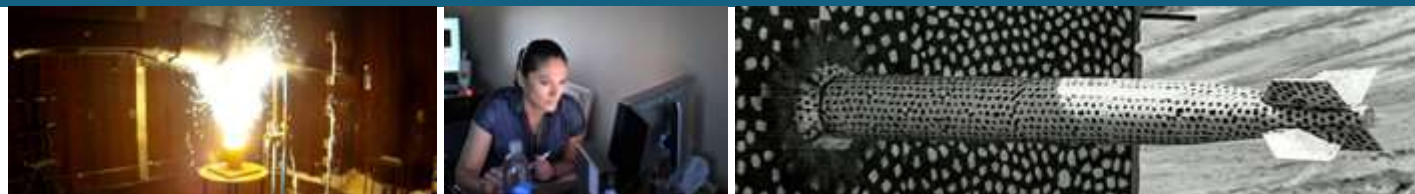




EVALUATION OF ENERGY STORAGE AND SOFTWARE TOOLS



PRESENTED BY

Tu A. Nguyen

2021 Energy Storage Workshop - ICC



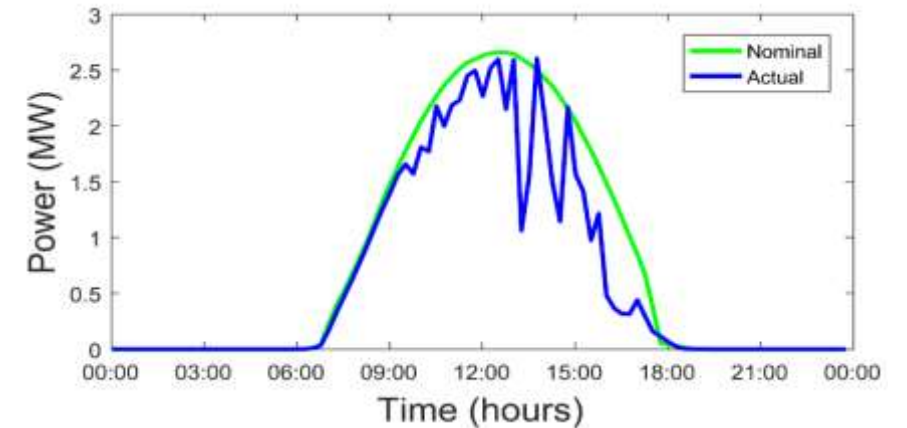
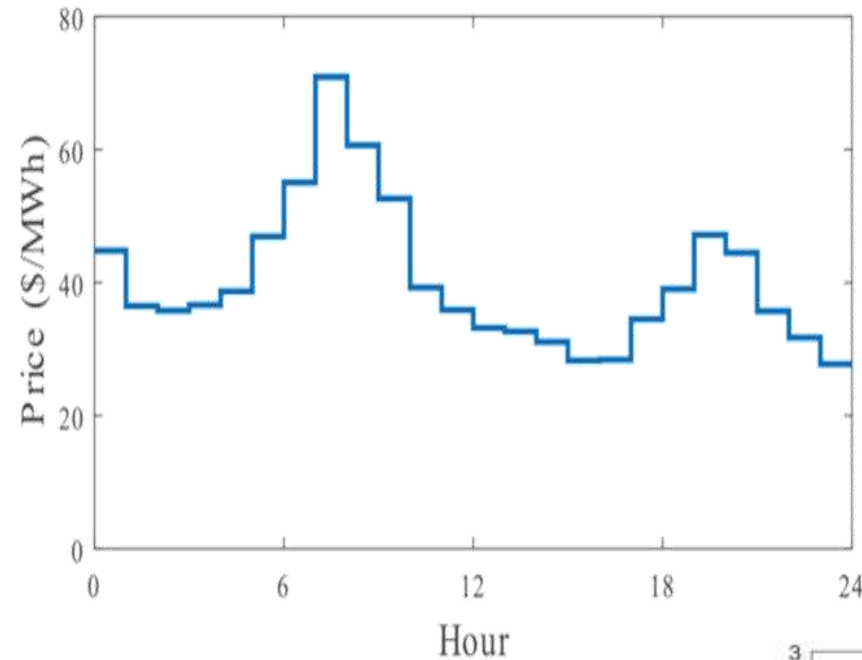
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- Energy storage applications
- Energy storage technology selection
- Energy storage valuation:
 - Market
 - Behind-the-meter
 - Energy equity
 - System performance
- QuESSt – Energy storage application suite
 - Overview
 - QuESSt – valuation
 - QuESSt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

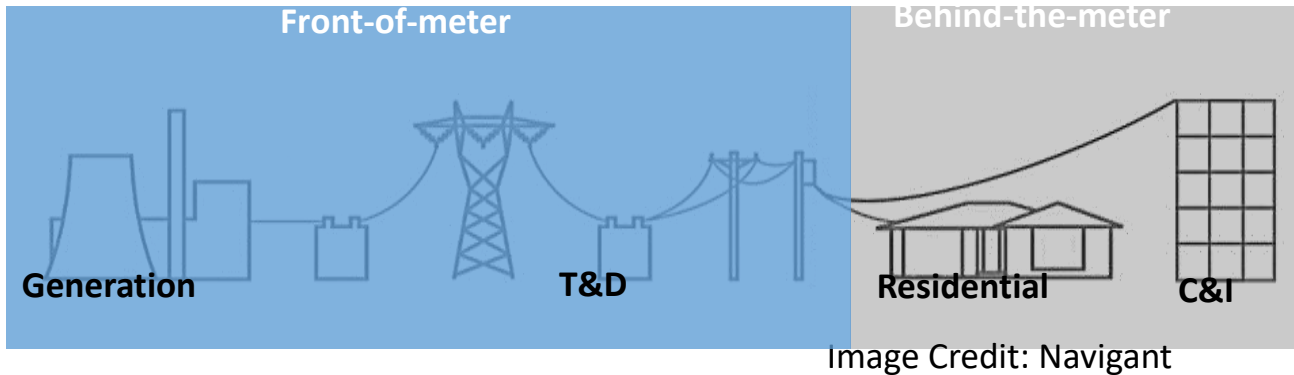
Energy Storage Applications – Power vs. Energy



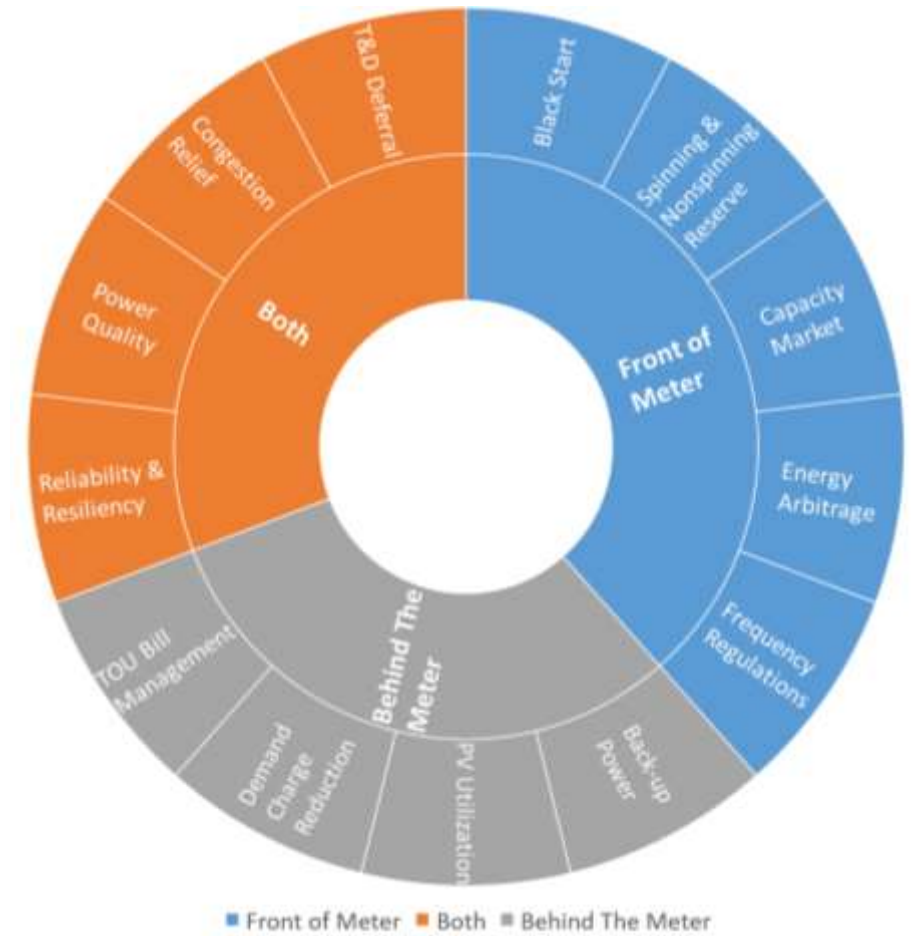
- Power applications
 - Frequency regulation
 - Voltage support
 - Small signal stability
 - Renewable smoothing
- Energy applications
 - Energy arbitrage
 - Renewable energy time shift
 - Customer demand charge reduction
 - Transmission and distribution upgrade deferral



Energy Storage Applications – FTM vs. BTM



- **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.



- 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.



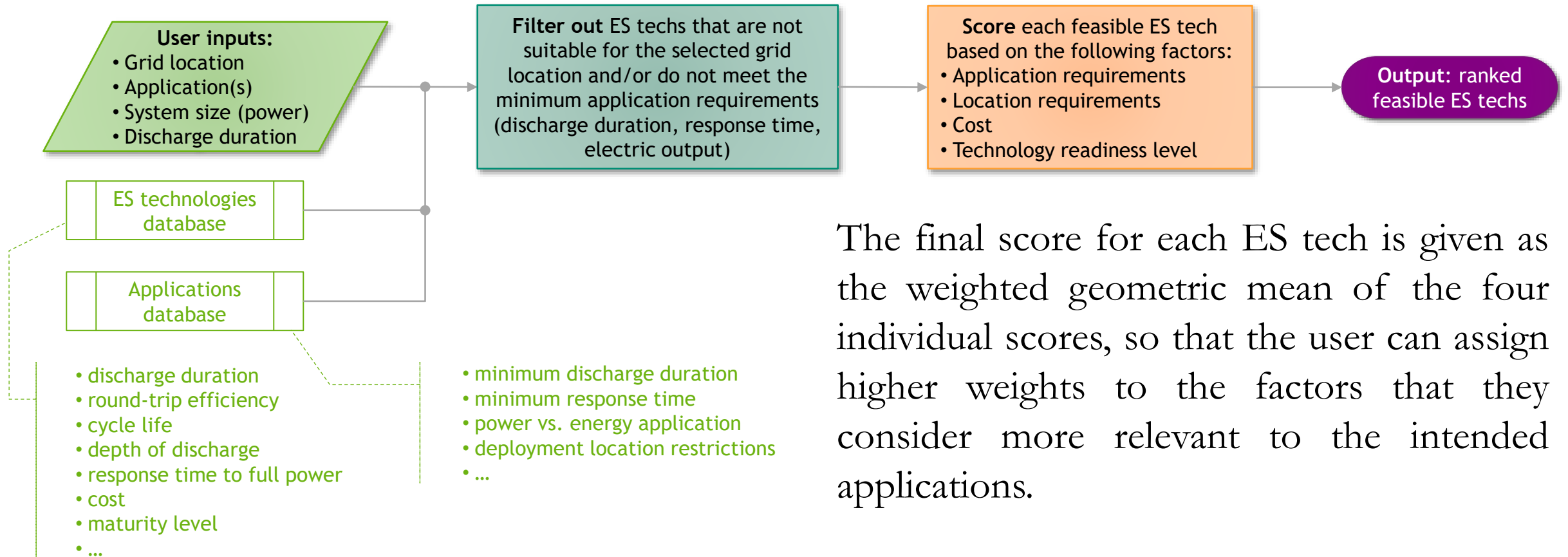
Energy Storage Technology Selection



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)



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.

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?

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

subject to:

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

$$0 \leq s_i \leq \bar{S}$$

$$q_i^d + q_i^r + q_i^{ru} + q_i^{rd} \leq \bar{Q}$$

state of charge definition

state of charge limits

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

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

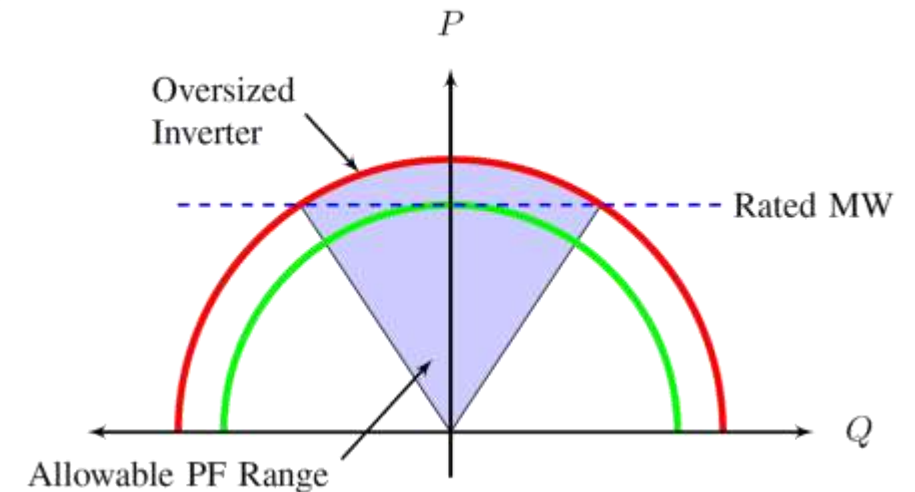
$$\min\{C_E^m + C_N^m + C_D^m\}$$

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 .

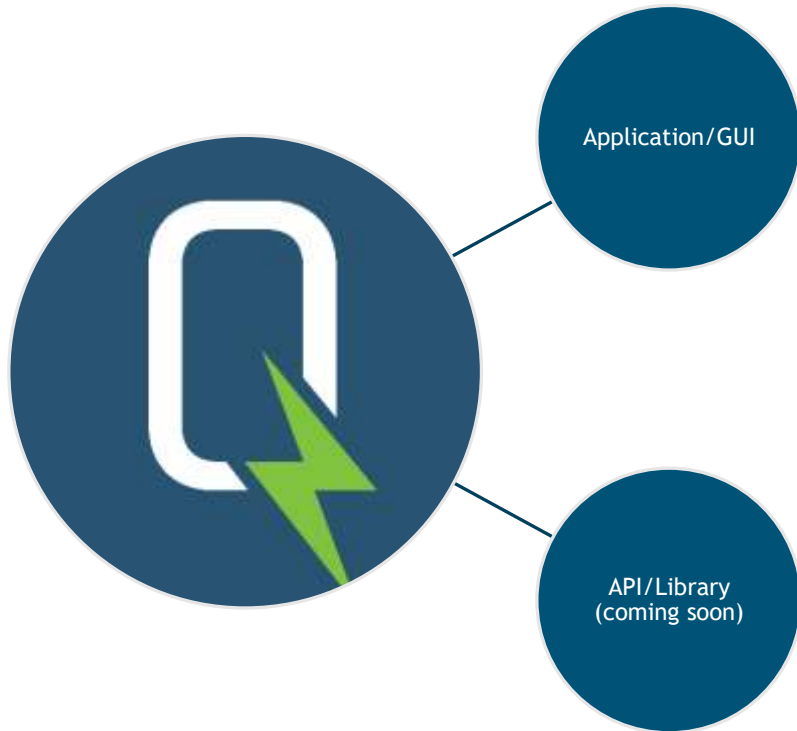




Given a Peaker loading profile, what are the optimal sizes of PV and storage for 1-to-1 replacement of that plant? What are the benefits for the environment?

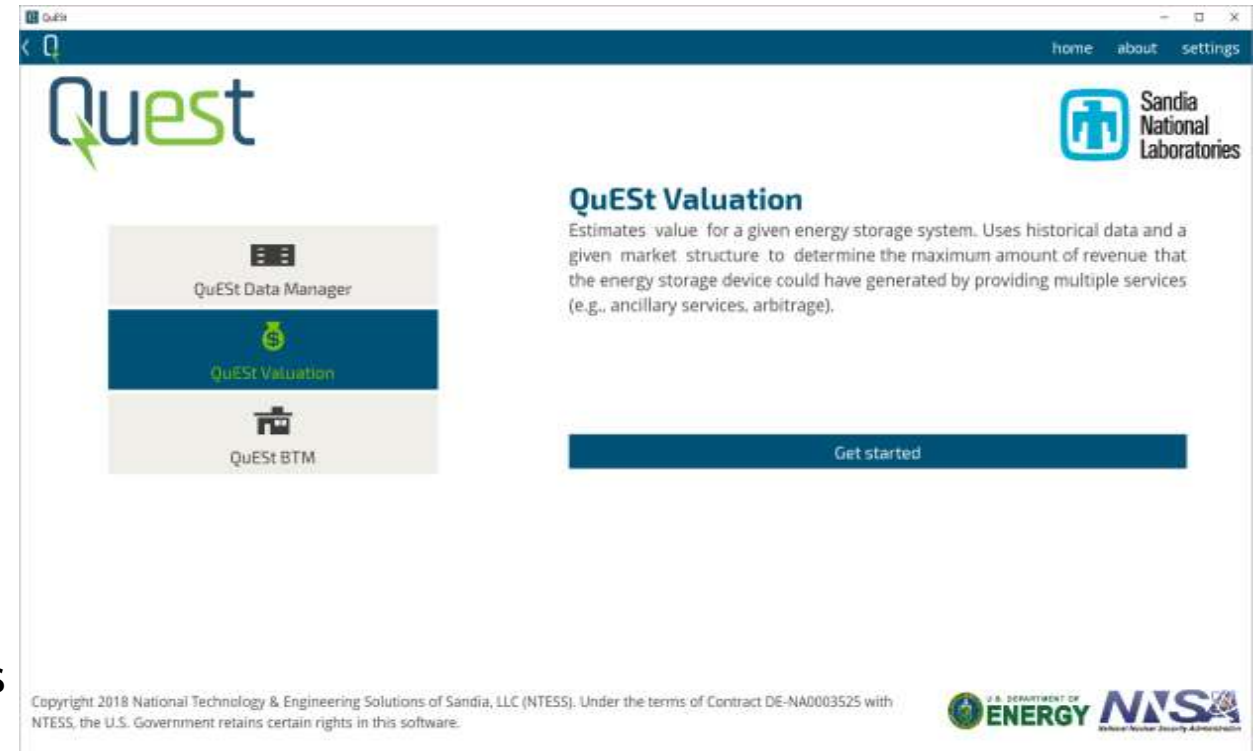
Given a charge/discharge profile of a BESS, how much energy is needed to run the HVAC that maintain system temperature within its operating range? What is the optimal size of the BESS considering the HVAC load?

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

home about settings

QuESt

Sandia National Laboratories

QuESt Data Manager

QuESt Valuation

QuESt BTM

QuESt Valuation

Estimates value for a given energy storage system. Uses historical data and a given market structure to determine the maximum amount of revenue that the energy storage device could have generated by providing multiple services (e.g., ancillary services, arbitrage).

Get started

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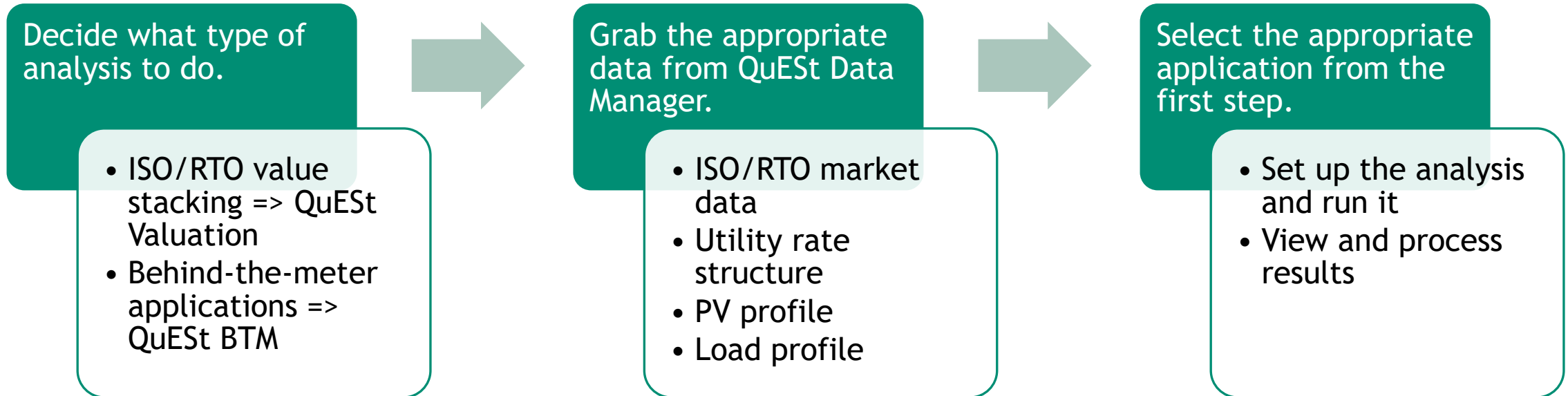
U.S. DEPARTMENT OF ENERGY NISA

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 – Valuation Application

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

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) 100.0

round trip efficiency (%) 90.0

energy capacity (MWh) 24.0

power rating (MW) 36.0

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

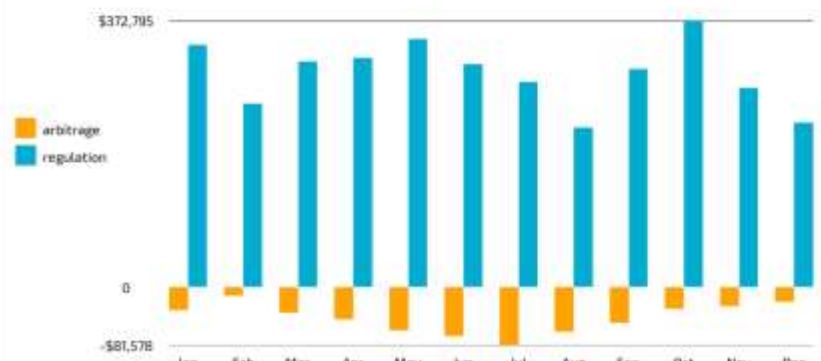
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Here's how the device generated revenue each month.

Revenue was generated based on participation in the selected revenue streams. The **gross revenue** generated over the evaluation period was **\$3,064,793.94**. The **gross revenue from arbitrage** was **-\$526,420.06**, an overall deficit. This implies participation in arbitrage was solely for the purpose of having capacity to offer regulation up services.

Reports

- Revenue (by month)
- Revenue (by stream)**
- Participation (total)
- Participation (by month)



Generate report

QuESt – BTM Application



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
- pefolta
- pnm-residential-tou**
- XYZ

Energy

Demand

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) 0 Peak demand max. (kW) inf Net metering type 1.0 Energy sell price (\$/kWh) 0.05

Previous Next

QuESt Time-of-Use Cost Savings home about settings

Specify the energy storage system parameters.

- energy capacity** The maximum amount of energy that the ESS can store. kWh
- power rating** The maximum rate that at which the ESS can charge or discharge energy. kW
- transformer rating** The maximum amount of power that can be exchanged. kW
- self-discharge efficiency** The percentage of stored energy that the ESS retains on an hourly basis. %
- round trip efficiency** The percentage of energy charged that the ESS actually retains. %
- minimum state of charge** The minimum ESS state of charge as a percentage of energy capacity. %
- maximum state of charge** The maximum ESS state of charge as a percentage of energy capacity. %
- initial state of charge** The percentage of energy capacity that the ESS begins with. %

Previous Next

QuESt Time-of-Use Cost Savings home about settings

Here's the total bill with and without energy storage for each month.

The total bill is the sum of demand charges, energy charges, and net metering charges or credits. It looks like the ESS was able to **decrease** the total charges over the year by **\$1,712.70**.

Reports

- Total bill
- Total bill comparison**
- Demand charge comparison
- Energy charge comparison
- NEM comparison
- Peak demand comparison

Generate report

Acknowledgements



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