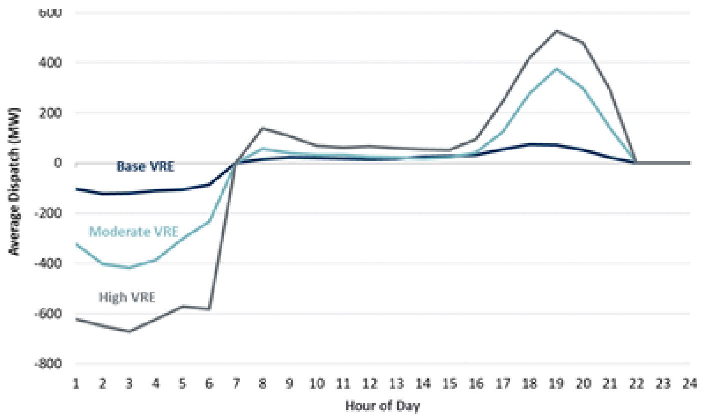
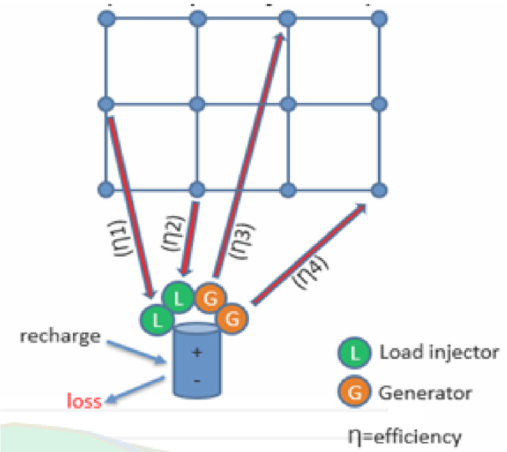
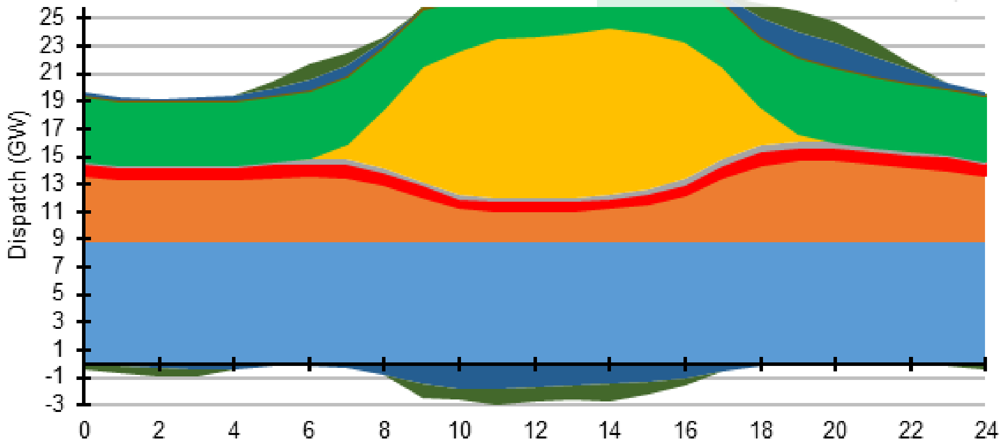
DE-EE0008783 - Predicting Unique Market Pumped Storage Significance (PUMPSS)







Aidan Tuohy
Electric Power Research Institute

atuohy@epri.com

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Project Overview

Project Summary

- Develop a framework to investigate the value pumped storage hydropower (PSH) provides to the grid, currently and in the future as the resource mix decarbonizes. Leverage and improve production cost modeling approaches to study the value across two different market structures (NYISO and Duke Carolinas) to better understand how different PSH technology characteristics, modeling approaches and system characteristics impact on the value of hydropower.

Intended Outcomes

- Improve the state-of-the-art in modeling of PSH and its value to the grid
- Identification of key drivers of value of PSH in the two regions studied, as well as guidance for how such issues should be modeled in other regions
- Based on a wide range of sensitivities, identify those that are most important for understanding value of PSH

Project Information

Principal Investigator(s)

- Aidan Tuohy, Joseph Stekli

Project Partners/Subs

- Nikita Singhal, Genevieve de Mijolla, Majid Heidarifar, Mobolaji Bello (EPRI)
- Bruce Tsuchida, Pablo Ruiz, Oleksandr Kuzura (Brattle)
- Russ Philbrick, John Goldis, (Polaris, Enelytix)

Project Status

Completed April 2022

Project Duration

- Aug 2019
- April 2022

Total Costed (FY19–FY21)

$1,249,750

Project Objectives: Relevance

Relevance to Program Goals:

- Relevant challenge from the hydropower program: Untapped potential for PSH to support a rapidly changing grid – we address this in a number of different ways
  - Modeling of different scenarios helps to understand the evolving needs of the rapidly changing grid
  - Improved modeling of PSH in commercial production cost tools supports the optimization of hydropower operations and planning—alongside other resources—to best utilize hydropower's capabilities
  - Sensitivity analysis approach allows for investigation of the full range of capabilities to provide grid services

- Supports intermediate outcomes:
  - Accurate representation and system value of hydropower and PSH capabilities in power system models
  - Increased inclusion of hydropower and PSH options in generation and transmission planning

- Long term outcomes:
  - Increase in U.S. hydropower and PSH fleet flexibility and greater value provided to the power system – modeling can allow for greater understanding of value across different regions

Project Objectives: Approach

Approach:

- This project aims to demonstrate a methodology to value PSH's contribution in multiple systems over a range of VRE penetration scenarios using real-world operating conditions from PSH facilities.
- Innovative advanced production cost modeling is leveraged that provides greater accuracy on aspects like treatment of uncertainty, inclusion of multiple decision steps from week(s) ahead to real time, and treatment of reserve requirements and provision from PSH
- This will allow for a greater understanding of both the value of existing and potential PSH in those systems, the differing value of various PSH technologies across regions, the value of individual services and attributes that PSH provides.
- Benchmarked cases for the existing system were developed and then future resource mixes developed with high and medium renewable penetration, as well as aspects like presence (or not) of battery storage and nuclear resources
- A case study matrix was developed in the first half of the project to determine specific issues to study that show value for PSH – these included operational assumptions, storage duration, fuel prices and market design sensitivities
- Key results were the cost savings due to presence of PSH, but other metrics such as emissions, load and reserve violations, PSH revenues and marginal prices/costs were also examined
- The extensive approach to modeling here provides additional information beyond similar previous studies

Project Objectives: Expected Outputs and Intended Outcomes

Outputs:

- New modeling capabilities, described in a paper, for PSH modeling in operational simulation software (production cost)
- Report describing framework and results with detailed modeling discussion and results sections
- White paper summarizing key results and conclusions

Outcomes:

- Improved understanding of value of PSH for the specific regions studied, supporting decisions being made to upgrade PSH, change operational practices or support integrated resource planning (IRP)
- Provide framework for others to study these issues, showing how to improve PSH modeling in commercial production cost tools and apply such models to study value of PSH

Project Timeline

FY 2019 (2nd half)

Gather data for Duke Carolinas and NYISO systems.

Define capabilities of existing plants and potential sensitivities.

FY 2020

Develop and run base cases and benchmark results

Design review to review initial results and determine future cases

FY 2021

Carry out additional future resource mix cases

Study different sensitivities

Report results/ conclusions

Original 2 year plan was extended 6 months due to delays contracting and then developing base cases

Case Matrix (updated since design review)

Sensitivity Type	NYISO			Duke Carolinas		
	Current Resource Mix	35% VRE with 4.5 GW offshore wind and 3 GW DPV	70% VRE with 9 GW offshore wind, 6 GW DPV, remainder from upstate wind and utility PV	Current Resource Mix	7.6GW VRE Capacity	20GW VRE Capacity
Renewable Penetration Sensitivities		X	X		X	X
Battery Storage Additions		X	X			
Nuclear retirement		X	X			
Market Design and System Operations						
Real time redispatching			X			
Changes to PSH hurdle rate			X			
Modify Optimization Horizon			X			
Modify Forecast Accuracy			X			
Reservoir Value Management				X	X	X
PSH cost factor				X	X	X
Fuel Price Sensitivity (Natural Gas)						
Fuel Price #1				X	X	X
Technology Sensitivities						
Modify C Rate			X	X	X	X
Variable Speed PSH			X	X	X	X

Project Budget

Total Project Budget – Award Information		
DOE	Cost-share	Total
$999.8K	$249.95K	$1249.75K

FY19	FY20	FY21	FY22	Total Actual Costs FY19–FY22
Costed	Costed	Costed	Costed	Total Costed
$ 1,709.00	$298,072.79	$ 519,155.44	$ 379,048.59	$ 1,197,985.82

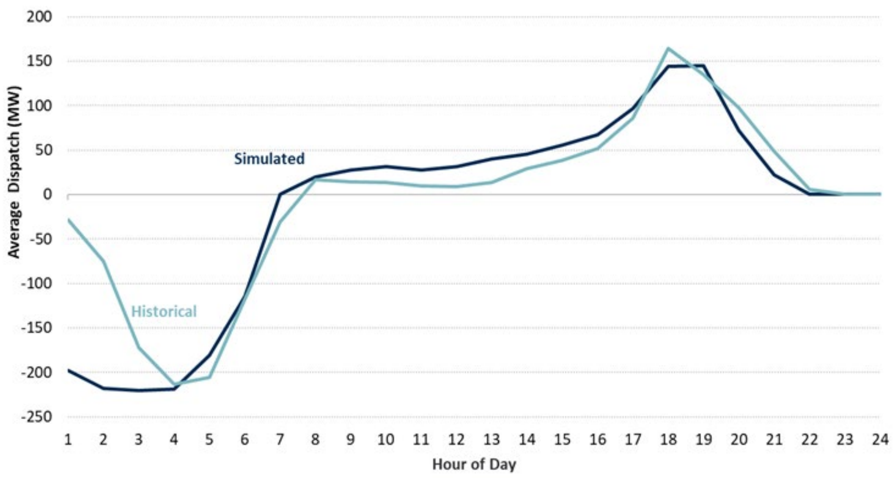
End-User Engagement and Dissemination

- Project benefits a number of stakeholder types:
  - Utilities that own/operate the specific PSH studied – they will better understand the current and future value under different assumptions about operations
  - ISOs in the region studied – can see how PSH could potentially provide value in their region and may be able to see where market design changes can support
  - Utilities/ISOs in other regions – can see how to model and value PSH and what might drive results, as well as how they might need to operate differently in future
  - Modelers/researchers – framework and modeling improvements can be leveraged for their own studies and research
- Engaged utilities and ISO in both regions through review meetings (Duke in particular on a more regular basis with their modelers, NYPA/NYISO at start and end of project)
- Engaged EPRI utility members more broadly to discuss the topics in general and get their feedback as to what aspects of the project is of most interest
- Engaged with models/software groups at FERC software conference to share modeling approaches and results

• Project results will be disseminated through 1-2 conference papers in coming year, as well as discussion with EPRI member utilities

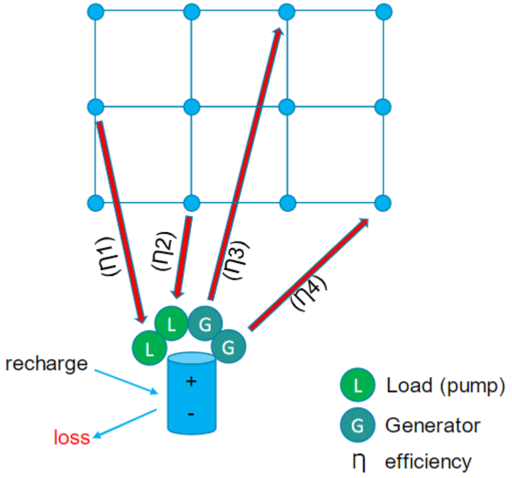
Performance: Accomplishments and Progress

- Models developed and benchmarked for each region
  - Included day/week ahead models (depending on region)
  - Benchmarked unit operations and showed close agreement
- Modeling of PSH improvements
  - Detailed mathematical approach described in final report and FERC paper*
  - Key contributions include accurate representation of unit-level PSH, including limits on pump/generate and flexible design for modeling PSH in market/system modeling



Benchmarking of NYISO model

Enhanced Model (multiple injectors)



*Heidarifar, M., Singhal, N. et al, "Modeling and Valuation of Pumped Storage Hydropower Resources", presented at FERC Technical Conference, June 2021

Performance: Accomplishments and Progress

Value of PSH plants with increasing Variable Renewable Energy (VRE):

- The **economic efficiency impacts of PSH are more prominent with increasing penetration levels of variable renewable resources** –value of PSH increased by 4x (Duke) to 9x (NYISO) for high VRE case (in line with relative increased of VRE), with the PSH being more valuable in Duke
- Potential **reliability improvements** with PSH – reserve violations reduced in all cases
- **Energy revenues increase with increasing penetration of VERs**, though ancillary services do not (Duke again saw higher benefit of PSH)

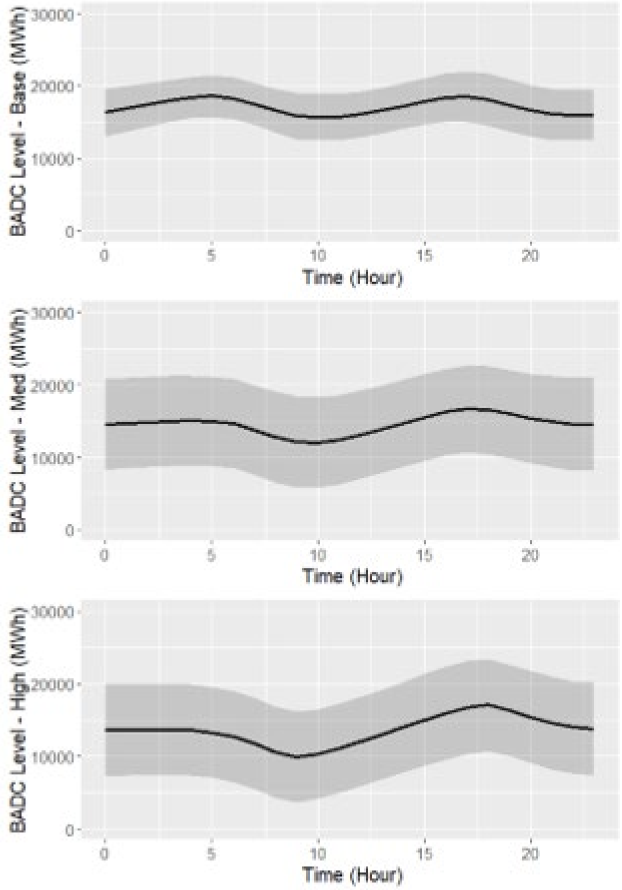
Metric Examined	Base VRE Mix		Moderate VRE Mix		High VRE Mix	
	w/ PSH	w/o PSH	w/ PSH	w/o PSH	w/ PSH	w/o PSH
Annual production costs ($billion)	$2.171B	$2.239B (↑3.12%)	$1.517B	$1.629B (↑7.36%)	$1.150B	$1.298B (↑13%)
Annual penalty costs ($million)	$0.03M	$1.61M (↑6000%)	$0.19M	$3.49M (↑1742%)	$0.48M	$3.11M (↑550%)
Annual RT production + penalty costs ($billion)	$2.171B	$2.240B (↑3.20%)	$1.517B	$1.632B (↑7.58%)	$1.151B	$1.301B (↑13%)
Annual RT contingency reserve violations (MWh)	22.6	124.9 (↑453%)	151.5	2791.7 (↑1742%)	382.5	2487.7 (↑550%)
Average real time PSH value to system operator ($/MWh)	19.5	N/A	29.1	N/A	34.8	N/A

Duke Carolinas Results

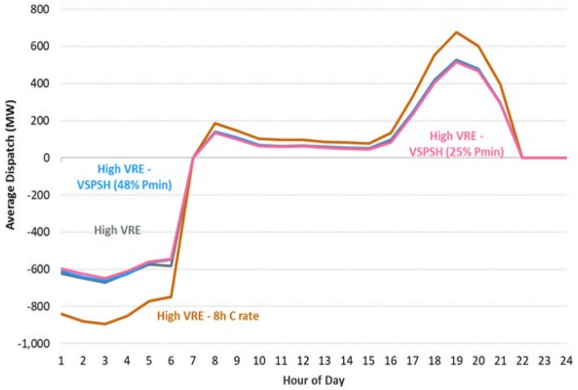
Performance: Accomplishments and Progress

Additional observations

- As VRE increases, PSH operations, and reservoir levels, exhibit more variability, similar to the 'duck curve' with changing periods of charge and discharge on average and higher spread when examining by time of day
- PSH impacts on the use of batteries and CCs most, with presence of batteries reducing value while PSH allows for more efficient, baseload like, operations of CCs
- Operational assumptions can have an impact, particularly assumptions of perfect foresight and reservoir management strategies – more aggressive use of PSH can result in some cost savings
- Variable speed drives can improve efficiency, particularly in terms of operating reserve provision
- MW vs MWh trade-offs were examined – in Duke, duration (MWh/MW) was shown to be important, but in NYISO the capacity (MW) seemed most relevant once certain number of hours of storage reached



Increasing spread for PSH in Duke as VRE added



Variable speed and duration sensitivities in NYISO

Q&A