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Optimal Sizing and Operating of PV+LDES for Providing Base Load and QuESt Updates.

Tu A. Nguyen

2022 DOE Energy Storage Peer Review

Presentation Number: 903

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U.S. DEPARTMENT OF ENERGY

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2022 DOE Energy Storage
Peer Review

- Project objective
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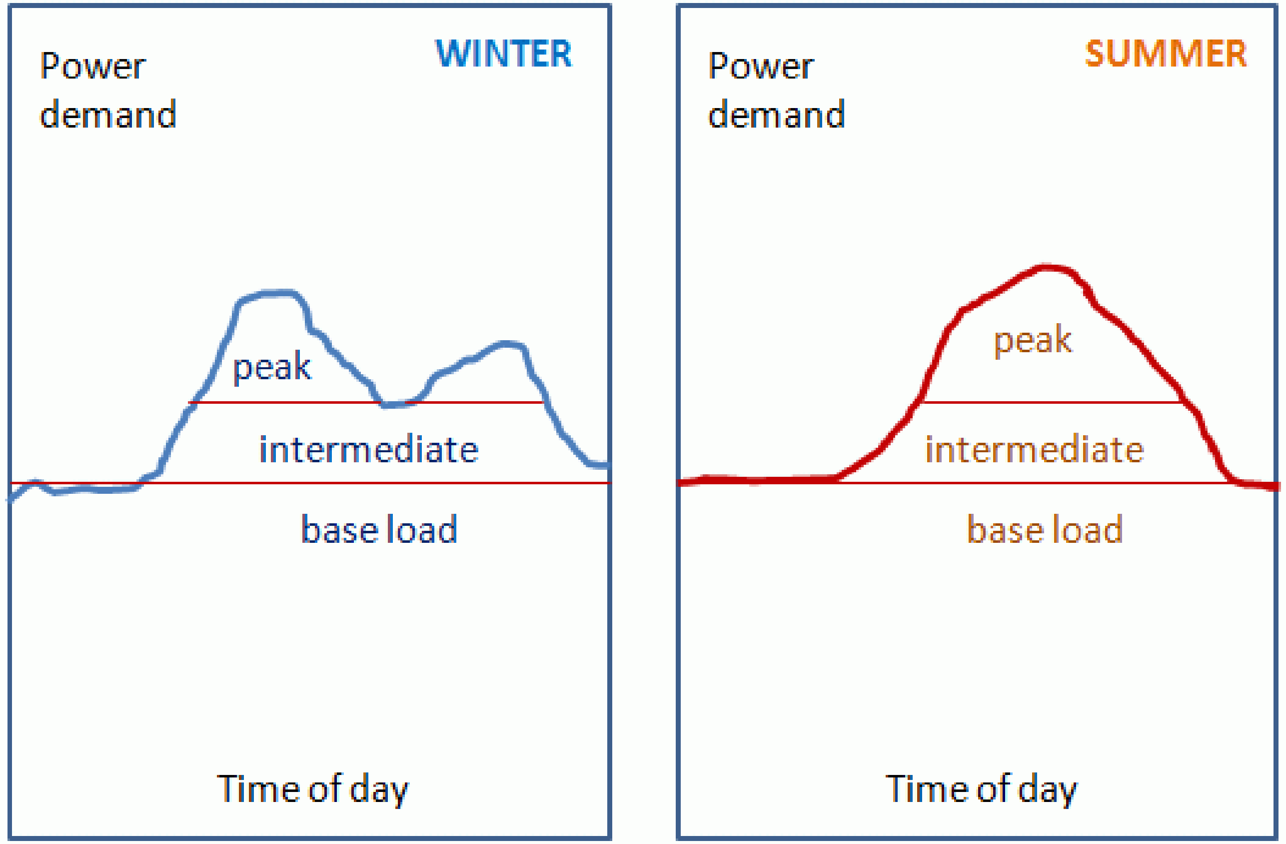
Project Objective

- *Objective:* to optimal size and operate a PV/Wind+LDES power plant that provides a constant base load.

- *Methodology:* we investigated 2 configurations (including 1-Storage and 2-storage configurations) and developed an optimization to size and operate each configuration of a PV/Wind+ESS power plant.

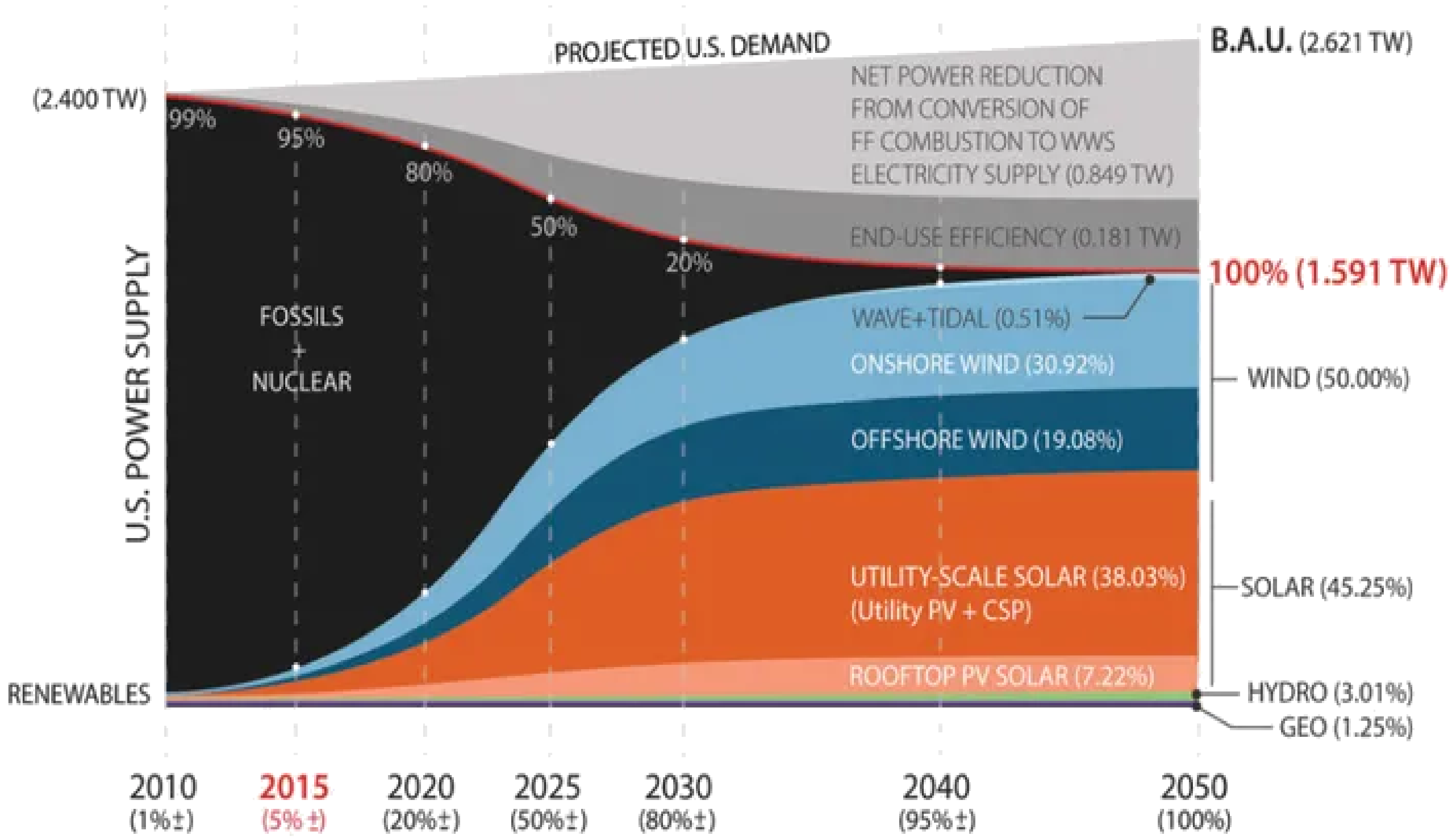
Background



Source: www.e-education.psu.edu/

- Base load is typically 30-40% of peak load.
- Non-renewable base load plants: coal, nuclear.
- Renewable base load plants: hydro, geothermal, biogas.
- Solar and wind plants are not used for base load due to their variability and uncertainty.

Covering Base Load by PV/Wind+LDES



(Jacobson et al., Energy & Environmental Science, 2015)

- Majority of energy will be provided by wind and PV in the future.
- Wind and PV power plants will also need to cover base load.

The Need for Long Duration Energy Storage

Image Credit: Form Energy

Long Duration Storage Shot seeks to achieve affordable long duration grid storage—for clean power anytime, anywhere.

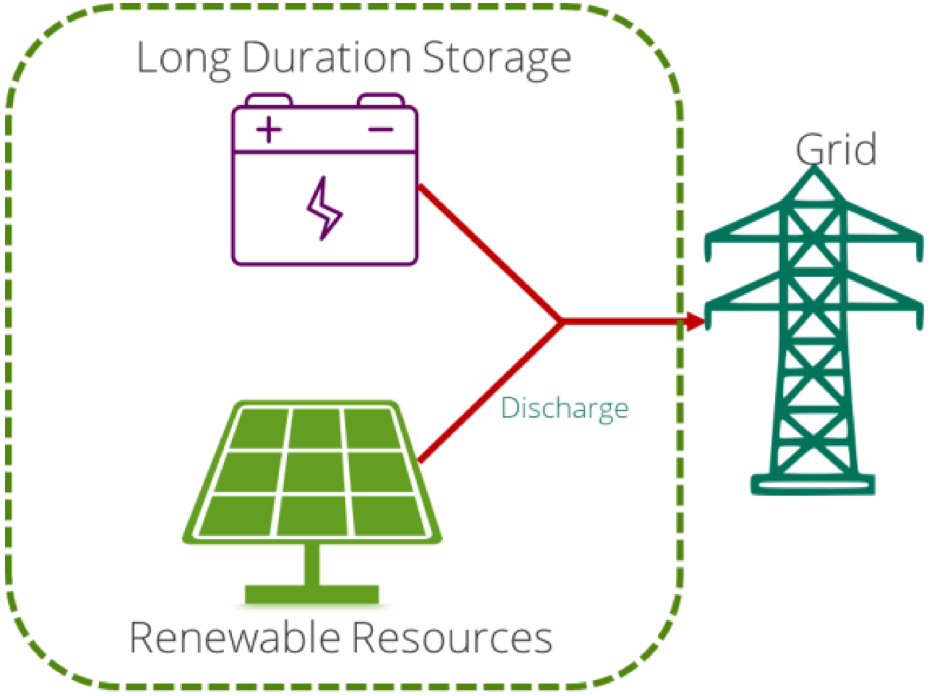
Reduce storage costs by **90%** from a 2020 Li-ion baseline...

...in storage systems that deliver **10+** hours of duration

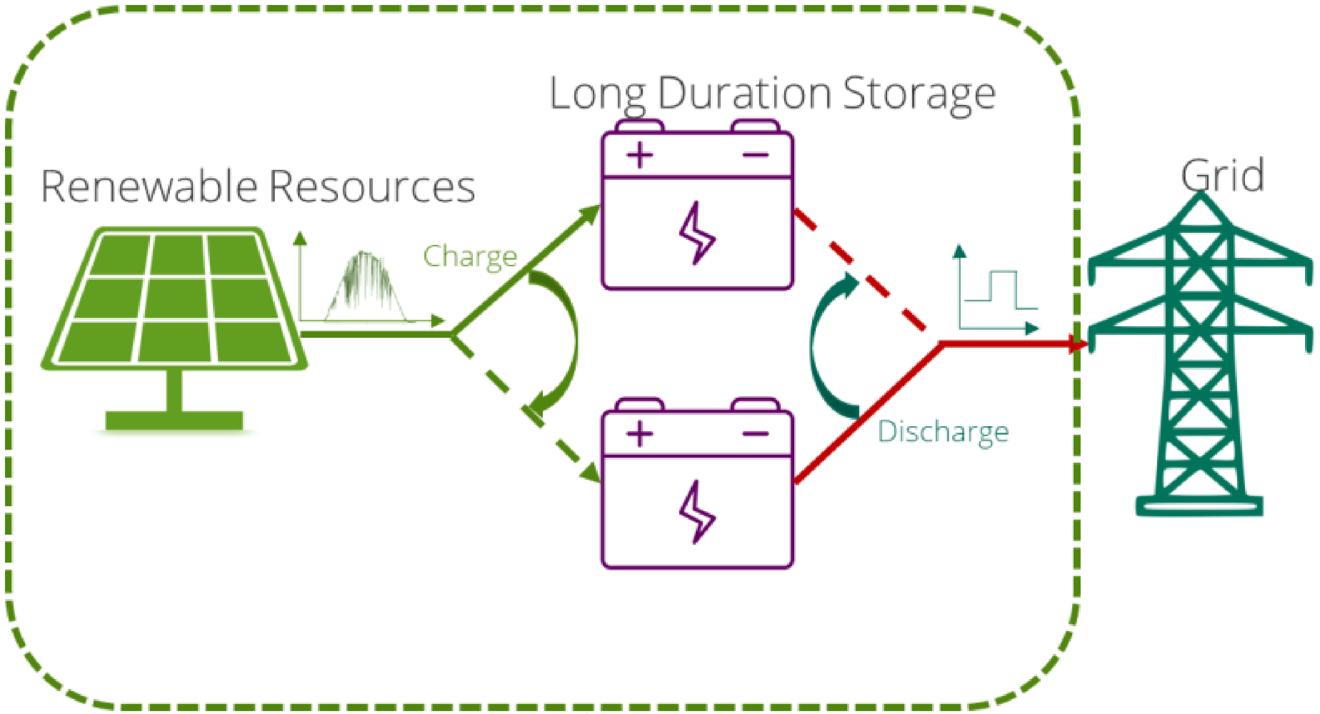
...in **1** decade

Image Credit: U.S. DOE

Configurations for PV+LDES Plants



1-Storage Configuration

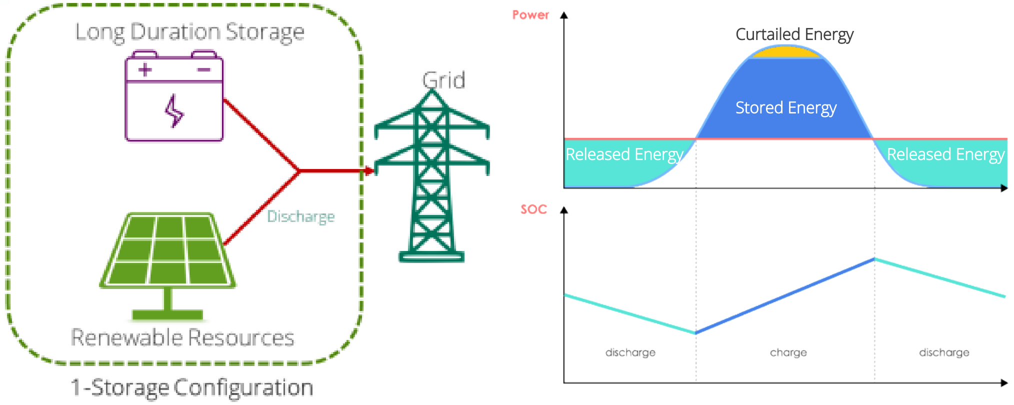


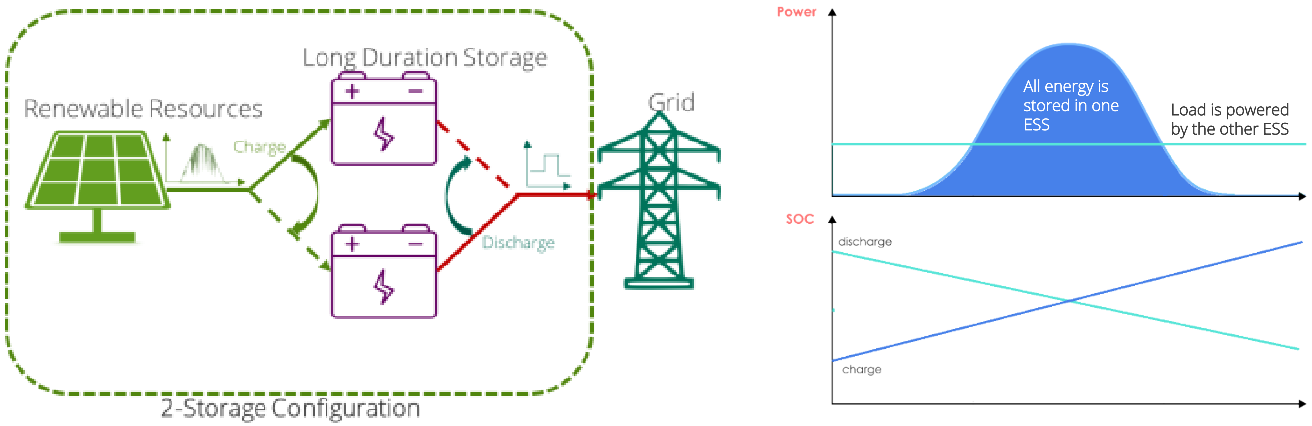
2-Storage Configuration

- Generation and load are balanced in real time.

- Generation and load are decoupled using two ESSs that are alternatively charge and discharge.

Operations of PV+LDES Plants

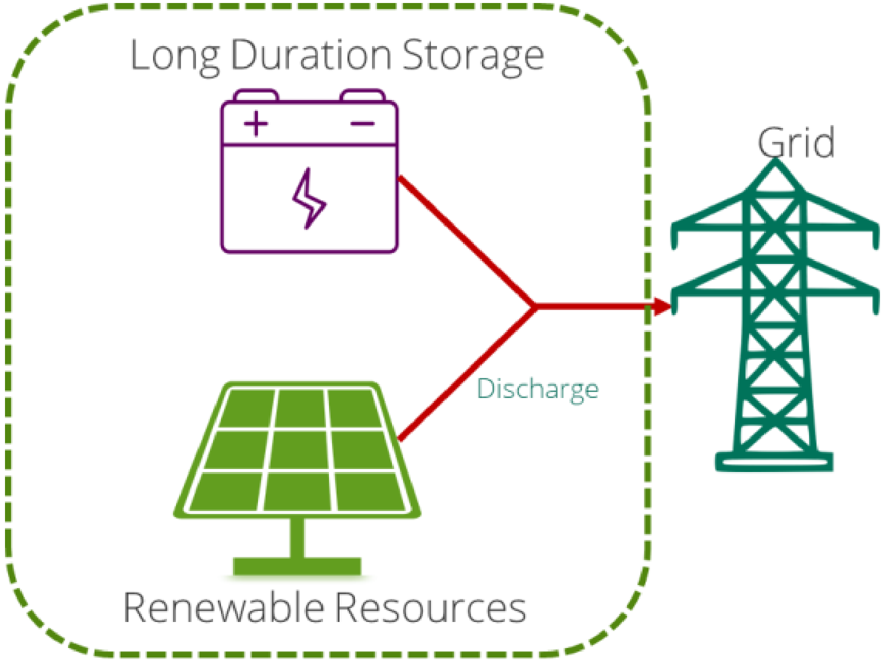




- Operation mainly relies long-term and short-term forecasts.
- PV, wind, and LDES must be sized considering forecast errors

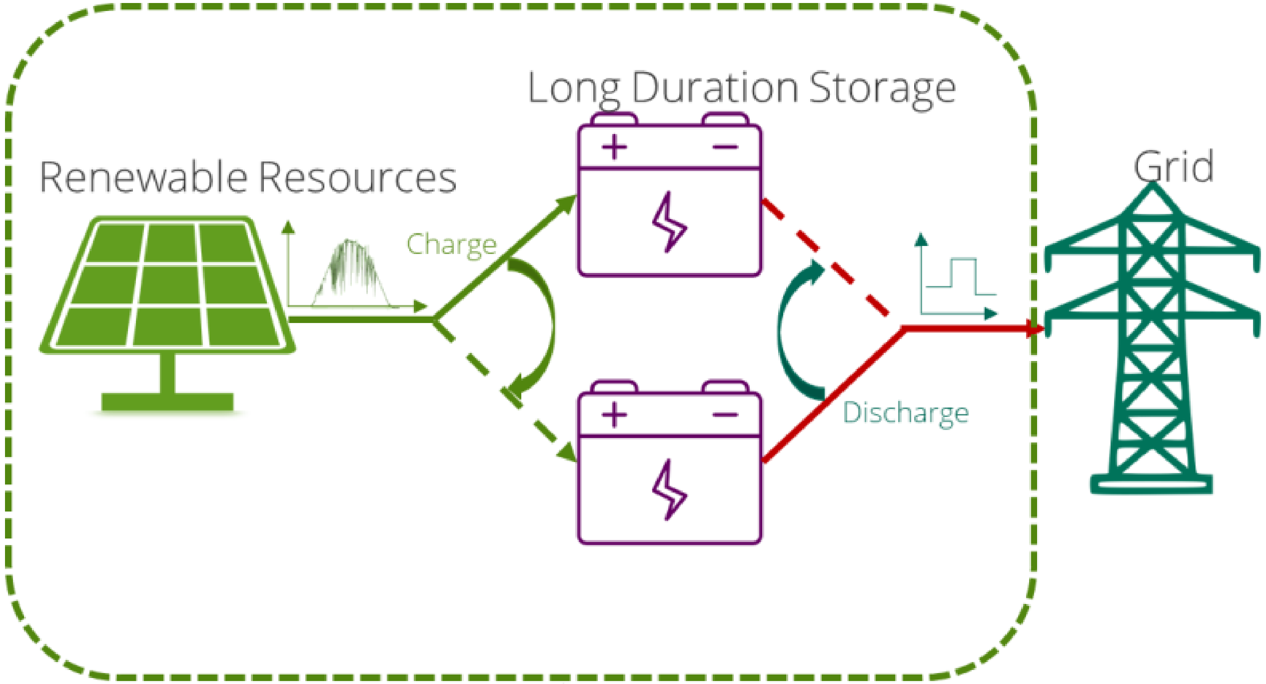
- All generated energy is stored in one ESS while the load is powered by the other ESS.
- PV, wind, and LDES must be sized considering the duration of charging/discharging periods.

Optimal Sizing Method for PV+LDES Plants



1-Storage Configuration

- Minimize total capital cost of PV/Wind and LDES
- Constraints:
  - Base load must be met at a given probability considering forecast errors.
  - SOC must be within an operating range
  - Charge/discharge power must be within power rating of ESS



2-Storage Configuration

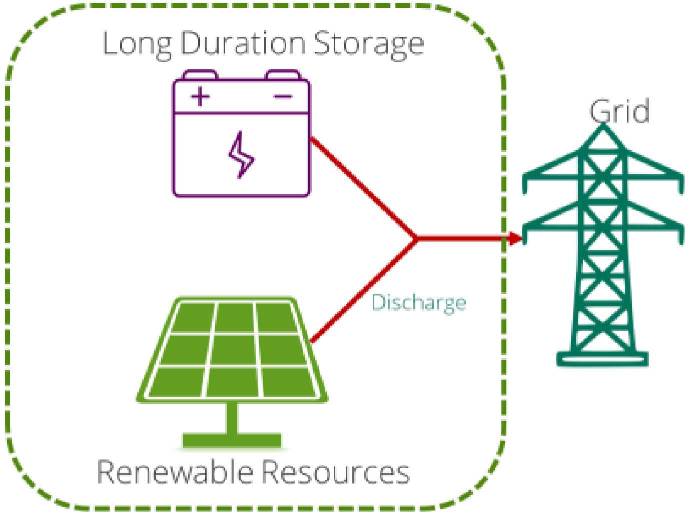
- Minimize total capital cost of PV/Wind and LDES
- Constraints:
  - Base load must be met by one of the two ESSs.
  - Renewable energy must be stored by the other ESS.
  - SOC of each ESS must be within an operating range.
  - Charge power must be less than power rating of the charger.
  - Discharge power must be less than power rating of the inverter.

Case Studies

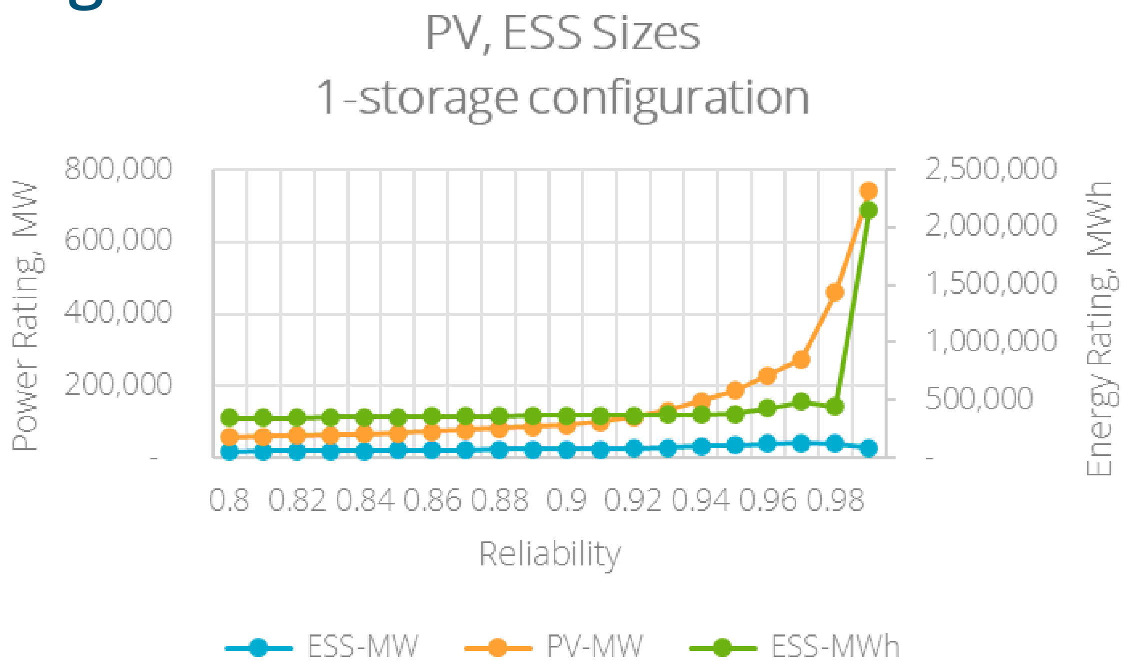
James H. Miller, Jr. Electric Generating Plant
Total nameplate generating capacity - 2,640 MW
Most polluted plant in the U.S.

- Optimal sizing PV+LDES for replacing James H. Miller, Jr. Electric Generating Plant in Alabama.
- Investigate both 1-Storage and 2-Storage configurations.
- Consider errors of D-1 forecast.

Case Studies – 1-Storage Configuration - Results

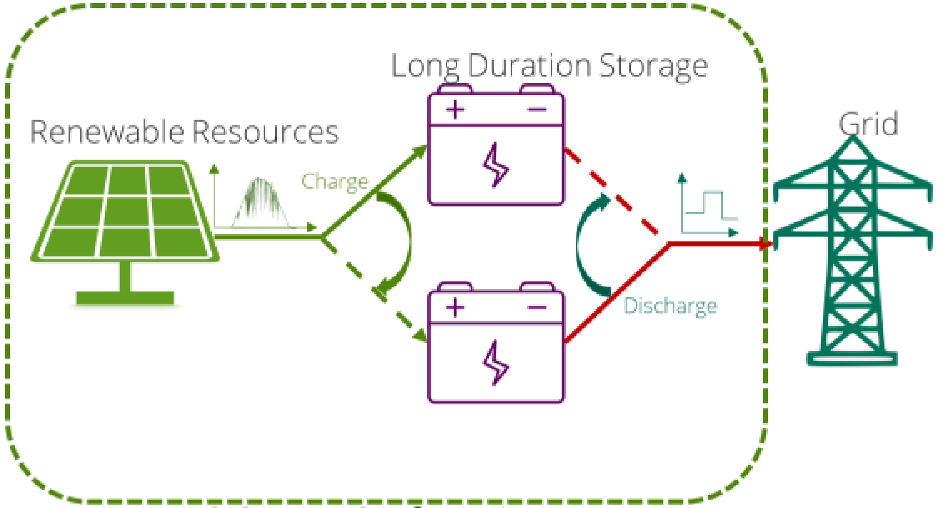


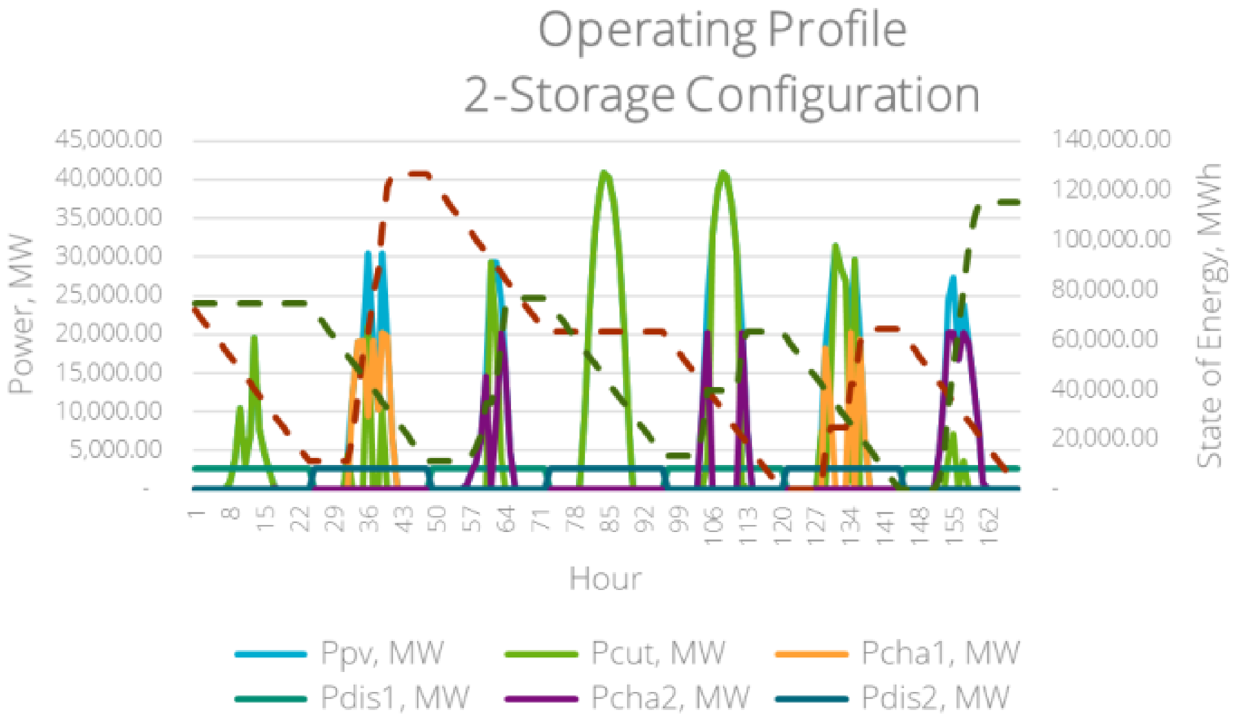
1-Storage Configuration



- Assumptions:
  - Storage efficiency = 85%.
  - ESS cost: $350k/MW and $350k/MWh
  - PV cost: $1.2M/MW

Case Studies – 2–Storage Configuration - Results





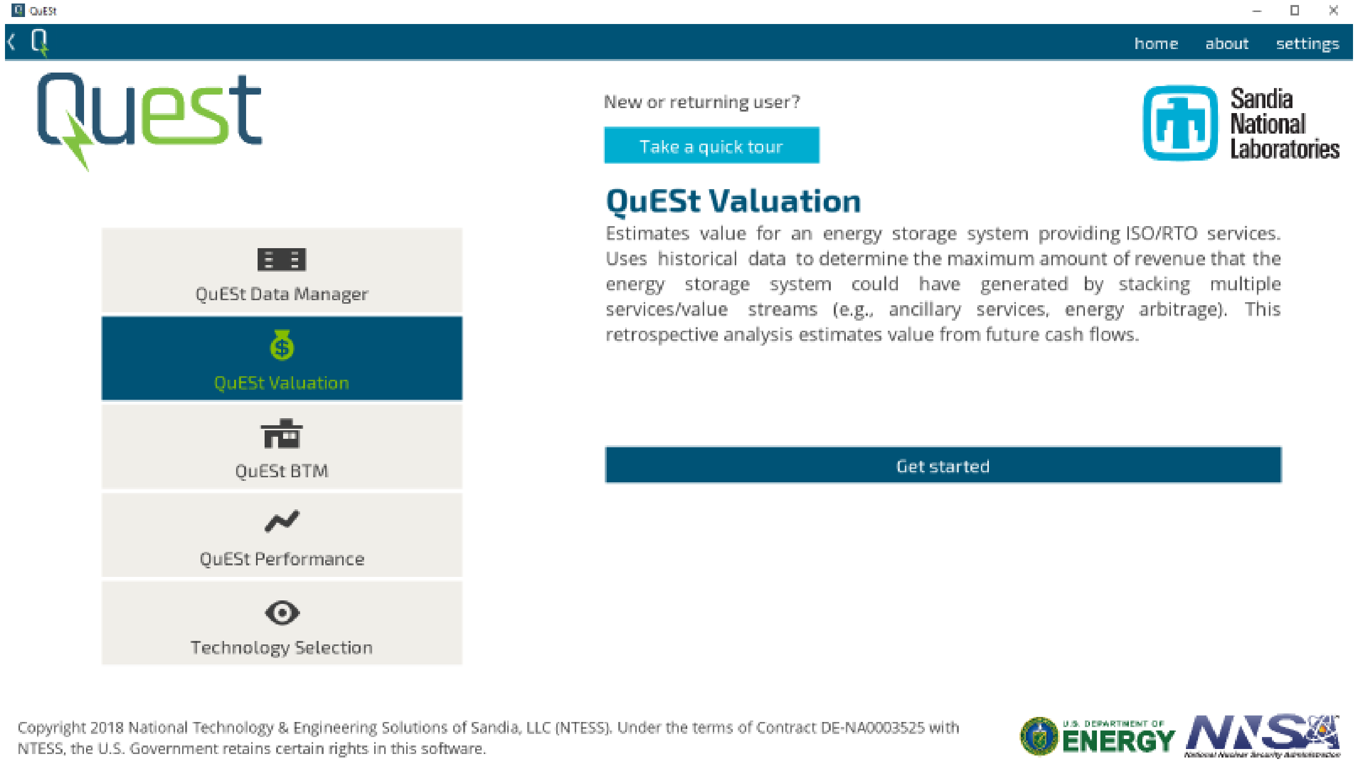
- Assumptions:
  - Storage efficiency = 85%.
  - ESS cost: $350k/MW and $350k/MWh
  - PV cost: $1.2M/MW
  - Two ESSs alternatively switching every 24hr

- Results:
  - Total storage =261,313 MWh
  - ESS MW rating = 2,640 MW
  - PV MW rating: 54,726 MW
  - Total cost: $158,055,158,214
  - Reliability is 100%

Key Takeaways

- Using current cost scenario, PV+LDES can cover base load at a huge cost. In order to make it economically possible, cost of both PV and LDES must be significantly lower.
- In 1-storage case, the cost is exponential to the reliability level. PV and LDES sizes depend very much on forecast accuracy.
- In 2-storage case, energy is absorbed before being dispatched. Therefore, forecast is not needed and the reliability is theoretically 100%.
- At a similar cost, 2-storage configuration can provide much higher reliability.
- Same methodology can be applied for Wind+LDES

QuESt - Updates



Updates in ver 1.6:

- **QuESt Technology Selection –** Support storage technology selection given applications and other requirements
- **QuESt Performance –** Evaluate energy storage system performance in different climates

Updates in ver 1.7:

- **QuESt Equity –** Size PV+ESS to replace a power plant and evaluate the environmental impact.

- Current version 1.6 available on GitHub: https://github.com/snl-quest/snl-quest

- Version 1.7 beta is under testing.

QuESt – Future Work

2017

2017
START THE DEVELOPMENT OF QUEST

2018-2019

2018
RELEASE QUEST 1.0 WITH VALUATION TOOL FOR ESTIMATING REVENUE OF ENERGY STORAGE IN ELECTRICITY MARKETS

2019
RELEASE QUEST 1.1, 1.2 WITH BEHIND-THE -METER (BTM) TOOL FOR VALUATING COST SAVING BY BTM ENERGY STORAGE FOR UTILITY CUSTOMERS

2020-2021

2020
- START THE DEVELOPMENT OF ENERGY STORAGE TECHNOLOGY SELECTION TOOL
- COLLABORATE WITH QUANTA TECHNOLOGY TO DEVELOP INTEGRATED RESOURCE PLANNING TOOL

2021
START THE DEVELOPMENT OF ENERGY EQUITY AND PERFORMANCE TOOLS

2022-2023

2022
- RELEASE QUEST 1.6 WITH ENERGY STORAGE TECHNOLOGY SELECTION AND PERFORMANCE TOOLS
- RELEASE QUEST 1.8 WITH ENERGY EQUITY AND MICROGRID
- REDESIGN QUEST LIBRARY AND QUEST DESKTOP APPLICATION.

2023
RELEASE QUEST 2.0 WITH TWO MAIN UPDATES: QUEST LIBRARY AND QUEST DESKTOP APP .

Current Plan

Develop open-source libraries and software tools with GUI for energy storage analytics.

5-year plan

Develop QuESt as a platform to host software tools/applications in energy research

Acknowledgements

Contact Information:

Tu Nguyen, Ph.D.
Sandia National Laboratories
utamrak@sandia.gov

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