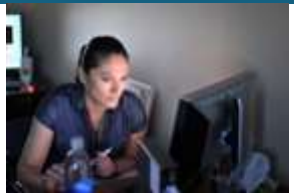
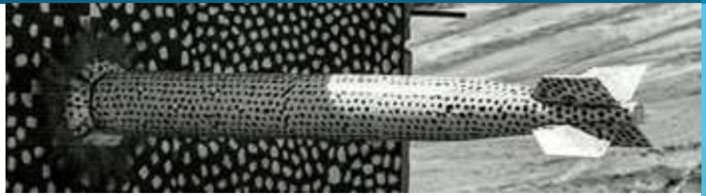
SAND2021-11983 C

Sandia National Laboratories

EVALUATION OF ENERGY STORAGE AND SOFTWARE TOOLS





PRESENTED BY

Tu A. Nguyen

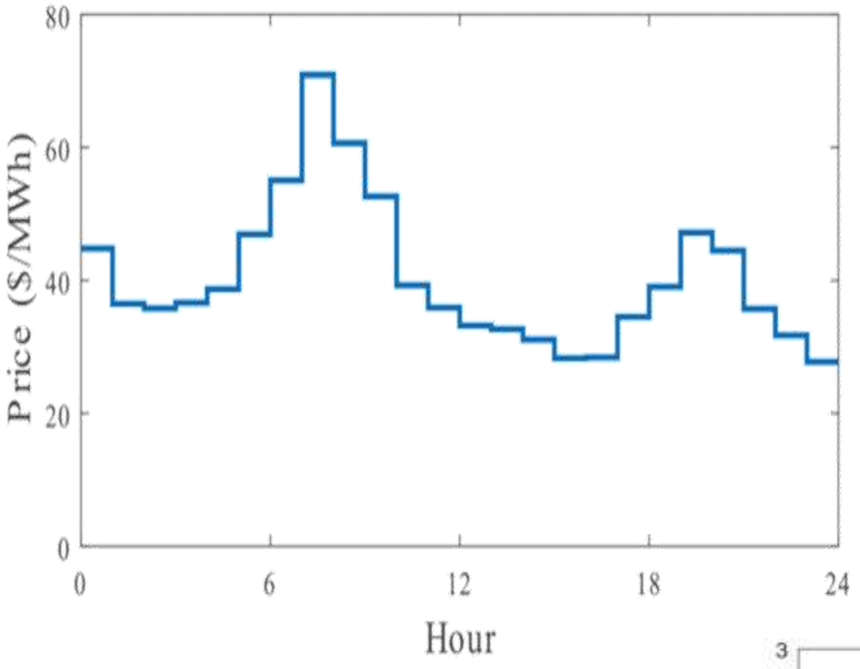
2021 Energy Storage Workshop - ICC

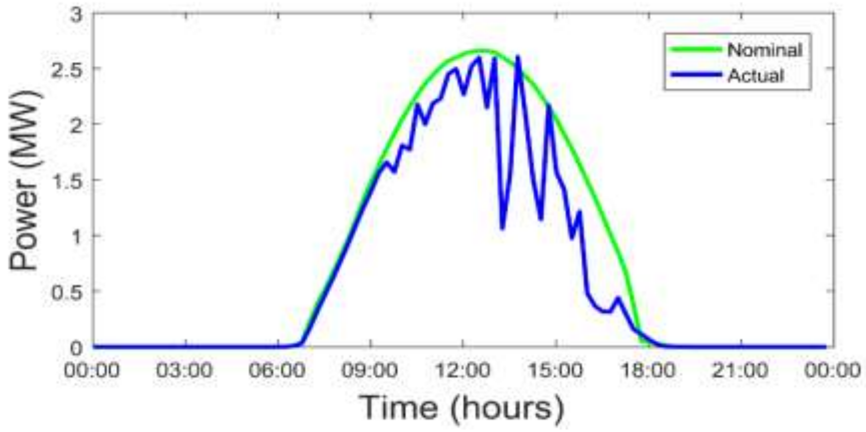
Outline

- Energy storage applications
- Energy storage technology selection
- Energy storage valuation:
  - Market
  - Behind-the-meter
  - Energy equity
  - System performance
- QuESt – Energy storage application suite
  - Overview
  - QuESt – valuation
  - QuESt – BTM

Energy Storage Applications – Power vs. Energy

- Power applications
  - Frequency regulation
  - Voltage support
  - Small signal stability
  - Renewable smoothing
- Energy applications
  - Energy arbitrage
  - Renewable energy time shift
  - Customer demand charge reduction
  - Transmission and distribution upgrade deferral





Energy Storage Applications – FTM vs. BTM

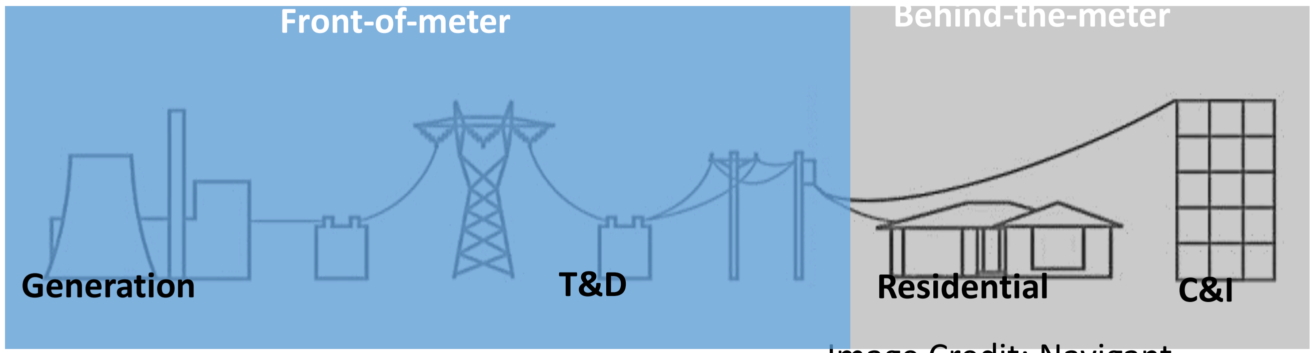


Image Credit: Navigant

- **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.

Techno-economic Analysis of Energy Storage

- Identify revenue streams: what are the possible services/applications that an ESS can provide?
- Select the right ES technology to provide those services.
- Evaluate the overall economic gain given the limits in performance of the selected storage technology.
- Optimally size ESS.

Energy Storage Technology Selection

Goal: given a set of user selections, perform an initial screening to identify and rank feasible energy storage technologies for a given project.

ES technologies currently in the database:

- Pumped hydro storage (PHS)
- Compressed air energy storage (CAES)
- Sodium (Na)
- Zinc (Zn)
- Flywheel – Long duration (FWLD)
- Flywheel – Short duration (FWSD)
- Flow battery – Vanadium (FBV)
- Flow battery – Iron (FBFe)
- Flow battery – Zinc bromide (FBZnBr)
- Nickel (Ni)
- Lithium-ion – Energy (LiE)
- Lithium-ion – Power (LiP)
- Lead (Pb)
- Lead carbon (PbC)

User inputs:
- Grid location
- Application(s)
- System size (power)
- Discharge duration

ES technologies database
- discharge duration
- round-trip efficiency
- cycle life
- depth of discharge
- response time to full power
- cost
- maturity level
- …

Applications database
- minimum discharge duration
- minimum response time
- power vs. energy application
- deployment location restrictions
- …

Filter out ES techs that are not suitable for the selected grid location and/or do not meet the minimum application requirements (discharge duration, response time, electric output)

Score each feasible ES tech based on the following factors:
- Application requirements
- Location requirements
- Cost
- Technology readiness level

Output: ranked feasible ES techs

The final score for each ES tech is given as the weighted geometric mean of the four individual scores, so that the user can assign higher weights to the factors that they consider more relevant to the intended applications.

Energy Storage Valuation – Market Problem

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?

$$\max \sum_i \Big(\underbrace{\lambda_i (q_i^d - \eta_c q_i^r)}_{\text{arbitrage}} + \underbrace{q_i^{ru}(\lambda_i^{ru} + \delta_i^{ru}\lambda_i)}_{\text{regulation up}} + \underbrace{q_i^{rd}(\lambda_i^{rd} - \delta_i^{rd}\lambda_i)}_{\text{regulation down}} \Big) e^{-Ri}$$

subject to:

$$s_{i+1} = \eta_s s_i + \eta_c q_i^r - q_i^d + \eta_c \delta_i^{rd} q_i^{rd} - \delta_i^{ru} q_i^{ru}$$ state of charge definition

$$0 \le s_i \le \bar{S}$$ state of charge limits

$$q_i^d + q_i^r + q_i^{ru} + q_i^{rd} \le \bar{Q}$$ power/energy charged limits

- Other constraints, such as requiring the final SoC to equal the initial SoC or reserving energy capacity for resiliency applications can be set.
- Varies based on market and available value streams

Energy Storage Valuation – BTM Problem

Given an energy storage device, a utility tariff structure, how would the device minimize the electricity bills for the customers?

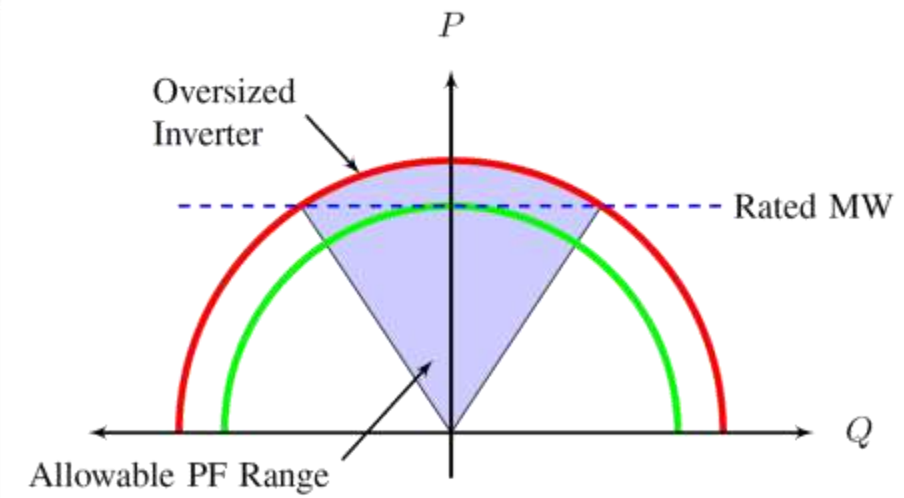
$$\min\{\mathrm{C_E^m} + \mathrm{C_N^m} + \mathrm{C_D^m}\}$$

s.t. energy storage and inverter constraints

$\mathrm{C_E^m}$ is the energy charge of period m

$\mathrm{C_D^m}$ is the demand charge of period m

$\mathrm{C_N^m}$ (≤ 0) is the net metering charge of period m.

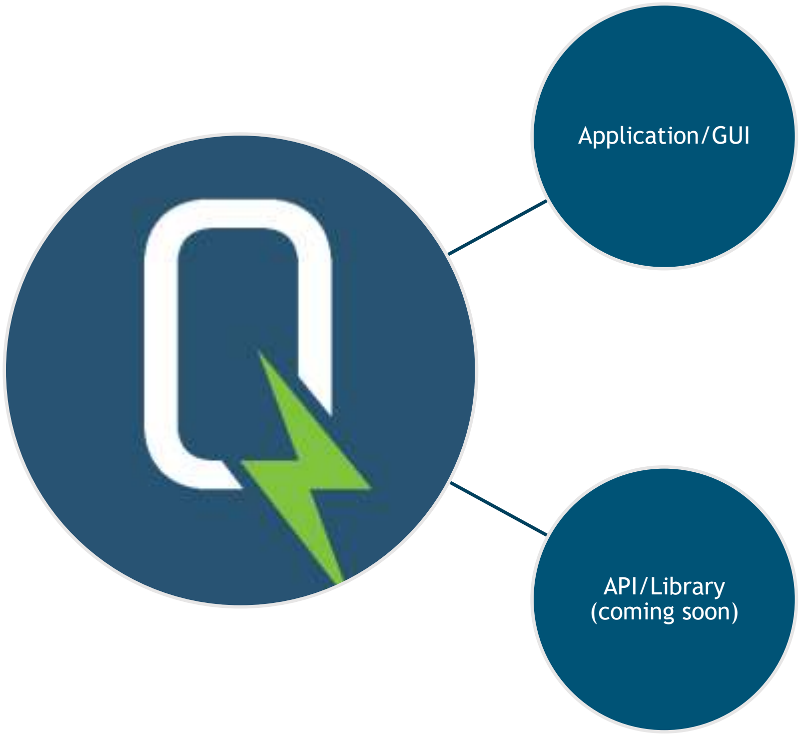


Energy Storage Valuation – Energy Equity and System Performance Problems

Given a Peaker loading profile, what are the optimal sizes of PV and storage for 1-to-1 replacement of that plant? What are the benefits for the environment?

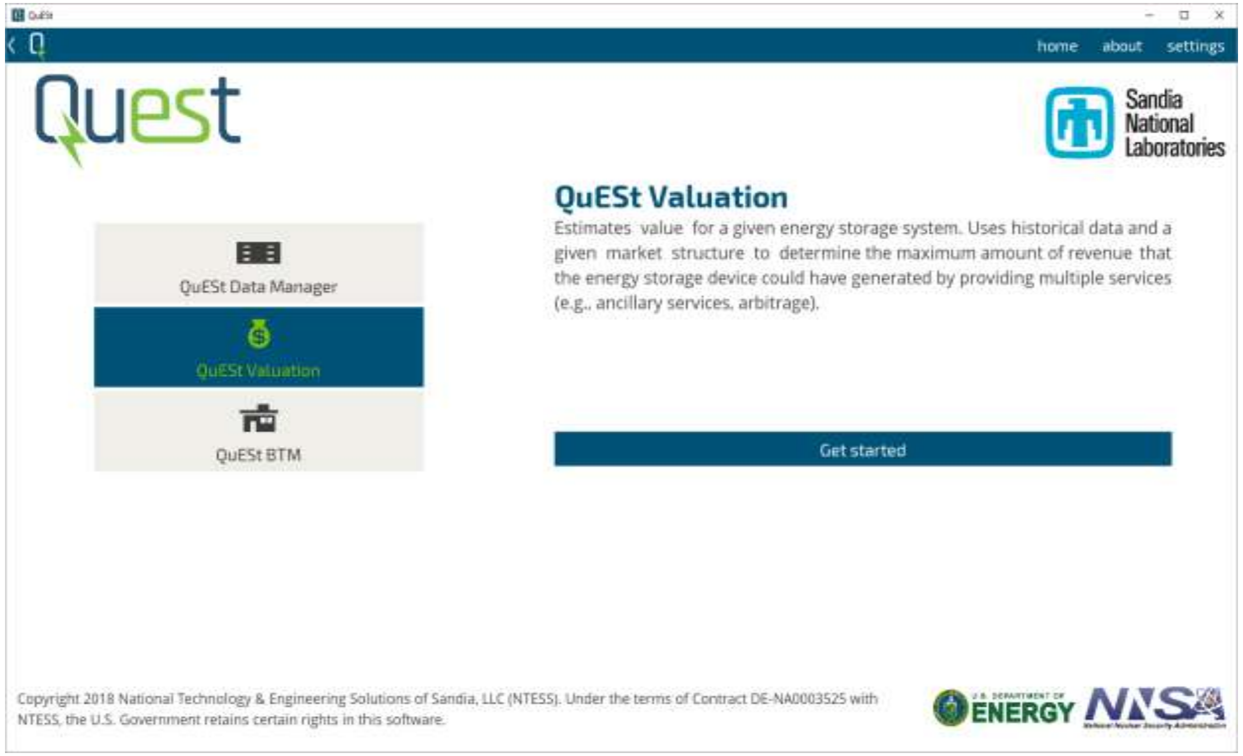
Given a charge/discharge profile of a BESS, how much energy is needed to run the HVAC that maintain system temperature within its operating range? What is the optimal size of the BESS considering the HVAC load?

QuESt Overview



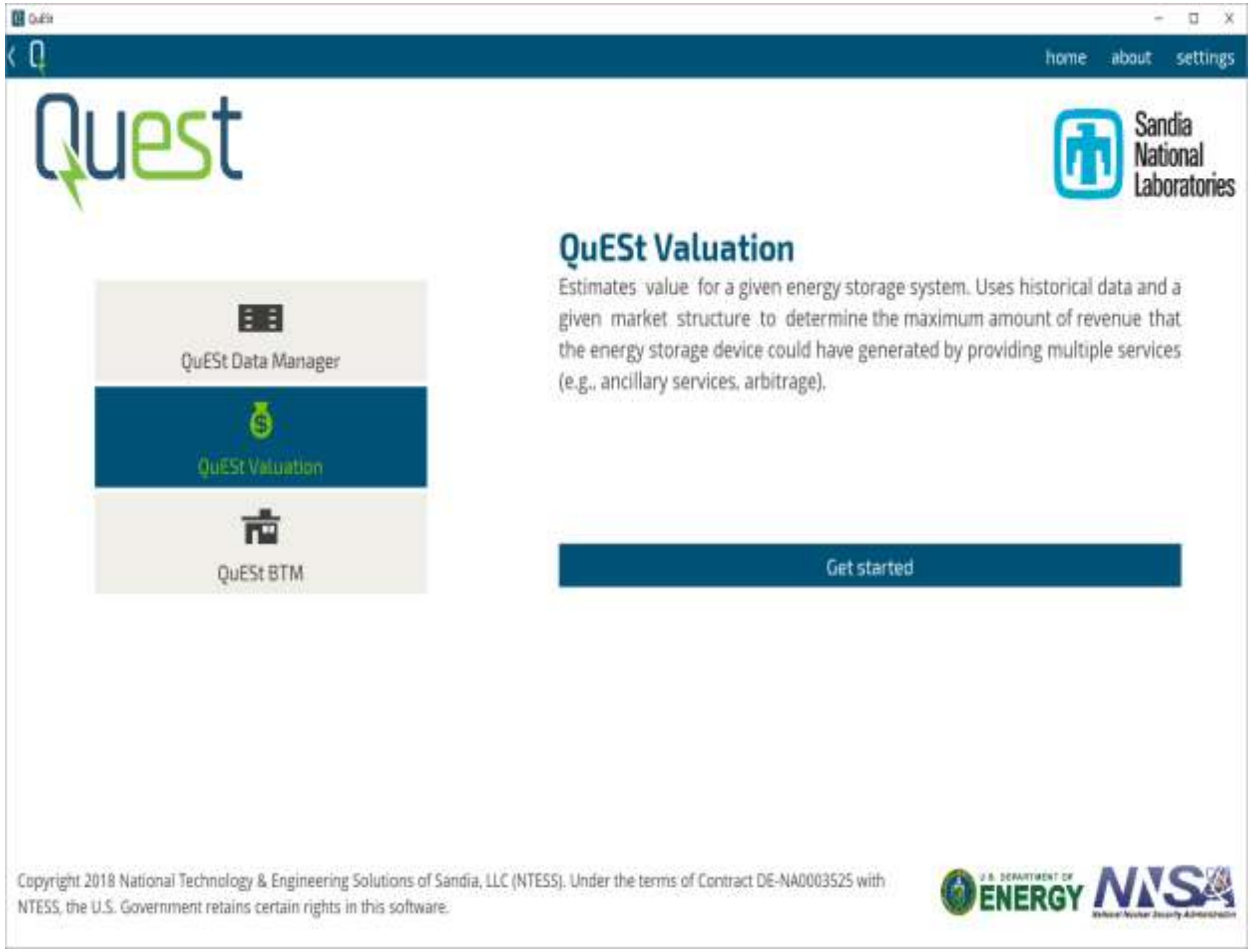
- Developed for user experience
- No hassle installation

- For power users
- Use for Python scripting
- More capabilities



- Energy storage analysis software application suite
- Version 1.0 publicly released in September 2018
- Version 1.2 available on GitHub
  - https://github.com/snl-quest/snl-quest

QuESt - Applications



Current:

- **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.

Future:

- **QuESt Technology Selection (Sep 2021)**
- **QuESt Equity (Dec 2021)**
- **QuESt Performance (Dec 2021)**

QuESt - Workflow

Decide what type of analysis to do.

- ISO/RTO value stacking => QuESt Valuation
- Behind-the-meter applications => QuESt BTM

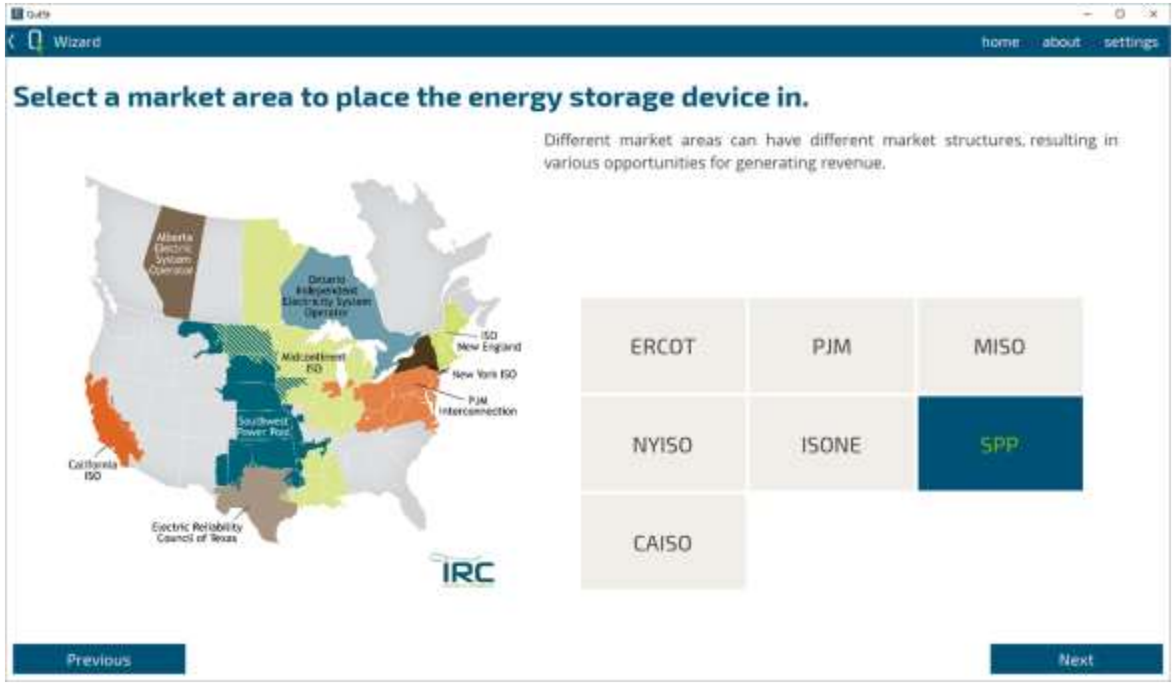
Grab the appropriate data from QuESt Data Manager.

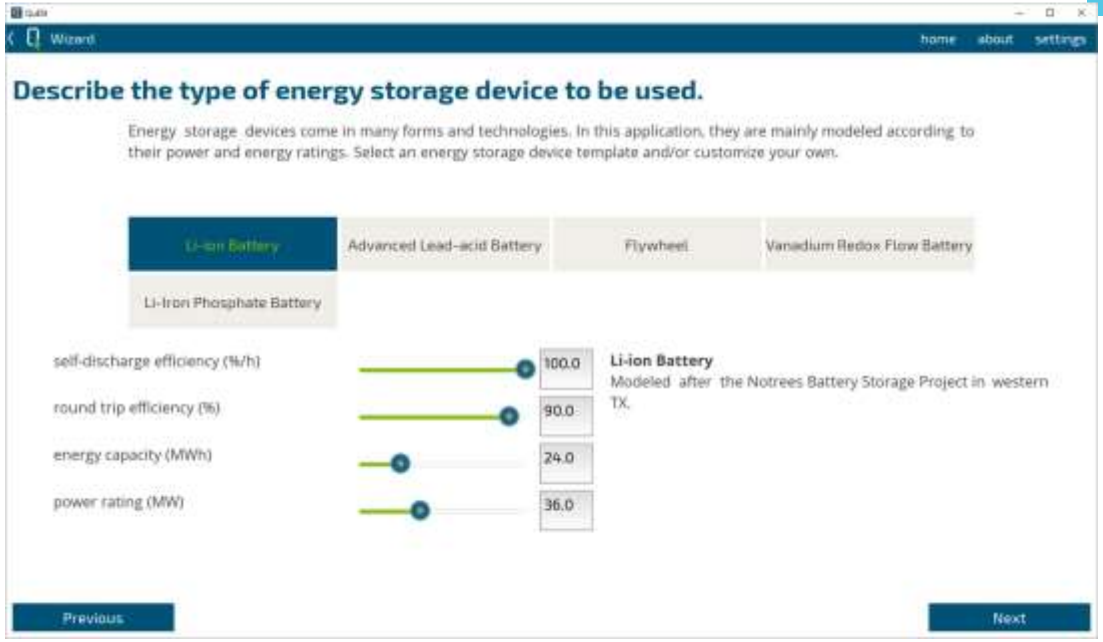
- ISO/RTO market data
- Utility rate structure
- PV profile
- Load profile

Select the appropriate application from the first step.

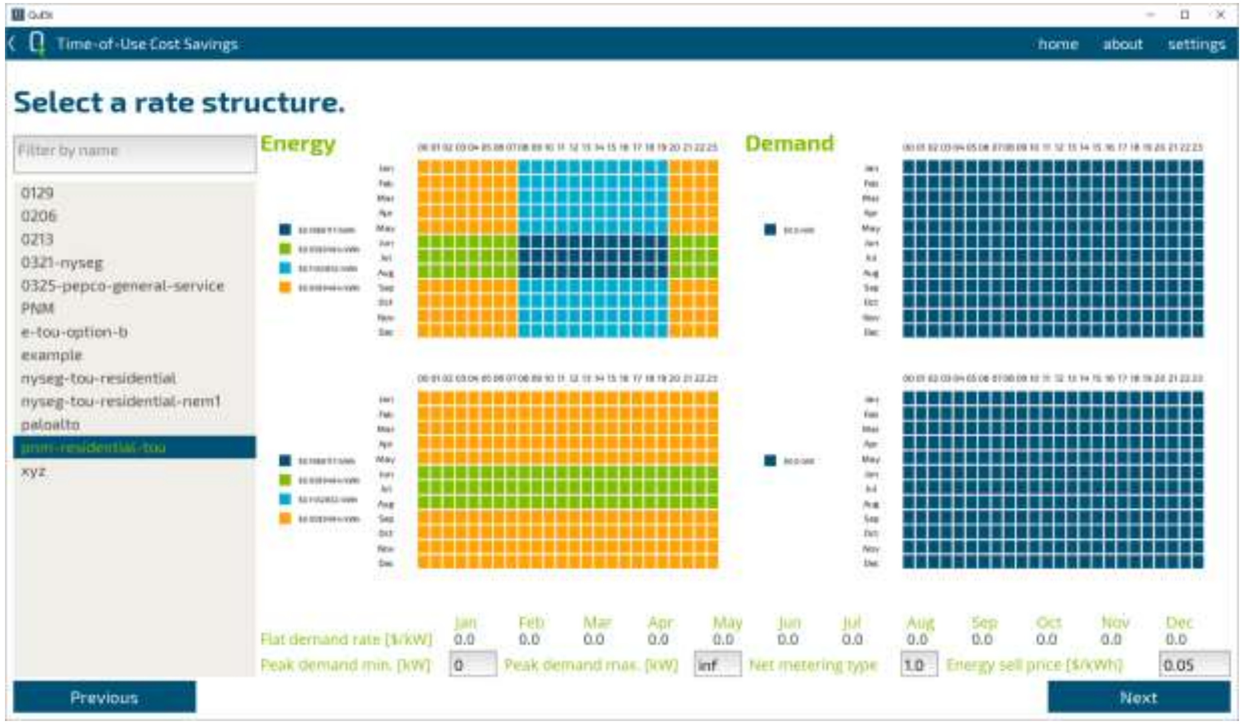
- Set up the analysis and run it
- View and process results

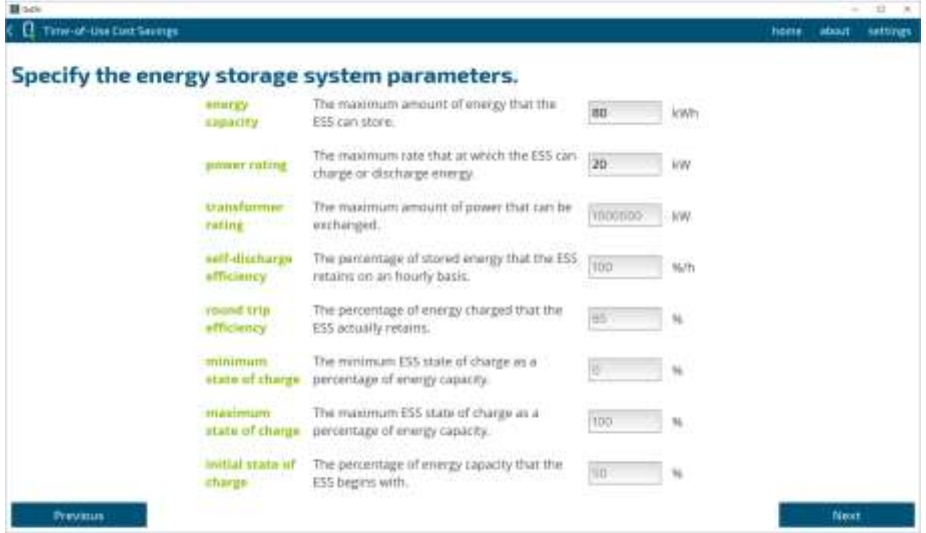
QuESt – Valuation Application

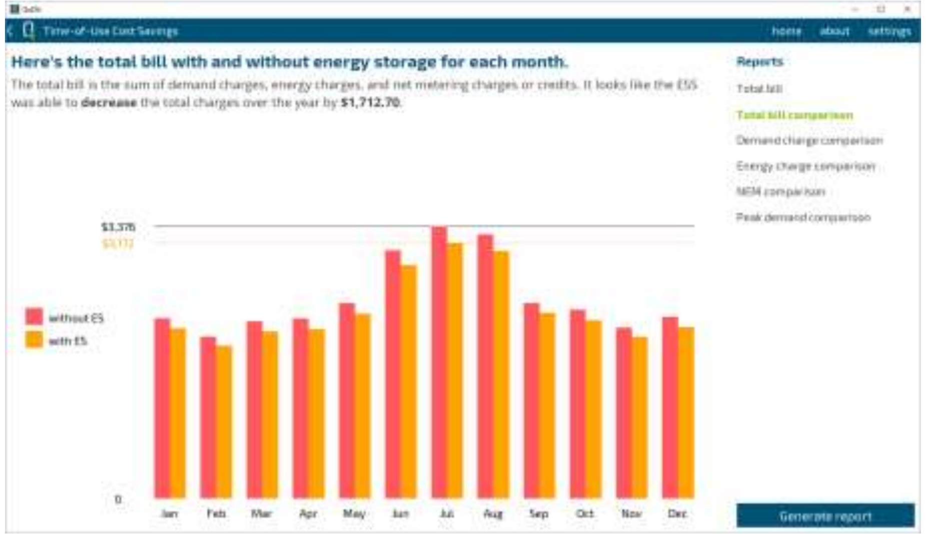




QuESt – BTM Application







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