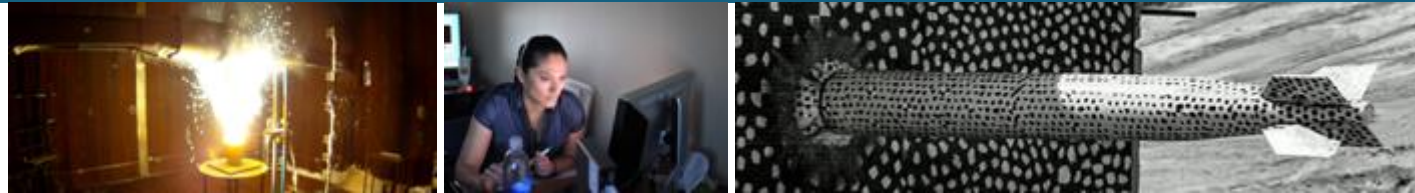


QuEST: Evaluation of Energy Storage



PRESENTED BY

Walker Olis

2023 DOE ENERGY STORAGE FINANCING SUMMIT



Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

- 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.



QuEST - Overview



home about settings

Quest

New or returning user?
Take a quick tour

Sandia National Laboratories

QuEST Valuation

Estimates value for an energy storage system providing ISO/RTO services. Uses historical data to determine the maximum amount of revenue that the energy storage system could have generated by stacking multiple services/value streams (e.g., ancillary services, energy arbitrage). This retrospective analysis estimates value from future cash flows.

Get started

QuEST Data Manager

QuEST Performance

QuEST Valuation

Technology Selection

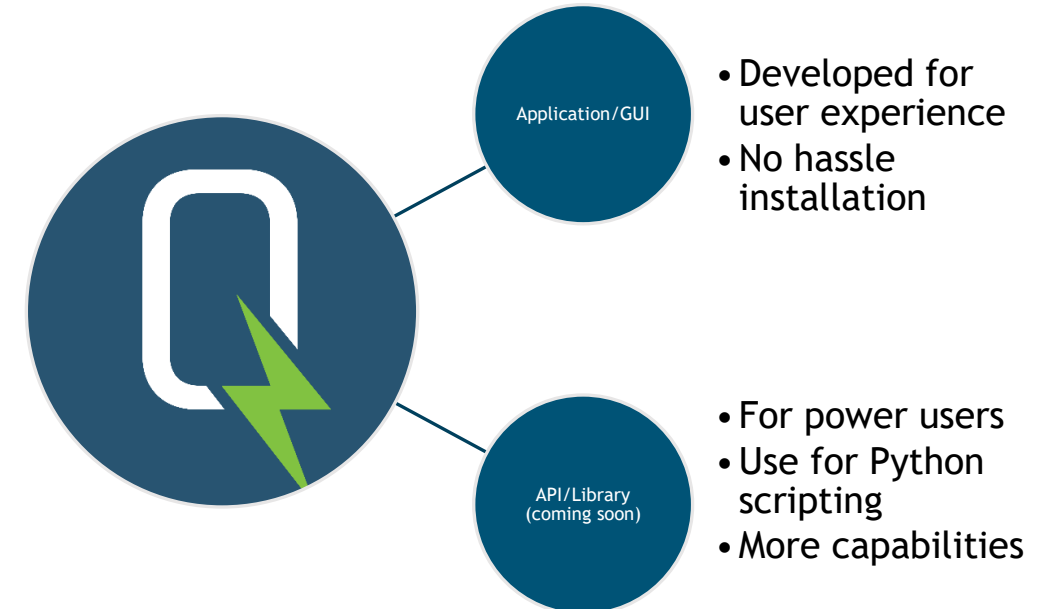
QuEST BTM

QuEST Equity

Version 1.6 available on GitHub: <https://github.com/snl-quest/snl-quest>

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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

Current (v1.6):

- QuEST Data Manager
- QuEST Valuation
- QuEST BTM
- QuEST Tech Selection
- QuEST Performance

Alpha Release:

- QuEST Equity

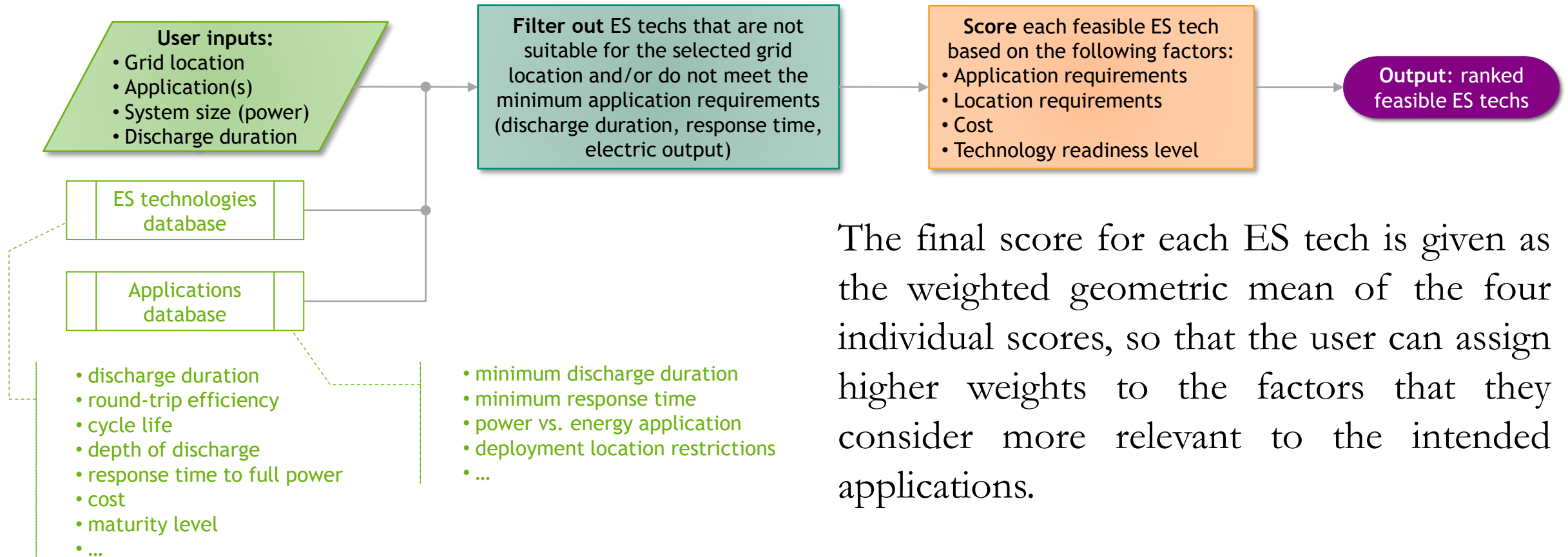
Energy Storage Technology Selection



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.

QuESt – Technology Selection



Welcome to the energy storage technology selection wizard!

This wizard will guide you through the process of identifying feasible energy storage technologies for a given project. Based on user inputs and pre-loaded databases that contain parameters to characterize multiple energy storage technologies and their grid applications, this tool identifies which storage technologies do not satisfy the minimum application requirements (such as discharge duration and response time). Then, the remaining feasible technologies are ranked to indicate their compatibility to the desired project.

The flowchart below depicts an overview of the steps performed during the energy storage technology selection analysis.

User inputs:

- Grid location
- Application(s)*
- System size (power)*
- Discharge duration*

1st filter: remove ES techs that are not suitable for the selected grid location

2nd filter: remove ES techs that are not suitable for the selected application (based on discharge duration, response time, electric output)

Scoring: for each ES tech vs. application pair, assign a score for each of the following factors:

- Application requirements
- Location requirements
- Cost
- Technology readiness level

Scoring: compute combined feasibility score considering the previous factors

Output: ranked feasible ES techs

*These inputs have default values according to the selected grid location

Get started

Energy Storage Technology Selection Application

Energy storage technologies feasibility

The plot below indicates whether each energy storage technology is a feasible option for your project.

	Grid location	Application requirements	Feasible?
Compressed-air energy storage	x	✓	x
Flow battery - Iron	✓	✓	✓
Flow battery - Zinc bromide	✓	✓	✓
Flywheel - Long duration	✓	✓	✓
Flywheel - Short duration	✓	x	x
Lead-acid	✓	✓	✓
Lead-carbon	✓	✓	✓
Lithium-ion	✓	✓	✓
Lithium-ion iron phosphate	✓	✓	✓
Lithium-ion nickel-manganese-cobalt	✓	✓	✓
Nickel	✓	✓	✓
Pumped hydro storage	x	✓	x
Sodium	✓	✓	✓
Vanadium redox flow	✓	✓	✓
Zinc	✓	✓	✓

Summary of user selections:

- Grid location: BTM: commercial/industrial
- Application: Retail TOU energy charges
- System size: 100 kW
- Discharge duration: 4 hrs

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Energy Storage Technology Selection Application

Ranking of feasible energy storage technologies

The plot below depicts the feasibility score of each energy storage technology for your project; higher scores indicate a better match between a technology and the requirements of your project. The *Adjustments* box allows users to modify some settings used for computing the total feasibility scores.

Summary of user selections:

- Grid location: BTM: commercial/industrial
- Application: Retail TOU energy charges
- System size: 100 kW
- Discharge duration: 4 hrs

Adjustments

Weights for each category:

- Application: 1.00
- Location: 1.00
- Cost: 1.00
- Maturity: 1.00

Target cost: 1000 \$/kWh \$/kW

Update scores

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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?

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

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

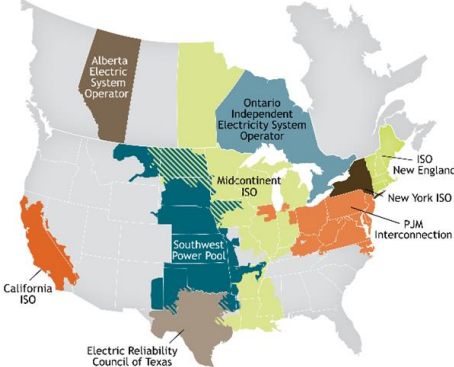
- Other constraints, such as requiring the final SoC to equal the initial SoC or reserving energy capacity for resiliency applications can be set.
- Varies based on market and available value streams

QuESt – Valuation Application

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

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) 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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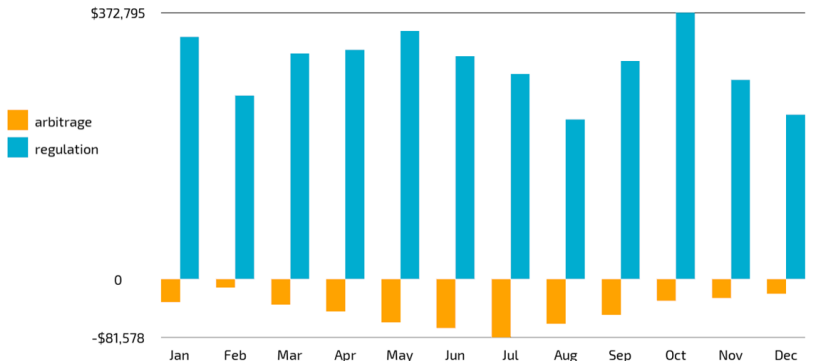
QuESt Wizard home about settings

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)



Month	Arbitrage	Regulation
Jan	-	~\$350,000
Feb	-	~\$250,000
Mar	-	~\$300,000
Apr	-	~\$300,000
May	-	~\$350,000
Jun	-	~\$300,000
Jul	-	~\$250,000
Aug	-	~\$150,000
Sep	-	~\$300,000
Oct	-	~\$370,000
Nov	-	~\$250,000
Dec	-	~\$200,000

Generate report

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

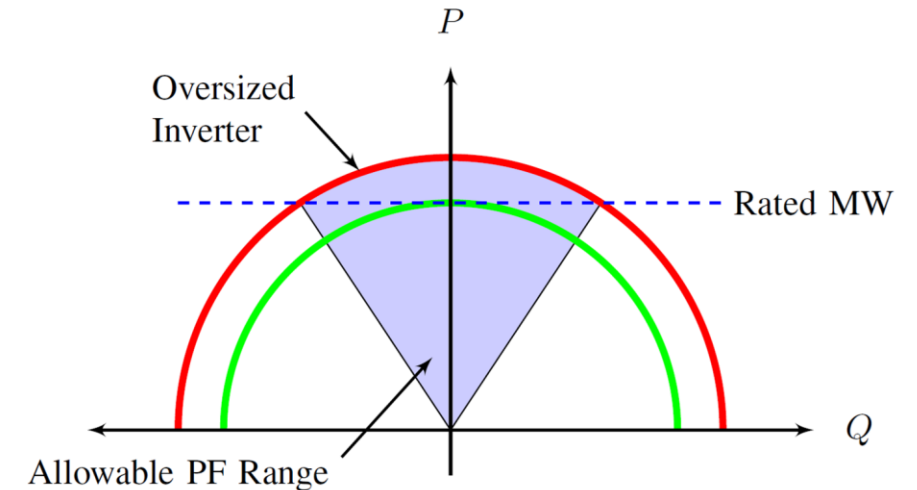
$$\min\{C_E^m + C_N^m + C_D^m\}$$

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 .



QuESt – BTM Application



Time-of-Use Cost Savings

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

00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23

Demand

00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23

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]

Time-of-Use Cost Savings

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. %/h
- 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. %

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Time-of-Use Cost Savings

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**.

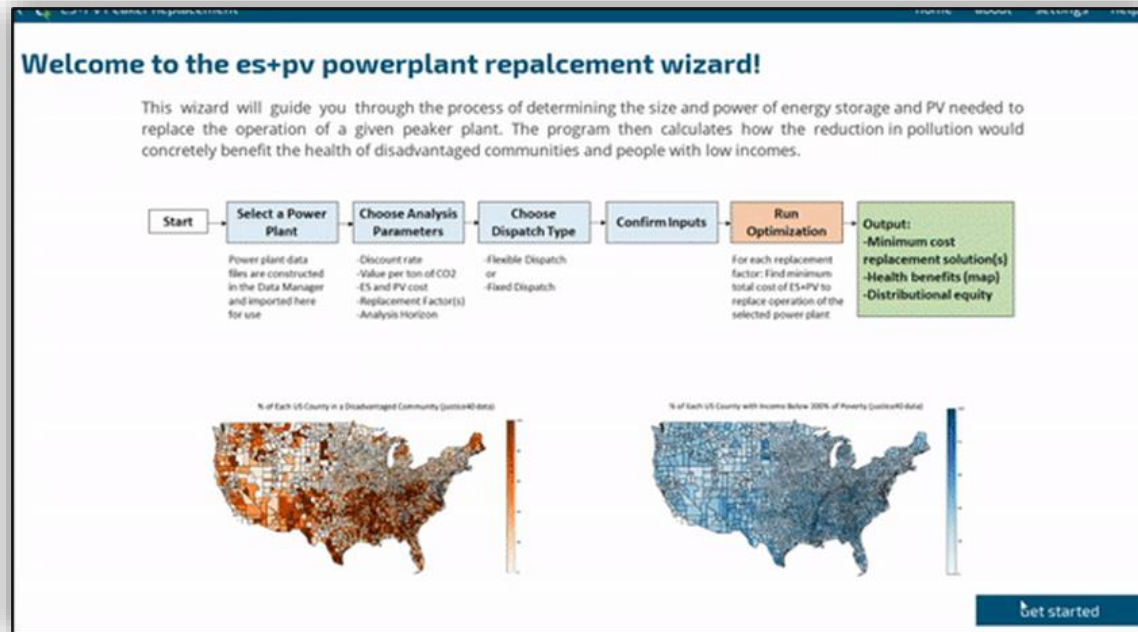
Month	without ES	with ES
Jan	\$3,376	\$3,172
Feb	\$3,376	\$3,172
Mar	\$3,376	\$3,172
Apr	\$3,376	\$3,172
May	\$3,376	\$3,172
Jun	\$3,376	\$3,172
Jul	\$3,376	\$3,172
Aug	\$3,376	\$3,172
Sep	\$3,376	\$3,172
Oct	\$3,376	\$3,172
Nov	\$3,376	\$3,172
Dec	\$3,376	\$3,172

Reports

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

Generate report

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 health and environmental benefits?

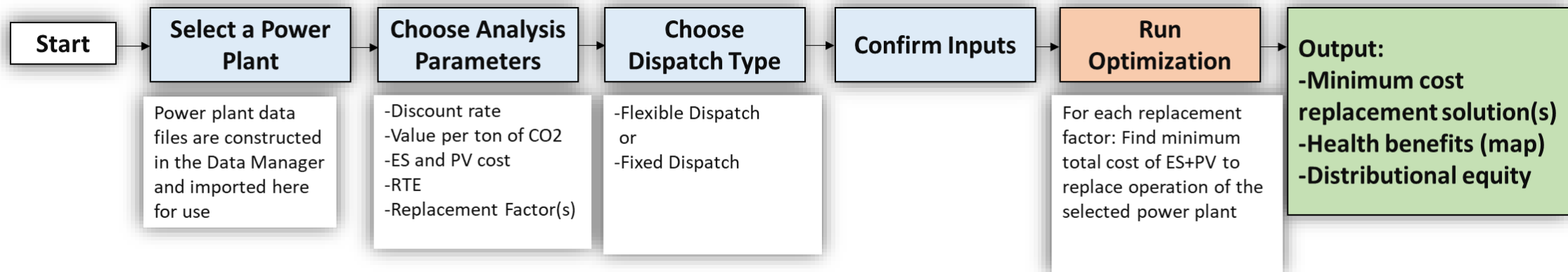


Inputs

- Powerplant Data File
- Battery and Analysis Parameters
- Dispatch Type Assumption

Outputs

- Minimum capital cost solution(s)
- Health Benefits
- Distributional Impacts



QuEST Performance

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? How does this affect expected performance and location?



QuEST Performance Simulations

Run performance simulations.

PTAC NY Valuation Jul 18, 2022 12:46:53

Select an input file

- 1ZoneUncontrolled_wESS_hvactemplate_ptacexp2.idf
- container_wESS_ptac.idf

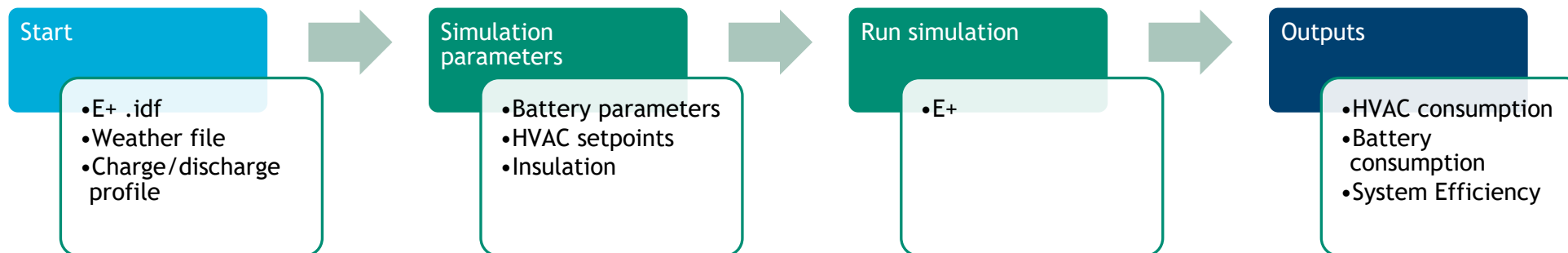
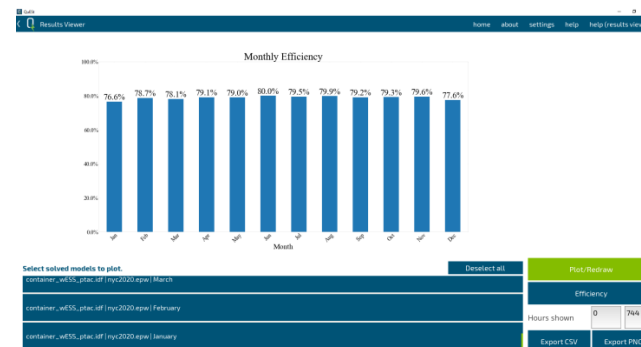
Select weather file

- nyc2020.epw

Select battery profile

- December
- November
- October
- September
- August
- July
- June
- May
- April
- March
- February
- January

Data Parameters Ready Go!





Example: 1MW, 1MWh Li-ion BESS located in NYC

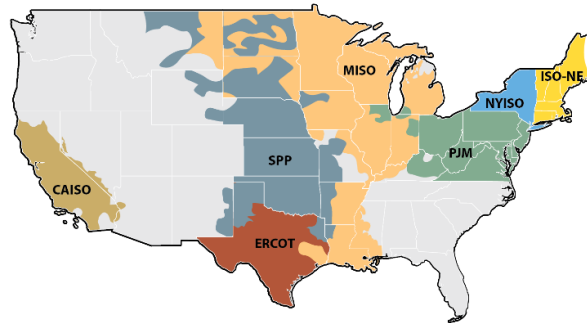
Prerequisites:

- NYISO NYC zone prices
- NYC weather data
- E+



Select a market area to place the energy storage device in.

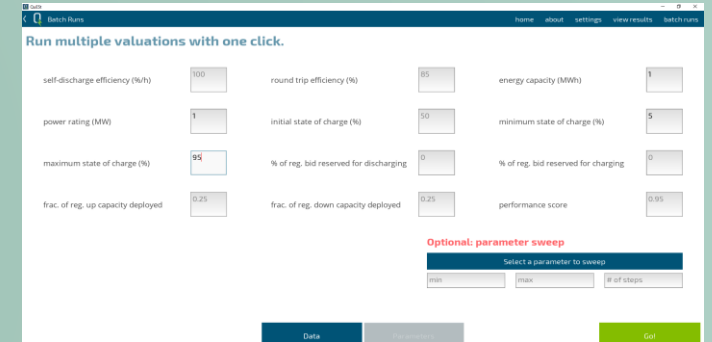
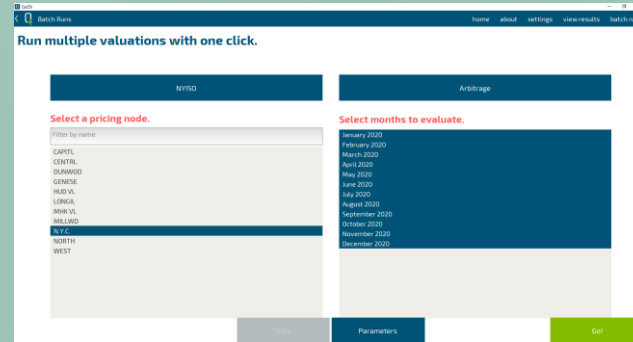
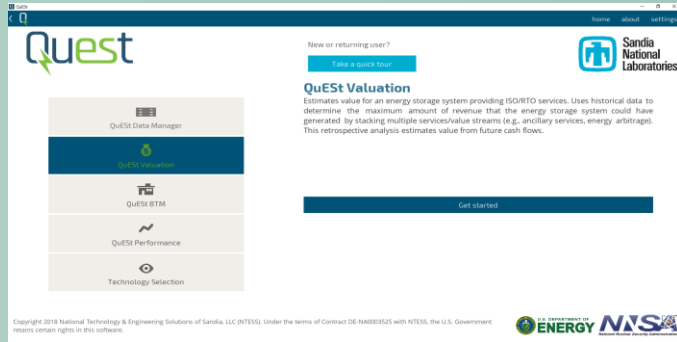
Different market areas can have different market structures, resulting in various opportunities for generating revenue.



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Example – QuEST Valuation and QuEST Performance

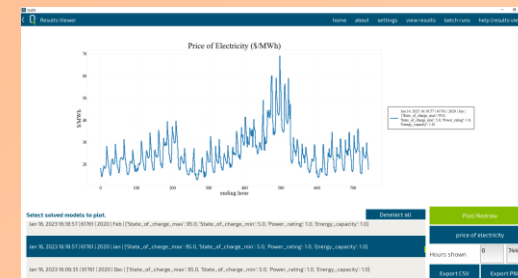
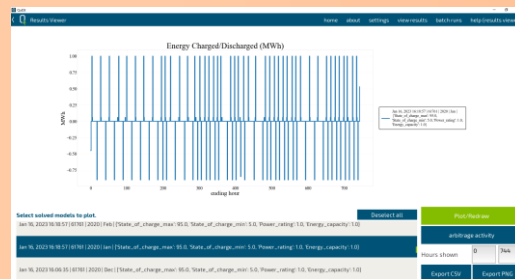
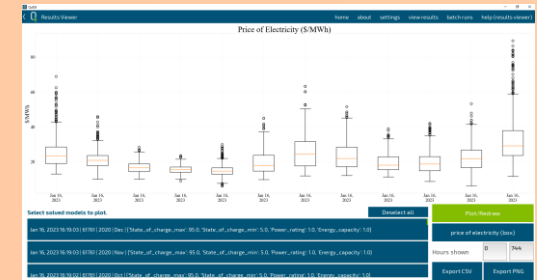
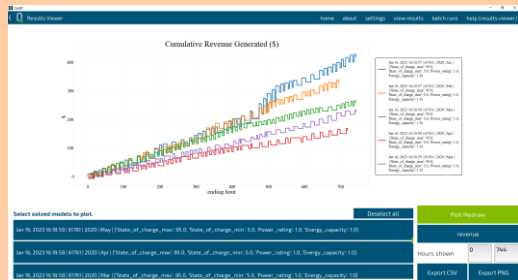


• Navigate to the QuEST Valuation tool.

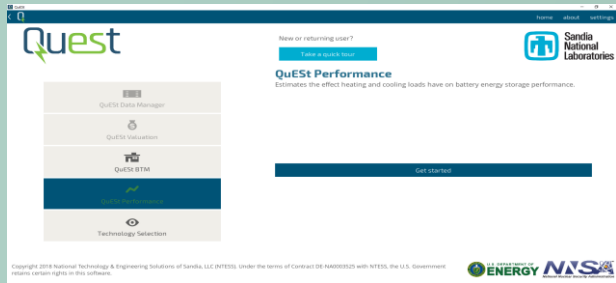
• Click on the Batch Runs Button -> select NYISO from the pull down options -> select N.Y.C. from the node options -> select arbitrage from the pull down options -> select all months of the year.

• Click the Parameters tab. Change the energy capacity to 1 MWh and the power rating to 1 MW. Change the minimum state of charge to 3% and the maximum state of charge to 95%.

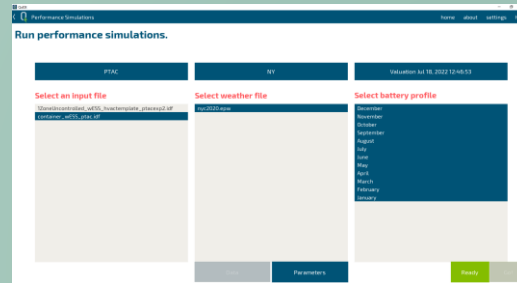
• Once everything looks correct, click Go! Once the simulations are finished, navigate back to the home page.



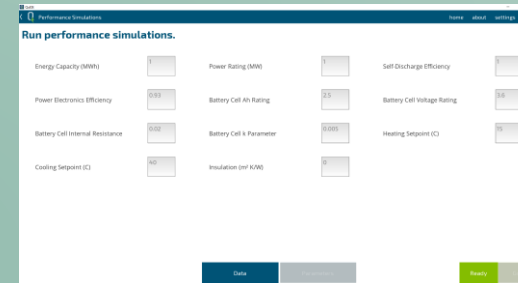
Example – QuEST Valuation and QuEST Performance



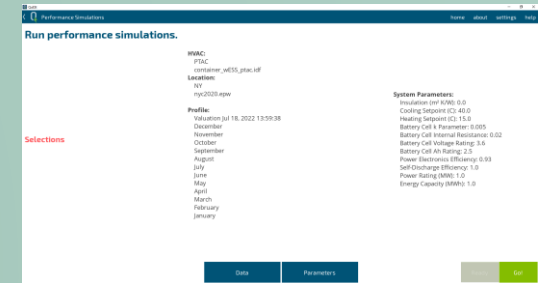
- Navigate to the QuEST Performance tool.



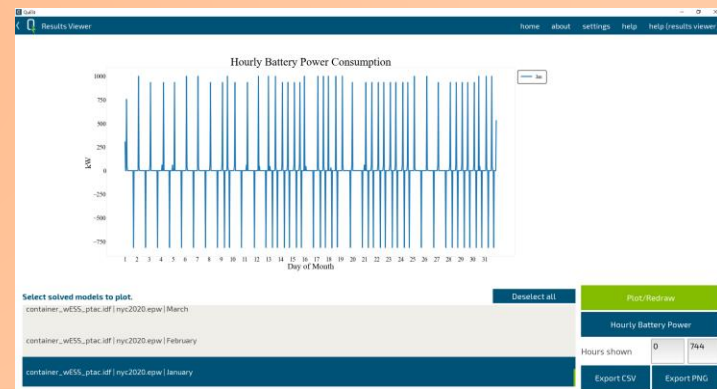
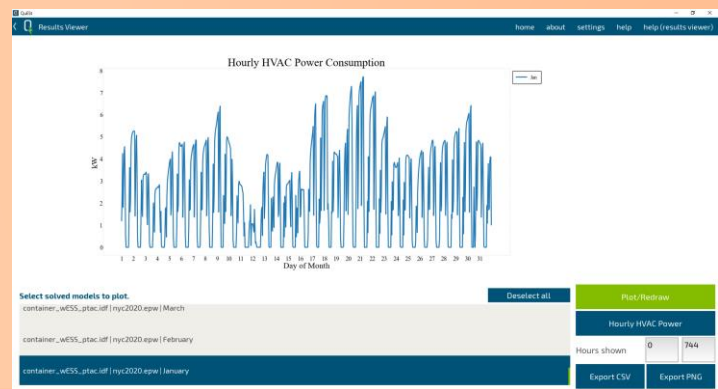
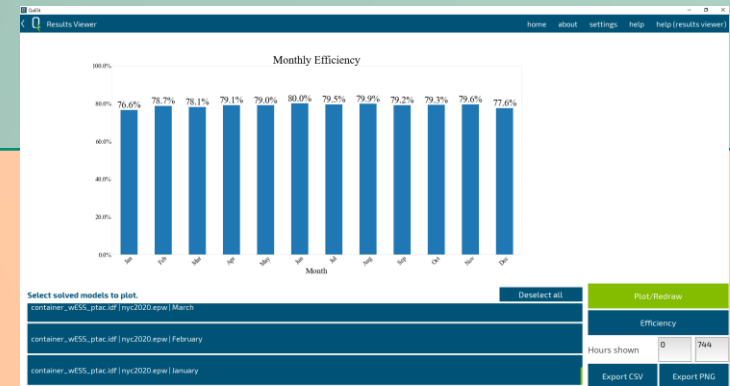
- Enter the Performance Simulations option. Select PTAC from the HVAC options. Select the provided input file describing a BESS in a shipping container. Select NY from the location dropdown. Select the weather file downloaded previously. Select the Valuation run from the Profile dropdown. Select the months available.



- Click the Parameters tab. Leave the default parameters as is, click the Ready Button.



- The selections made will be displayed. If everything looks correct, press Go!



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Thank You!

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