

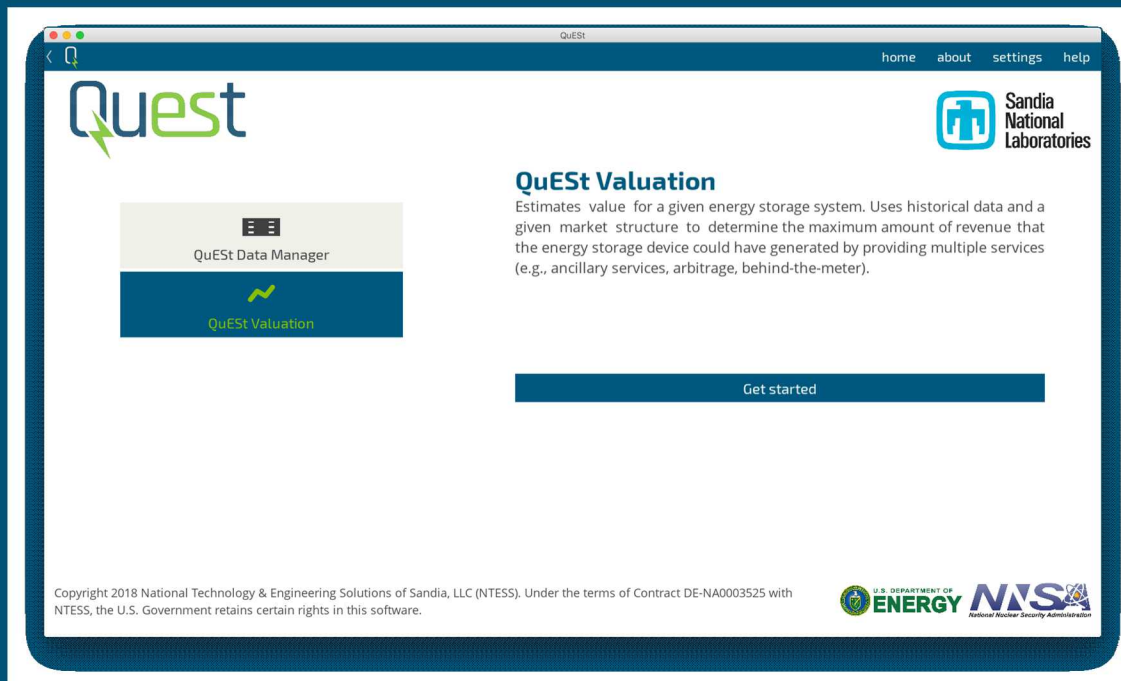


An Energy Storage Application Suite



PRESENTED BY

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- Open source, Python-based energy storage analysis software application suite
- Developed as a graphical user interface for the optimization modeling capabilities of SNL's energy storage analytics group
 - Early prototype was presented by David Copp at last year's peer review (2017)
- Initial development driven by Pyomo models for energy storage valuation
- Now publicly available on GitHub
 - github.com/rconcep/snl-quest



3 Energy storage valuation

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?

How much revenue could a flywheel plant located at the Houston pricing node in the ERCOT market have generated in the month of July 2016 by participating in energy arbitrage? What if it also provided frequency regulation services?

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

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.

The solution of the mathematical program is the optimal policy of managing state of charge based assuming perfect foresight of market conditions. The corresponding objective value is an upper bound.

The ValuationOptimizer class for wrapping Pyomo models

Idea: Create a Python class that abstracts away the details of Pyomo models (encapsulation) while also supporting an entire family of optimization models, e.g., energy storage valuation for every market area in the US.

ValuationOptimizer

```
+ market_type
+ solver
+ price_electricity
...
+ set_model_parameters()
+ run()
+ get_results()
```

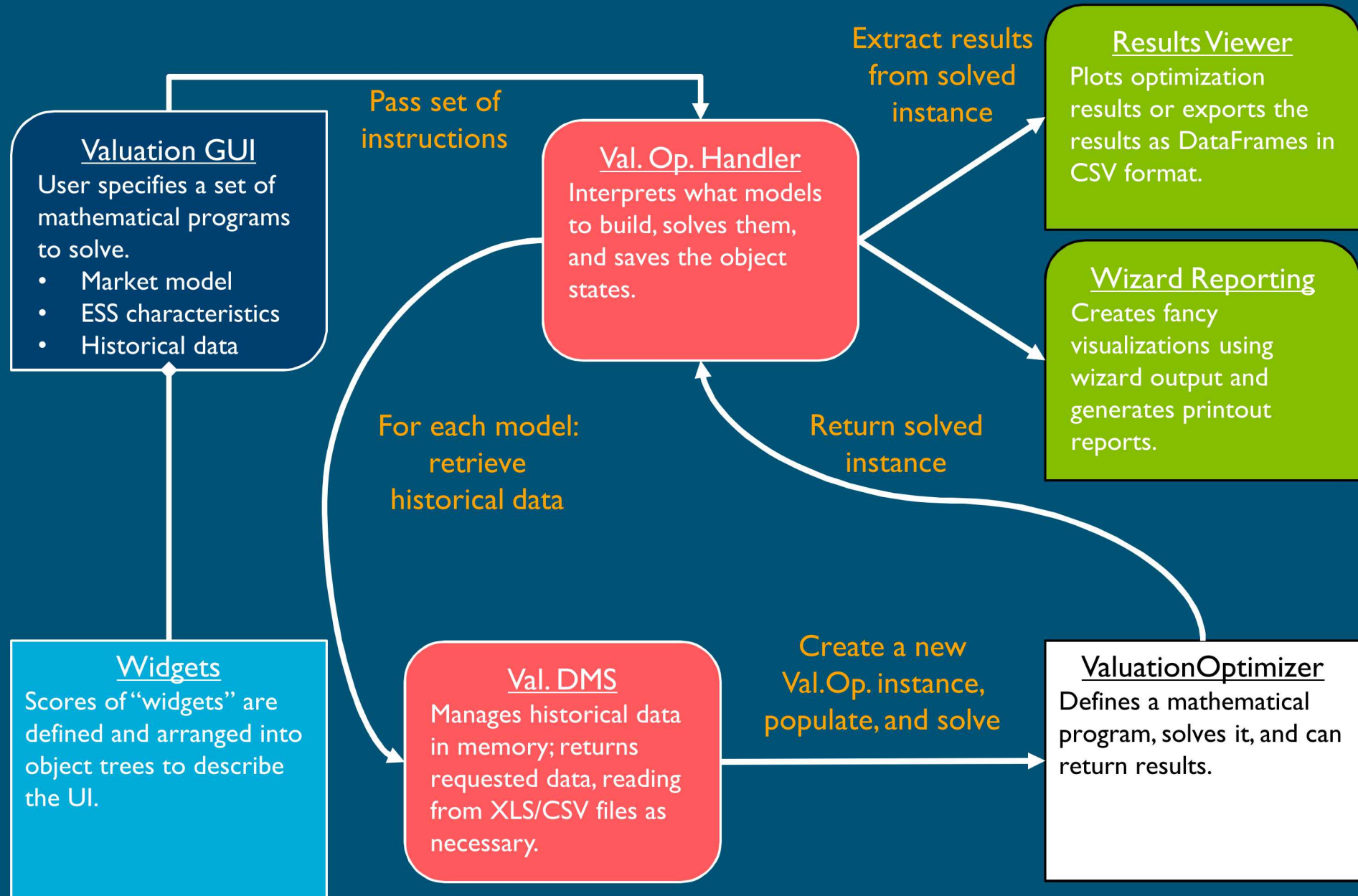
Builds a Pyomo model that you can solve and obtain the results from.

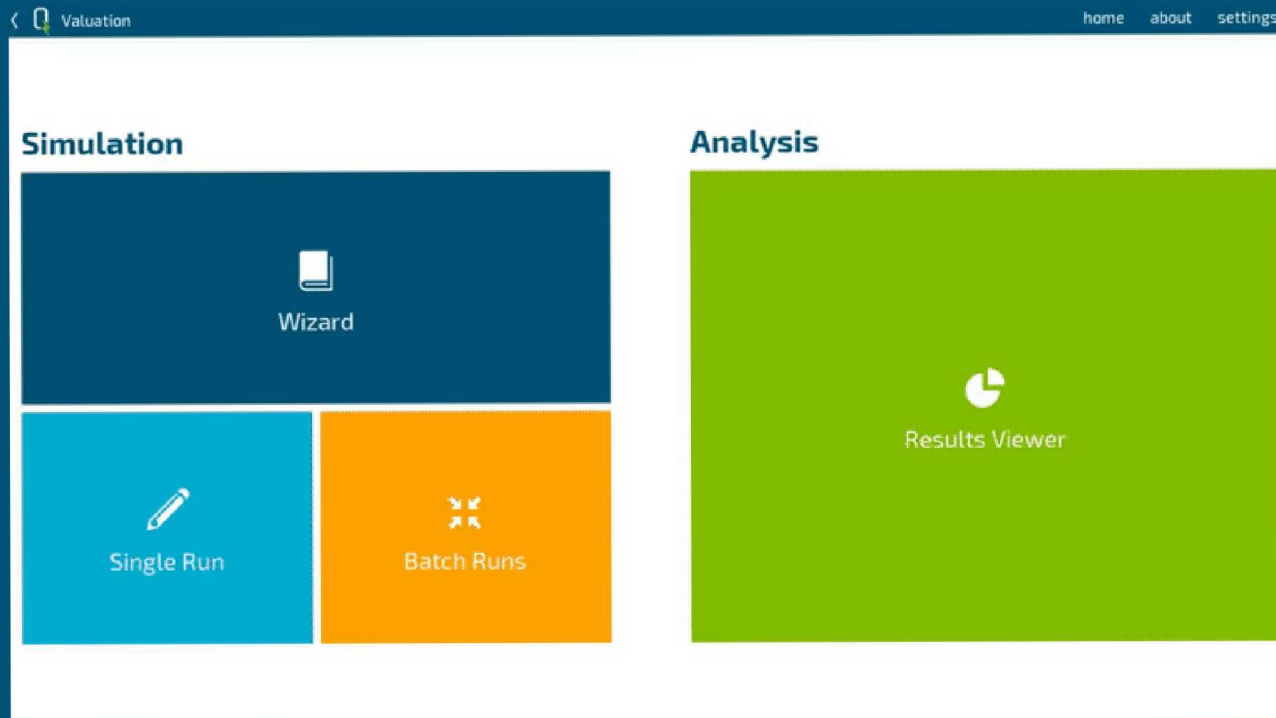
ExpressionsBlock

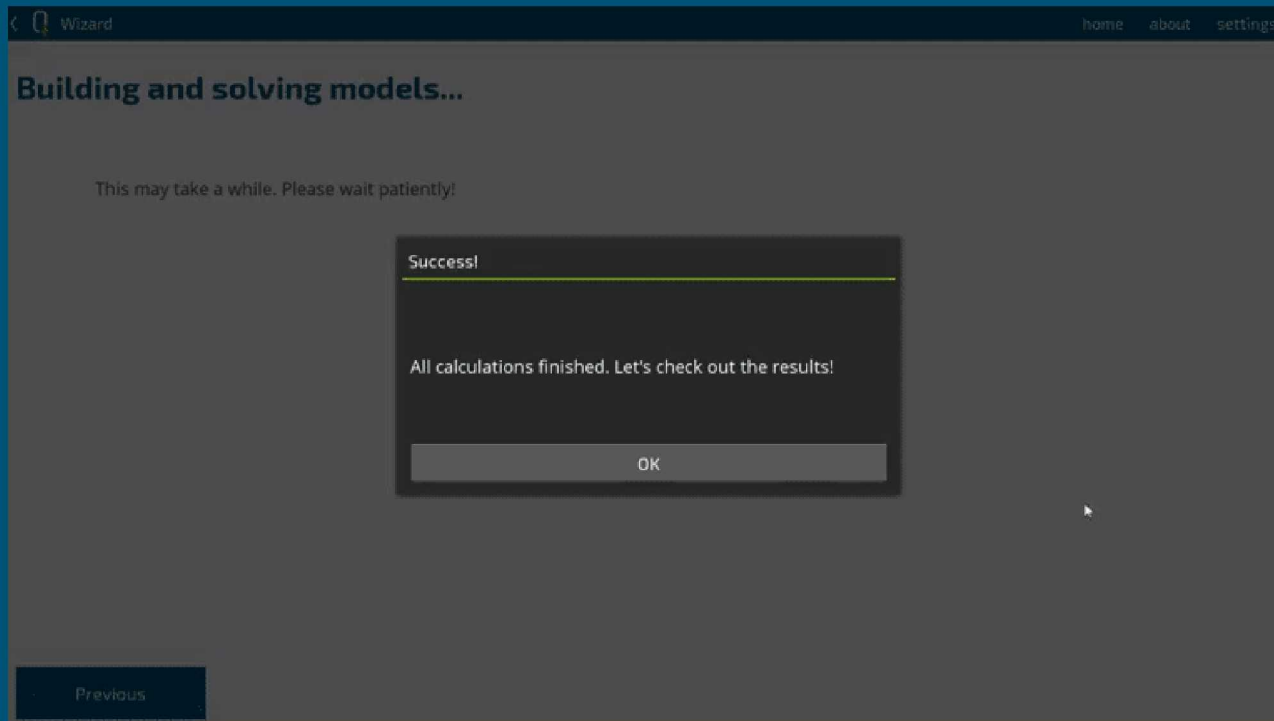
```
+ market_type
+ set_expressions()
- objective_arb()
- constraints_arb()
...
```

Defines the objective function and constraints that describe the problem.

All a user needs to know is how to interact with ValuationOptimizer object; they do not need to know anything about Pyomo.







8 QuESt Valuation Batch Runs

[Batch Runs](#)[home](#)[about](#)[settings](#)[view results](#)[batch runs](#)

Run multiple valuations with one click.

Select market area

ERCOT

MISO

Select month to evaluate:

Data

Parameters

Go!

The screenshot shows a web application titled "Data Manager: ISO/RTO Market and Operations Data". It has navigation links for "home", "about", and "settings". The main heading is "Download ISO/RTO market and operations data.". Below this, there are three tabs: "ERCOT", "MISO" (which is selected and highlighted in green), and "PJM". The "MISO" tab content area includes a sub-header "MISO" in green, a red label "Range of months", and two rows of input fields. The "Start:" row has "Month" and "Year" dropdowns. The "End:" row has "Month" and "Year" dropdowns. Below these fields is a large, empty rectangular box. To the right of this box is a blue "Download" button. At the bottom right of the interface is a blue "Settings" button.

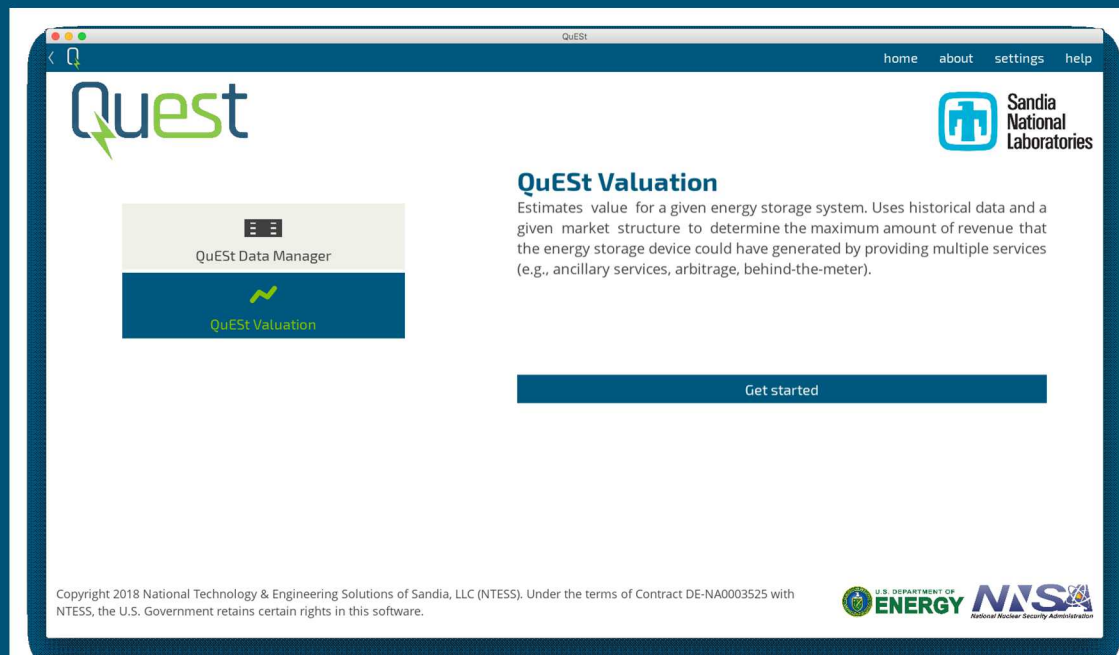
We do not own the historical data that we use, so we cannot distribute any.

- Uses “web crawling” to search ISO/RTO website for download links
- Uses API provided by ISO/RTO to make queries
- Prepares a data bank for use in other applications, e.g., QuESt Valuation
 - Downloads and extracts compressed archives
 - Formats API query results
 - Names files and creates directory structure to keep track of what’s been downloaded

The Future

Mission: Continue adding applications and new capabilities to the suite, building upon the software architecture and GUI foundation that we have established.

- Add support in QuEST Valuation/Data Manager for the remaining US markets
- Consider more complex valuation models, such as modeling degradation
- New applications
 - Behind-the-meter ES valuation
 - Technology selection assistant
 - Data explorer for ES finance information
 - ?



The authors would like to acknowledge the support and guidance from Dr. Imre Gyuk, the program manager for the U.S. Department of Energy Office of Electricity Energy Storage program.

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Follow us on GitHub:

github.com/rconcep/snl-quest