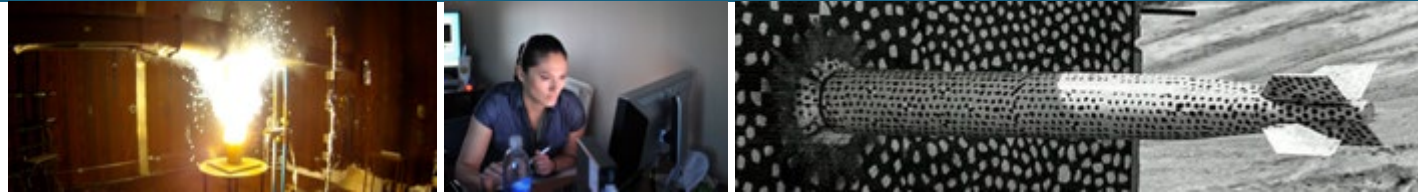
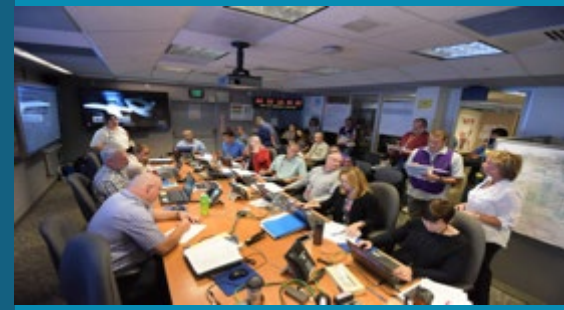


INTRODUCTION TO **Quest**



PRESENTED BY

Atri Bera

Vermont PUC Webinar Series

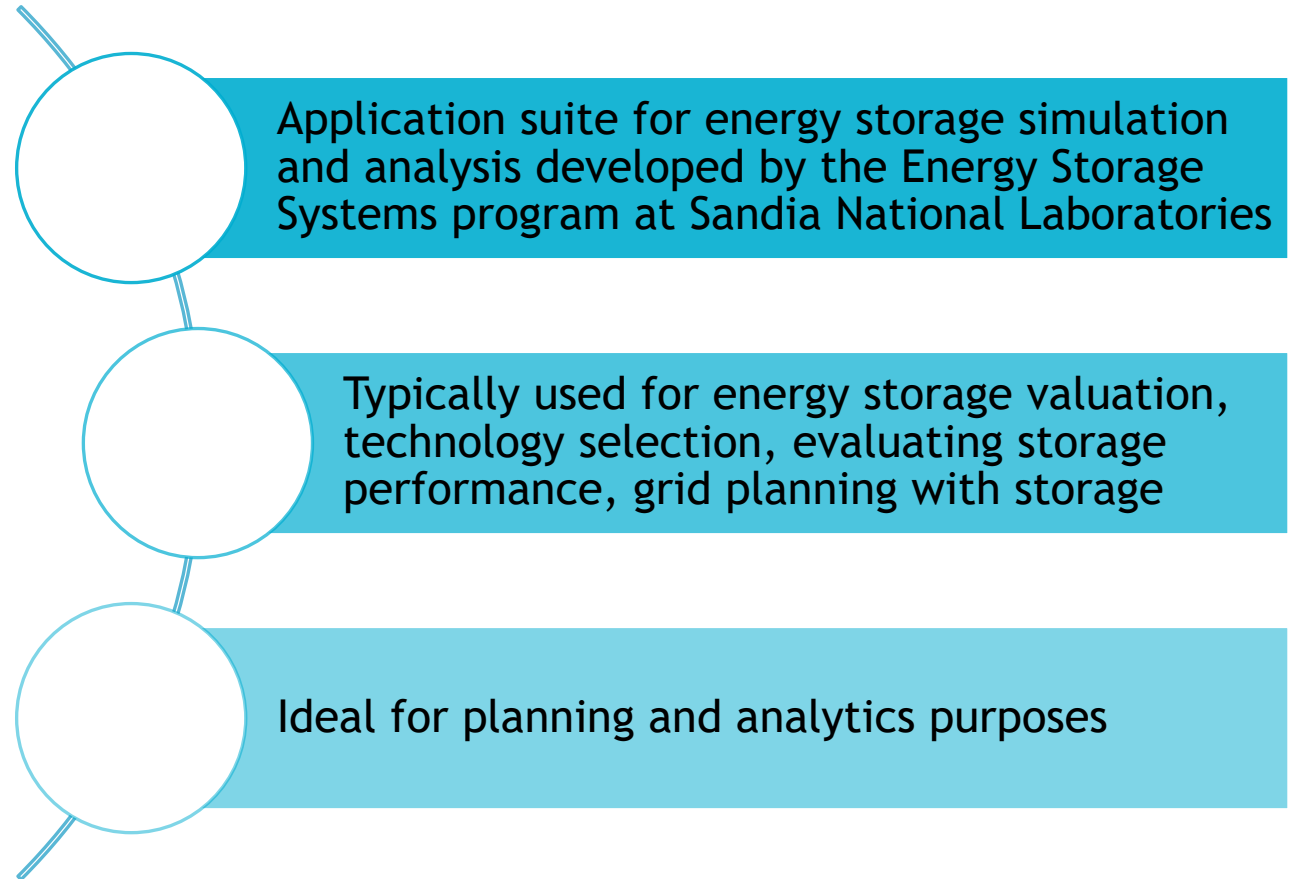


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SAND2023-11413C

- What is QuEST?
- 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

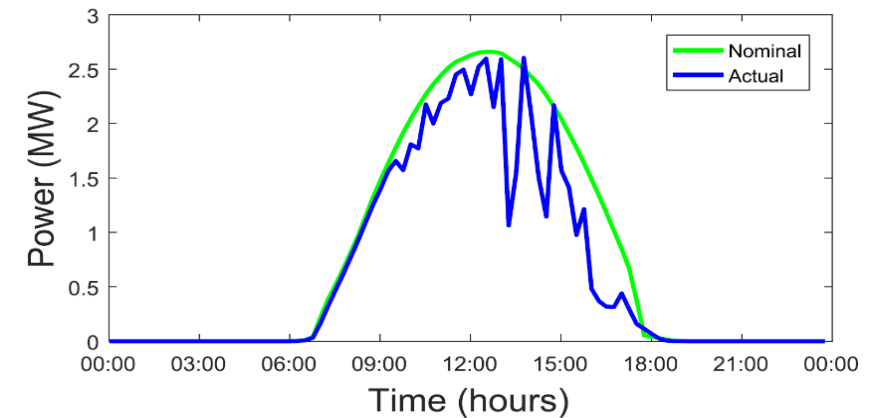
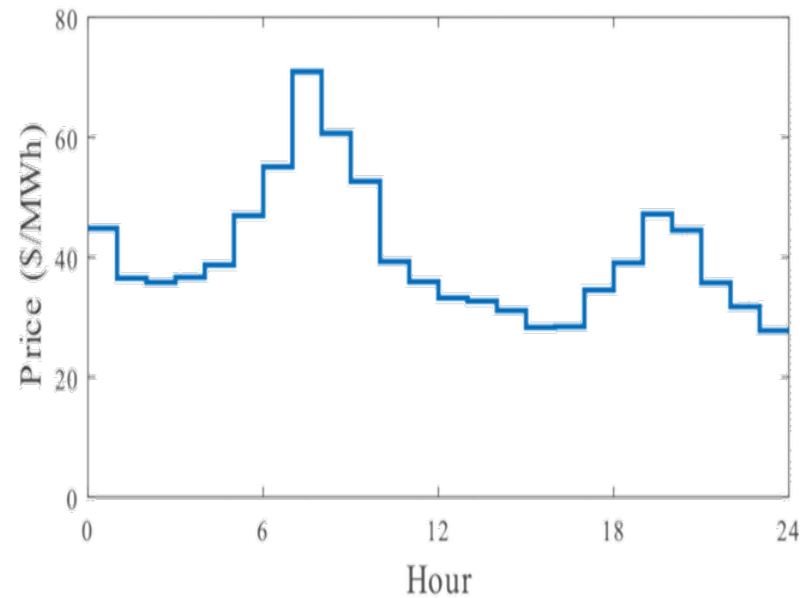
What is QuEST?



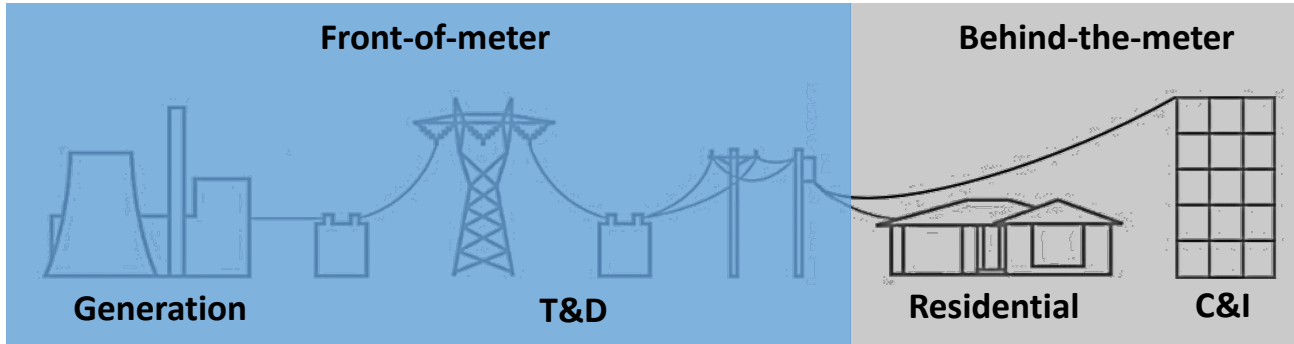
Energy Storage Applications – Power vs. Energy



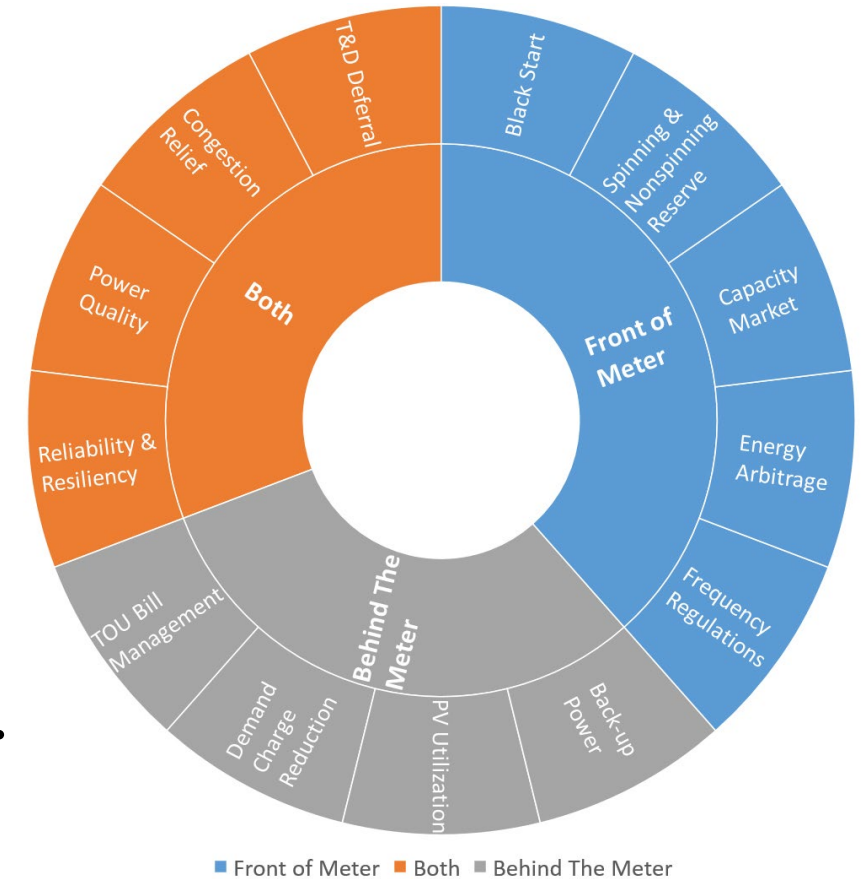
- Power applications
 - Frequency regulation
 - Voltage support
 - Small signal stability
 - Renewable smoothing
- Energy applications
 - Energy arbitrage
 - Renewable energy time shift
 - Customer demand charge reduction
 - Transmission and distribution upgrade deferral



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



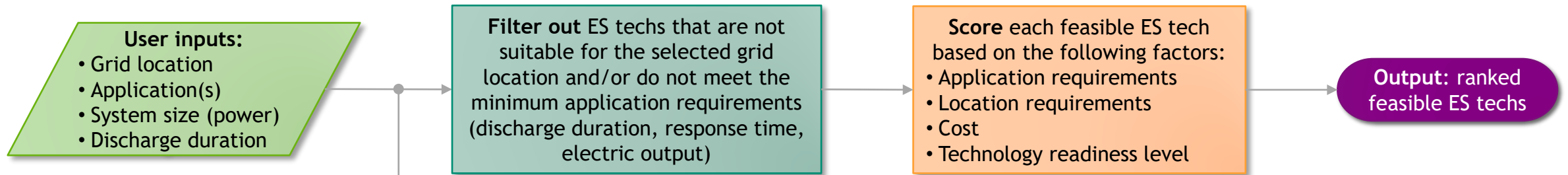
Energy Storage Technology Selection



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)



- discharge duration
- round-trip efficiency
- cycle life
- depth of discharge
- response time to full power
- cost
- maturity level
- ...

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

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?

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

subject to:

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

$$0 \leq s_i \leq \bar{S} \quad \text{state of charge limits}$$

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

- 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 (≤ 0) is the net metering charge of period m .

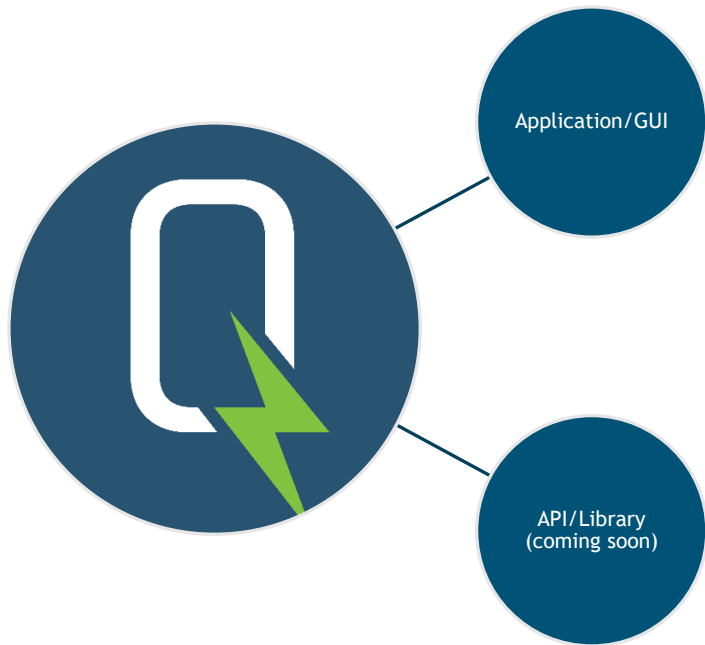
Energy Storage Valuation – Energy Equity and System Performance Problems



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

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- Energy storage analysis software application suite
- Version 1.0 publicly released in September 2018
- Version 1.6 available on GitHub
 - <https://github.com/sandialabs/snl-quest>



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Current:

- **QuEST Data Manager** - Manages acquisition of data.
- **QuEST Valuation** - Estimate potential revenue generated by energy storage systems providing ancillary 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.
- **QuEST Technology Selection** - Support storage technology selection given applications and other requirements
- **QuEST Performance** - Evaluate energy storage system performance in different climates

Next Release: QuEST Microgrid, QuEST Equity

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 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	-\$50,000	\$3,000,000
Feb	-\$50,000	\$2,500,000
Mar	-\$50,000	\$2,800,000
Apr	-\$50,000	\$2,900,000
May	-\$50,000	\$3,000,000
Jun	-\$50,000	\$2,800,000
Jul	-\$50,000	\$2,500,000
Aug	-\$50,000	\$2,200,000
Sep	-\$50,000	\$2,800,000
Oct	-\$50,000	\$3,200,000
Nov	-\$50,000	\$2,800,000
Dec	-\$50,000	\$2,500,000

Generate report

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

Legend: \$0.186617/kWh, \$0.0599494/kWh, \$0.1452852/kWh, \$0.0599494/kWh

Demand

Legend: \$0.0/kWh

Flat demand rate [\$/kWh] 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]

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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.

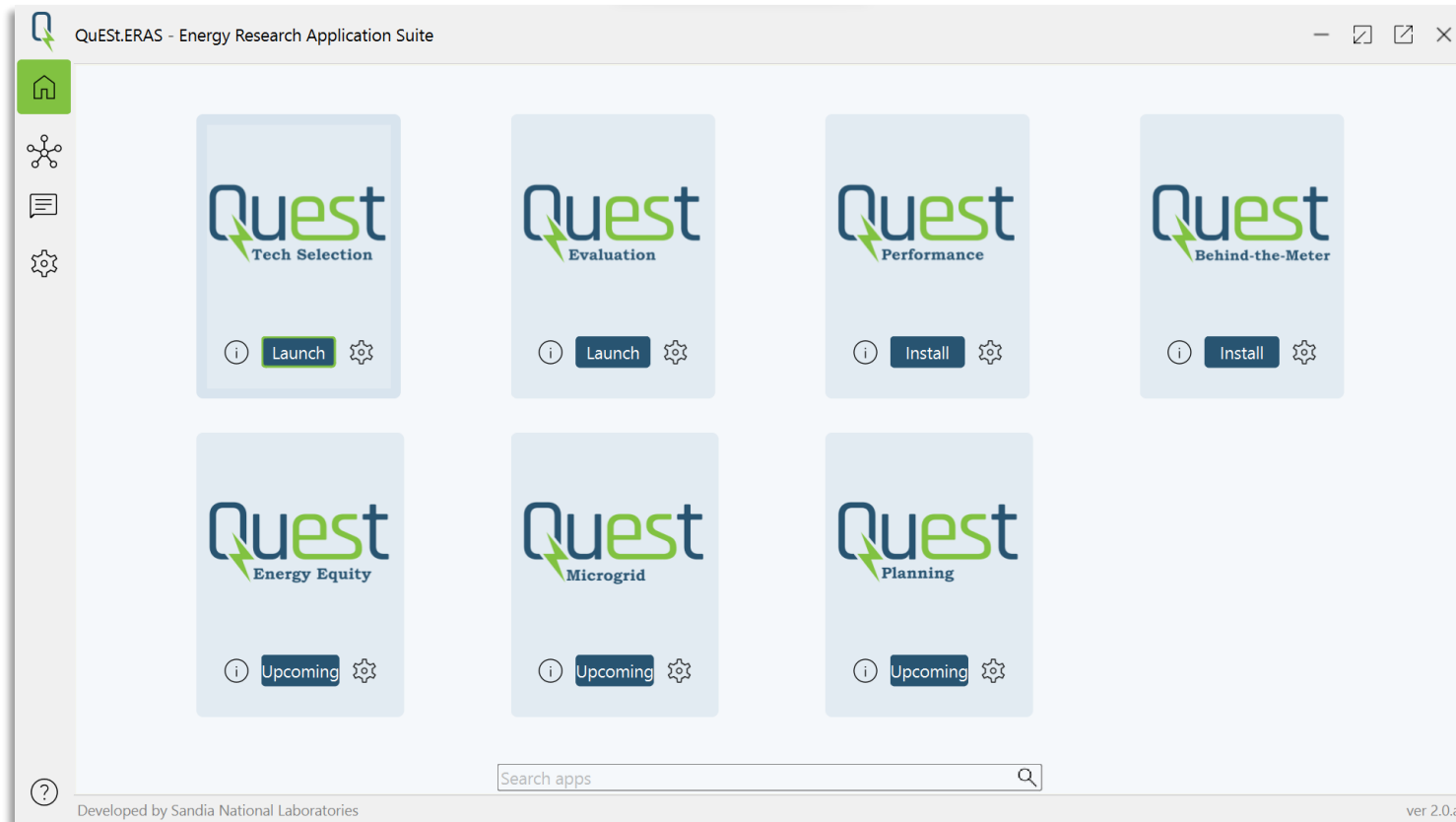
The total bill is the sum of demand charges, energy charges, and net metering charges or credits. It looks like the ESS was able to **decrease** the total charges over the year by **\$1,712.70**.

Legend: without ES (red), with ES (orange)

Reports

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

Generate report

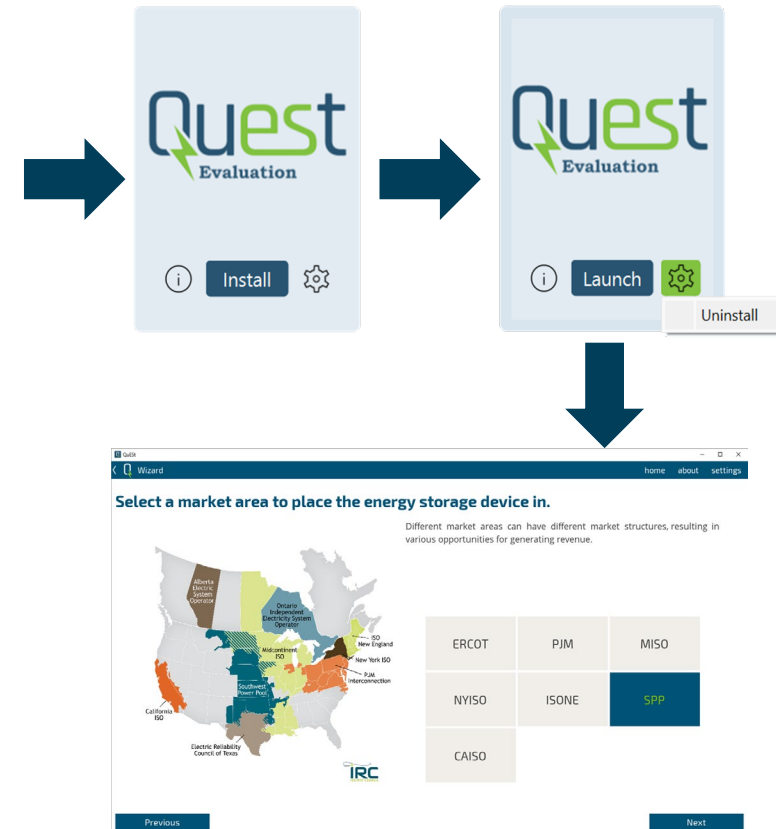
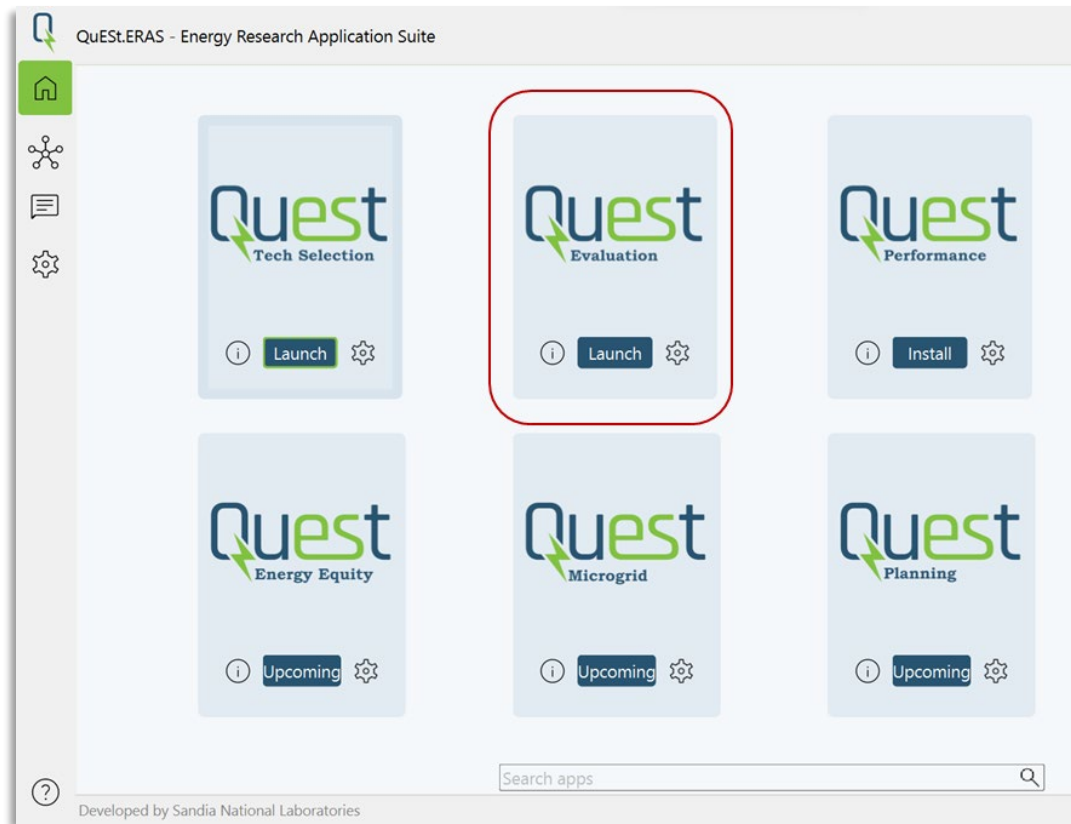


QuEST 2.0 includes 3 main components:

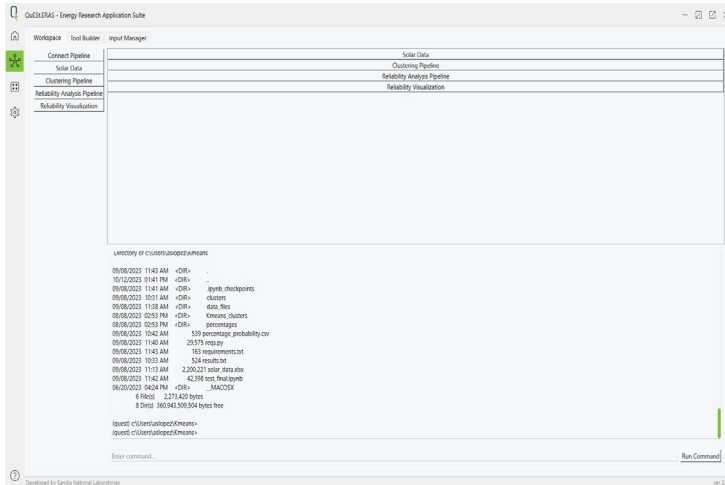
- QuEST App Hub works like an apps store that provides access points to multiple apps.
- QuEST Workspace provides an environment for integrating multiple apps into a work process
- QuEST GPT is a data analytic tool for the characterization and visualization of large datasets.

In Version 2.0, QuEST is being transformed from a software to a software platform.

QuEST App Hub

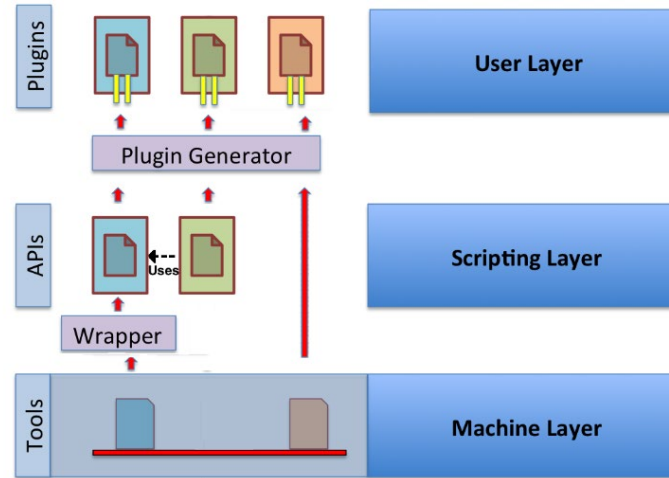


- **Main features:**
 - Users can find and install applications that suite their needs.
 - Installation initiates the creation of an isolated environment.
 - Each application runs in an isolated environment
 - Multiple applications can be installed and run simultaneously.



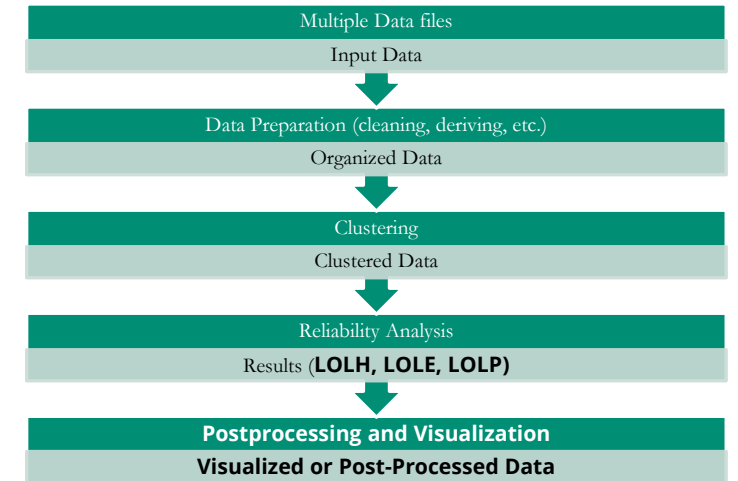
Workspace Overview

Workspace is where users can create work processes that integrate multiple apps by assembling pipelines using plugin extensions (Apps).



Conceptual Design of PluMA

Python, Perl and R plugins interface to the scripted layer of PluMA. Compiled plugins in C++ or CUDA to the computational (machine) layer.



Pipeline Example

Each stage in PluMA gets executed sequentially, with the output of a specific stage serving as input to a later stage of the pipeline.

Acknowledgements



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