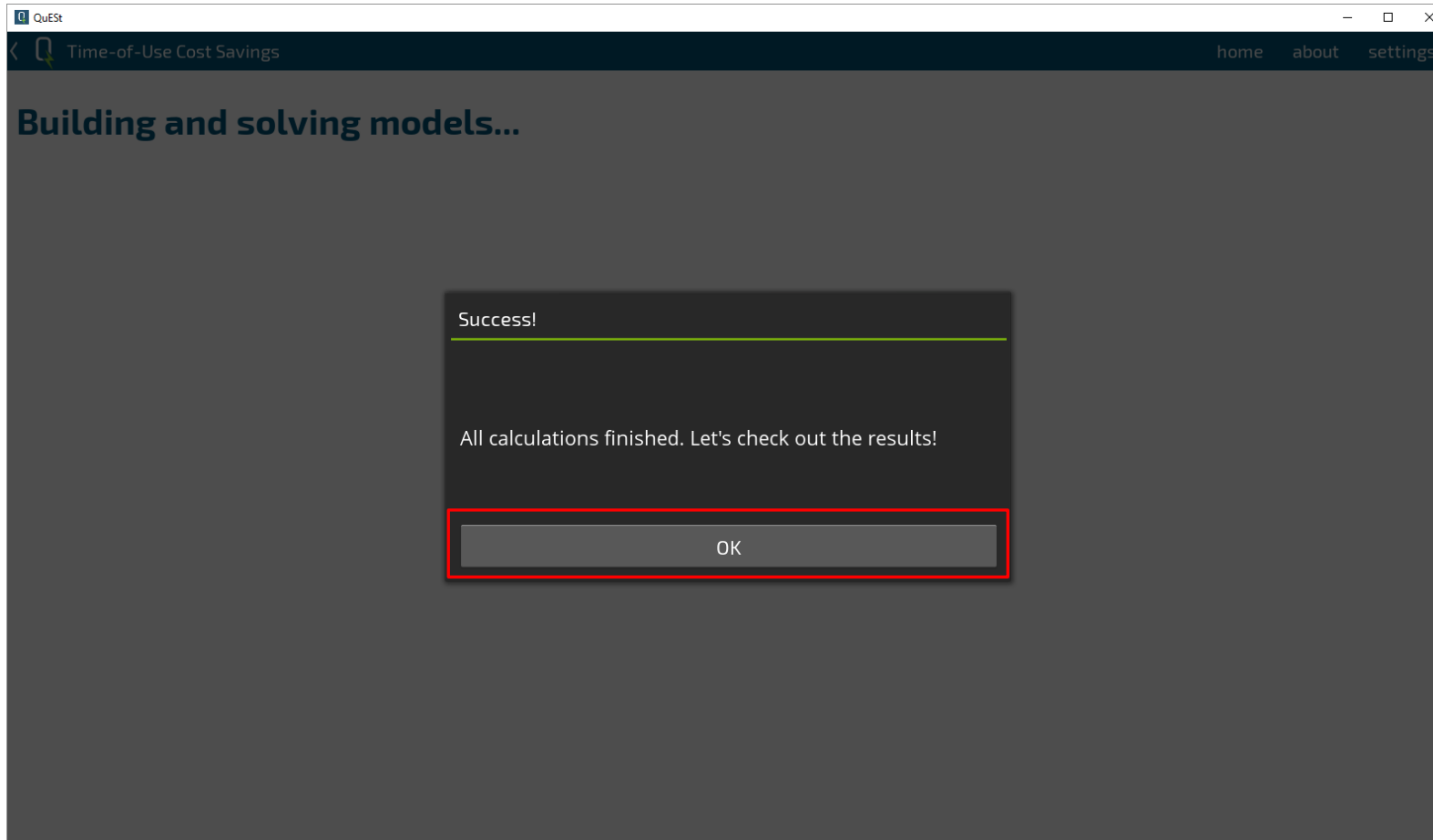
<b>Rate Structure:</b> my-SF-hotel-PGE Pacific Gas & Electric Co. E-19 Medium General Demand TOU (Secondary, Voluntary)	<b>System Parameters:</b> initial state of charge: 50 % maximum state of charge: 100 % minimum state of charge: 0 % round trip efficiency: 85 % self-discharge efficiency: 100 %/h transformer rating: 1000000 kW power rating: 100 kW energy capacity: 400 kWh
<b>Load Profile:</b> commercial/RefBldgLargeHotelNew2004_7.1_5.0_3C_USA_CA_SAN_FRANCISCO.csv	
<b>PV Profile:</b> Location: 37.78, -122.42 System Capacity: 50 kW Azimuth: 180 deg Tilt: 37.78 deg Array Type: Fixed (roof mounted) Module Type: Standard System Losses: 14%	

Previous

Next

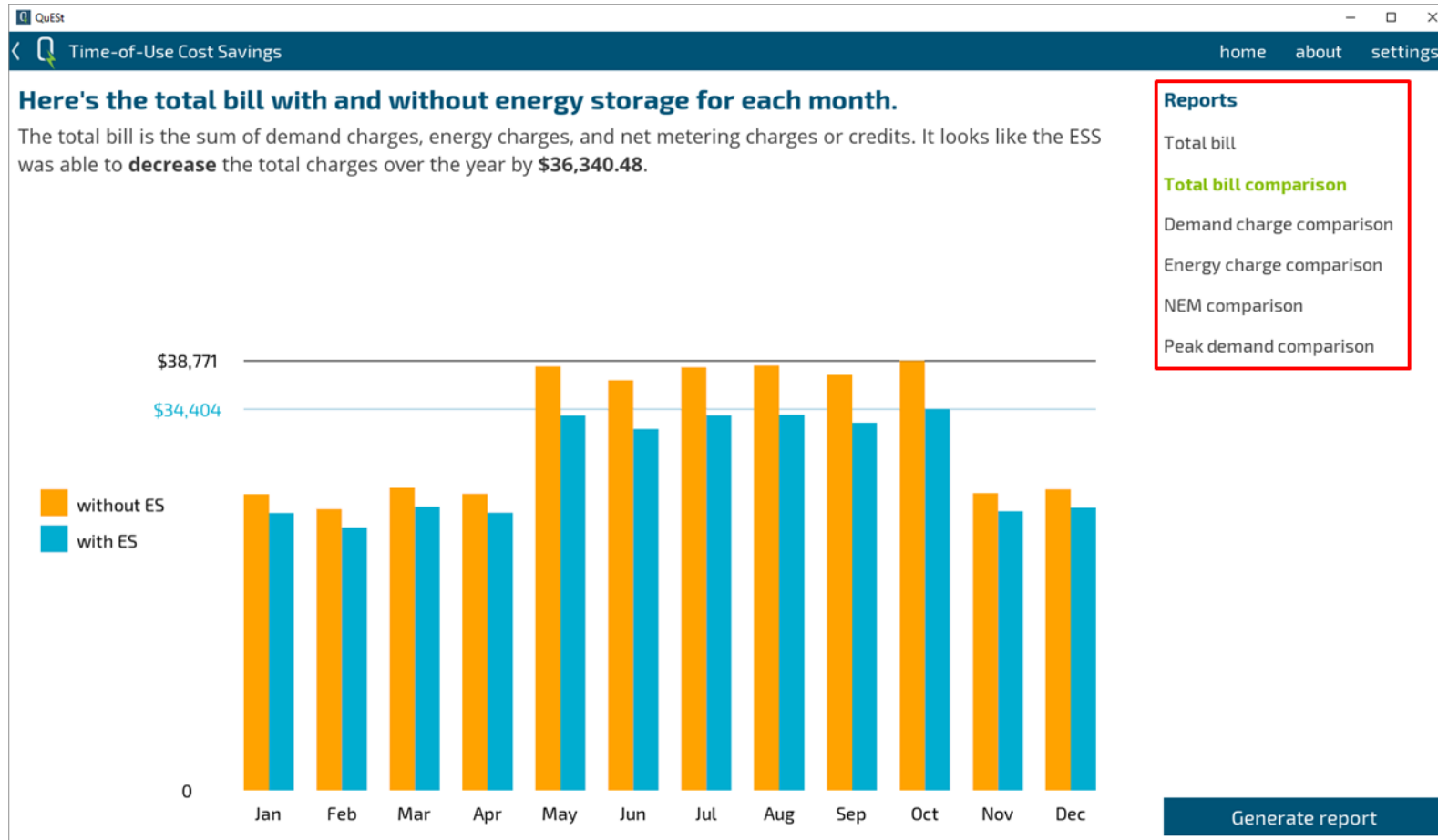
- Once everything's setup, we'll click "Next" to initiate the model building and solution process.
- In the background, the specified data is being loaded, the optimization models are being constructed, and the models are being solved.
- After a brief wait, a prompt will notify you that the computation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

# CASE STUDY: LARGE HOTEL WITH SOLAR + STORAGE



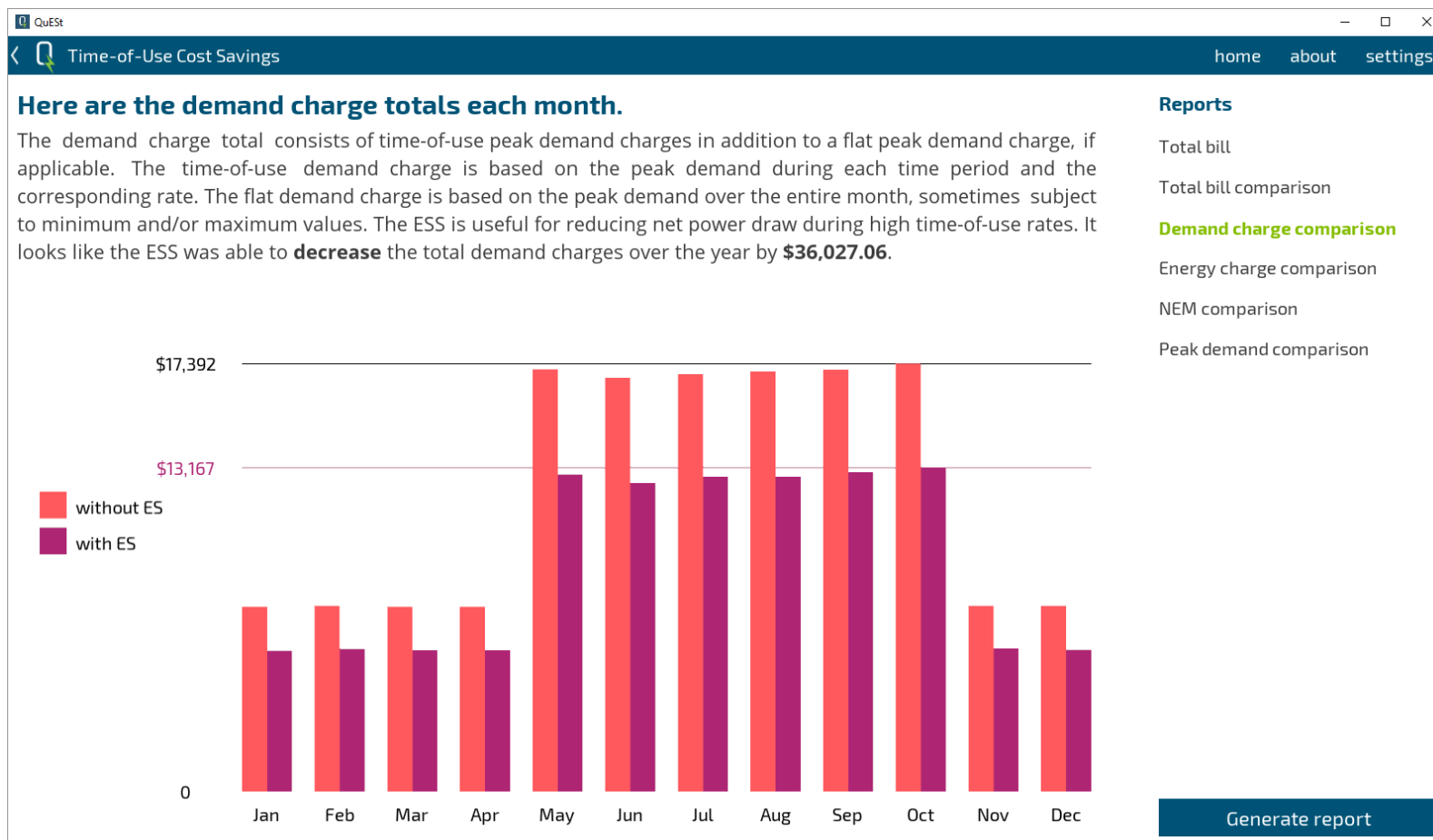
- Once everything's setup, we'll click "Next" to initiate the model building and solution process.
- In the background, the specified data is being loaded, the optimization models are being constructed, and the models are being solved.
- After a brief wait, a prompt will notify you that the computation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

# CASE STUDY: LARGE HOTEL WITH SOLAR + STORAGE



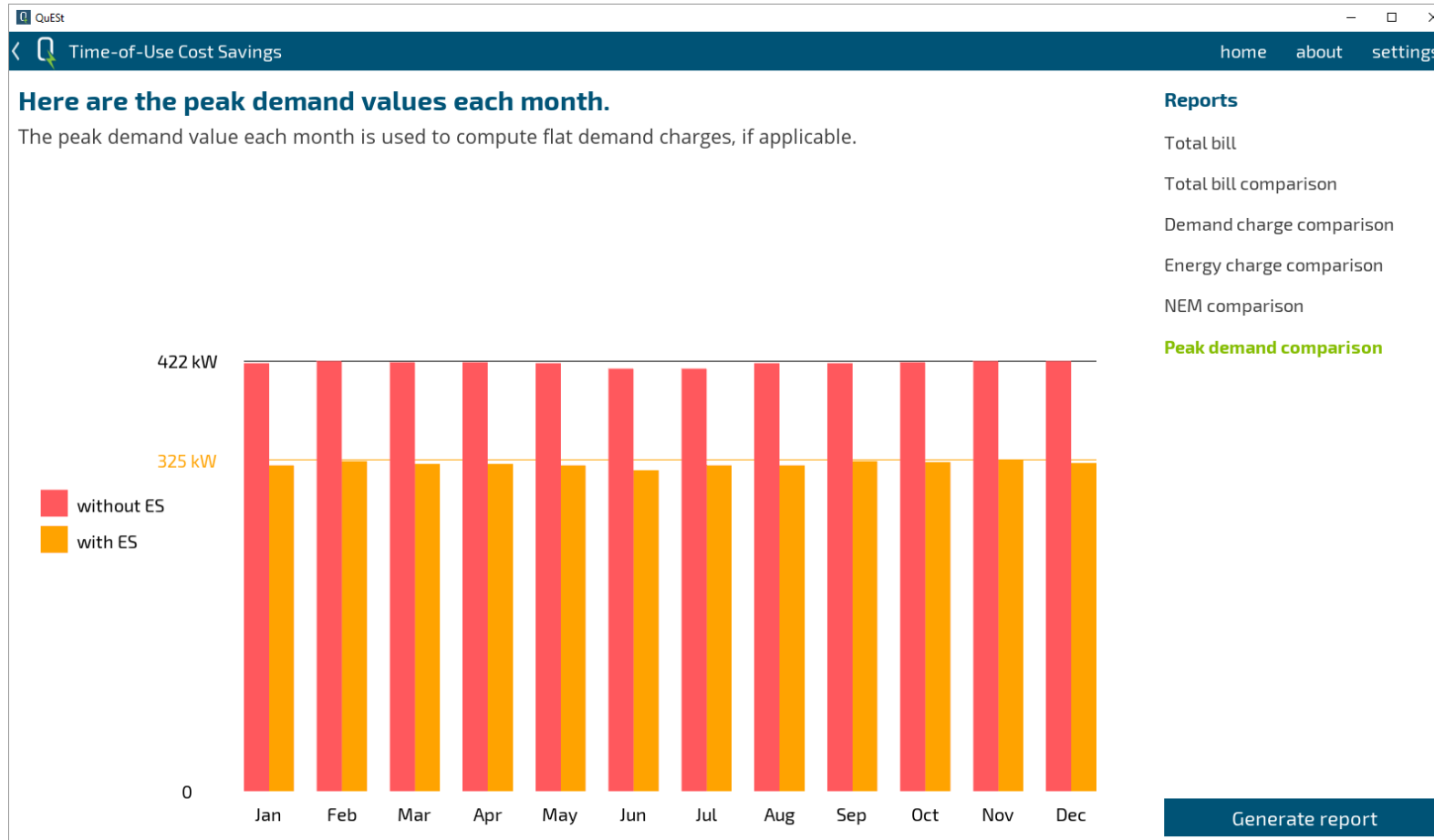
- We can now view the wizard's report of results and view several summary graphics.
- Based on the calculations, the addition of the energy storage system reduced annual charges by about \$36k.
- This was mostly due to demand charge reduction.
- Peak demand each month was reduced by about 100 kW.

# CASE STUDY: LARGE HOTEL WITH SOLAR + 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 \$36k.
- This was mostly due to demand charge reduction.
- Peak demand each month was reduced by about 100 kW.

# CASE STUDY: LARGE HOTEL WITH SOLAR + 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 \$36k.
- This was mostly due to demand charge reduction.
- Peak demand each month was reduced by about 100 kW.
- We can also create a summary report that includes formulation details and the results.



## Behind-the-Meter Energy Storage Cost Savings Report

*Autogenerated using QuEST BTM*

**May 13, 2019**

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

### Scenario Summary

**Utility:** Pacific Gas & Electric Co.

**Rate Structure:** E-19 Medium General Demand TOU (Secondary, Voluntary)

**Load Profile:** commercial/RefBldgLargeHotelNew2004\_7.1\_5.0\_3C\_USA\_CA\_SAN\_FRANCISCO.csv

### Photovoltaic Power Profile

Location: 37.78, -122.42

System Capacity: 50 kW

Azimuth: 180 deg

Tilt: 37.78 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	100	kW

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

## CASE STUDY: LARGE HOTEL WITH SOLAR + 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.

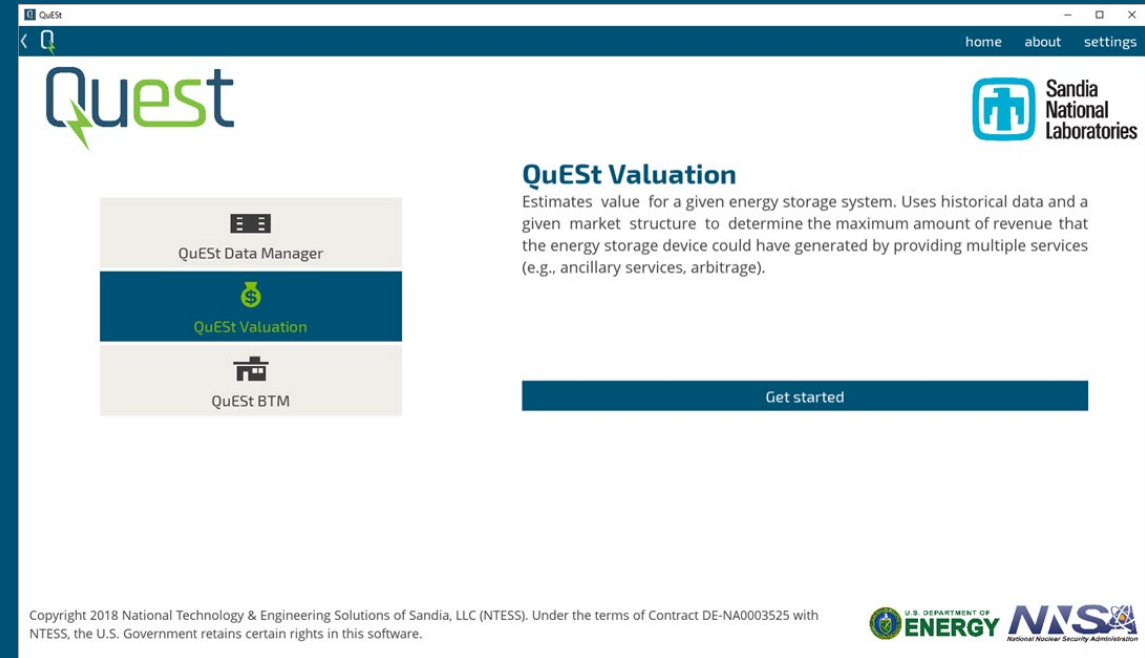


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- Develop new applications
  - Integrated resource planning tools
  - Optimizing with costs
  - Resilience
  - More value streams
  - RFP templates
- Release API/Library
- Webinars, tutorials, workshops
- Integrate user feedback and requests





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