Pumped Storage Hydropower Valuation Tool Demonstration

Mark Weimar, Pacific Northwest National Laboratory; Jonghwan Kwon, Argonne National Laboratory
Pumped Storage Hydro (PSH) Valuation Team

Argonne National Laboratory (Argonne) (Guidebook Lead)

Idaho National Laboratory (INL)

National Renewable Energy Laboratory (NREL)

Oak Ridge National Laboratory (ORNL)

Pacific Northwest National Laboratory (PNNL) (Tool Lead)
Project Goals and Objectives

Advance the state of the art in the assessment of value of PSH plants and their role and contributions to the power system

- Develop a Comprehensive and Transparent Valuation Guidance
- Test the PSH Valuation Methodology
- Transfer and Disseminate the PSH Valuation Guidance
Techno-Economic Studies

A variety of analyses are carried out to assess the costs and benefits of various PSH services and contributions to the grid.
Collaboration with Two Industry Partners

**Banner Mountain PSH**
*(Absaroka Energy)*
- 400 MW, quaternary technology
- Closed loop
- Site near Casper, WY

**Goldendale Energy Storage Project**
*(CIP & Rye Development)*
- 1,200 MW, adjustable speed technology
- Closed loop
- Site just north of OR/WA border

CIP = Copenhagen Infrastructure Partners
Key Products of the PSH Valuation Project
PSH Decision Tree

- The decision tree model walks the user through a set of questions that lead them to:
  - **Price-taker model** for small, modular PSH (i.e., <10MW)
  - **15-step BCA process** for large-scale PSH deployments
    - Using existing tools (A-LEAF, Aurora, ProMod, PLEXOS, etc.)
    - Provide BCR, IRR, payback period, and ROI, etc.
PSH Valuation Tool

• Help the users navigate the PSH valuation process
• Evaluating a broad set of use cases
• Key features:
  • Embedded price-taker model
  • Embedded price-influencer model
  • Multi-criteria decision analysis model
  • Embedded financial worksheets and benefit-cost analysis (BCA) model
Overview of the Price-influencer Model

New Addition in 2022!

• The project team has extended the PSHVT's capability by embedding the Argonne Low-carbon Electricity Analysis Framework (A-LEAF) as a default model for the price-influencer valuation method.

• An embedded price-influencer model enables the model to perform all calculations internal to the PSHVT, eliminating need for external models.

• The tool will guide the user through the selection of use cases and use of A-LEAF for assessing benefits.
What is A-LEAF?

- Integrated **national-scale power system simulation framework**
- Suite of least-cost generation & transmission expansion, unit commitment, and economic dispatch models
How does A–LEAF work in the PSH Valuation Tool?

- A–LEAF is embedded as an option
- Use the default national scale dataset
- Support several use cases in the PSH valuation tool
- Co-optimization of multiple use cases

<table>
<thead>
<tr>
<th>Category</th>
<th>Service</th>
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<tbody>
<tr>
<td>Bulk Energy Services</td>
<td>Electricity price arbitrage</td>
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<td>Bulk power capacity</td>
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<td>Ancillary Services</td>
<td>Frequency regulation</td>
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<td>Contingency reserve</td>
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<td>Flexibility reserve</td>
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<td>Black start service</td>
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<tr>
<td>Reliability and Resilience</td>
<td>Reduced power outages and restoration costs</td>
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<tr>
<td>Power System Indirect Benefits</td>
<td>Reduced electricity generation cost</td>
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<td></td>
<td>Reduced cycling and ramping of thermal units</td>
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<td>Reduced curtailments of variable generation</td>
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<td>Transmission Infrastructure Benefits</td>
<td>Transmission upgrade deferral</td>
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<td>Transmission congestion relief</td>
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<tr>
<td>Energy Security Benefits</td>
<td>Fuel availability, savings, and diversification</td>
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<td>Major blackouts avoided</td>
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Ongoing A-LEAF Enhancements With Potential for the PSHVT

**Climate and Weather Data Analysis**
- Wind/solar availability
- Wind/solar forecasting
- Extreme weather events

**Translation of the Climate Data into Grid Model Inputs**
- Electricity demand
- Wind/solar profile
- Grid asset de-rating
- Grid asset outage

**Modeling of the U.S. Electric Power Grid**
- Configurable network
- Transmission network
- Resource potentials

**Wholesale Market Designs / Policies / Regulations**
- Forward and spot markets
- State and national policies
- Price formation
- Capacity and A.S.

**Advanced Operations & Planning Tools**
- Generation portfolio
- Generation scheduling
- Energy prices
- Value of LDES

**Decarbonization, Reliability, Resiliency**

**Interdependency**
- Material & Manufacturing
- Transportation
- Natural gas
- Water
Price–Taker PSH Evaluation Model

• Adapt PNNL Battery Storage Evaluation Tool (BSET) to PSH

• Embed BSET tool will provide:
  • Optimization across of single or multiple services customized by users
  • Optimize society’s, system’s, or operator’s perspective
  • User defined scheduling
  • Power and energy limit specifications
  • Optimal storage and energy rating

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<tr>
<th>Category</th>
<th>Use Case</th>
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<tr>
<td>Bulk Energy</td>
<td>Energy Arbitrage</td>
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<td>Capacity</td>
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<tr>
<td>Ancillary Services</td>
<td>Frequency Regulation</td>
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<td>Spin / Non-Spin</td>
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<td>Transmission</td>
<td>Upgrade Deferral</td>
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<td>Congestion Relief</td>
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<tr>
<td>Distribution</td>
<td>Upgrade Deferral</td>
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<td>Volt-VAR</td>
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<td>Customer Energy Management</td>
<td>Power Reliability</td>
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<td>TOU Charge Management</td>
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<td>Demand Charge Management</td>
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Bundling Services: How To Do It Optimally

- Multi-dimensional co-optimization procedures are required to ensure no double counting of benefits
- Different services compete for limited PSH capacity
- By using more energy in one hour, less is available in future hours
BESS vs PSH Modeling

- A set of equations and constraints, or tables representing operational flexibility and physical constraints
- Often black- or grey-box models at a system level

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<thead>
<tr>
<th></th>
<th>BESS</th>
<th>PSH</th>
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<tbody>
<tr>
<td><strong>Similarities</strong></td>
<td>Charging/discharging power</td>
<td>Pumping/generation power</td>
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<tr>
<td></td>
<td>Energy change rate</td>
<td>Volumetric flow rate</td>
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<tr>
<td></td>
<td>Energy state</td>
<td>Volume level</td>
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<tr>
<td></td>
<td>Charging/discharging efficiencies</td>
<td>Energy conversion coefficients</td>
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<tr>
<th><strong>Differences</strong></th>
<th>BESS</th>
<th>PSH</th>
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<tr>
<td></td>
<td>System-level model</td>
<td>Unit-level model</td>
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<td>Two operating modes</td>
<td>More operating modes</td>
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<td></td>
<td>Fully controllable within rated power</td>
<td>Minimum power/fixed pumping power</td>
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<td></td>
<td>One-to-one mapping</td>
<td>One-to-many mapping</td>
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<td></td>
<td>Degradation effects</td>
<td>Start-up cost</td>
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Price–Taker Engine Design and Integration

- **Data management and security**
  - Account and user group information
  - Parameters, flags, input files, results from PCM, evaluation results
- **Computational requirement**
  - Large-scale optimization
  - Dynamic formulation
  - Various optimization solvers set up in Docker
- **Process management**
  - Task management with ranking rules
THANK YOU! QUESTIONS?

MARK WEIMAR (MARK.WEIMAR@PNNL.GOV)
JONGHWAN KWON (KWONJ@ANL.GOV)