Value and Role of Pumped Storage Hydropower under High Variable Renewables

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VALUATION OBJECTIVES

EVALUATE AND UNLOCK FULL POTENTIAL OF PSH TO SUPPORT GRID OPERATIONS, STABILITY & RESILIENCY

Overcome market barriers and enable PSH technology deployment for utilities, Public Utility Commissions (PUCs), developers and regional planners

- Develop a **PSH scheduling tool** to co-optimize energy and ancillary services, considering price elasticity in the power market
- Analyze and quantify the **potential value of PSH** under different system conditions
- Develop a set of **Variable Speed PSH stability models** for transmission planners to study the impact of PSH on the grid
- Investigate the dynamic **stability capability of VSPSH** and assess its impact on grid frequency response and transient stability
- Investigate the **PSH contribution to resource adequacy**

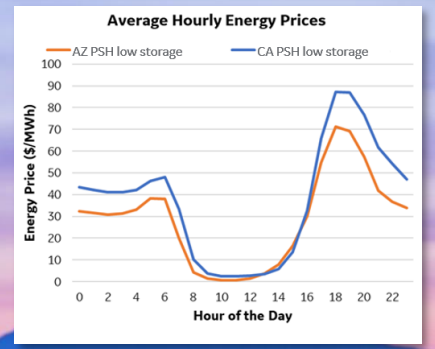
PSH PROVIDES MULTIPLE VALUE STREAMS

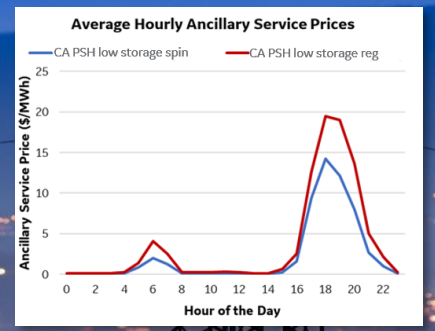
- ✓ Plants evaluated: 1) 2GW/20GWh PSH in Arizona 2) 0.5GW/4GWh PSH in California
- ✓ Simulations showed that PSH and BESS are ***not competing against each other*** but mainly against themselves.
- ✓ Installation of these PSH plants has a positive impact on the electric grid:
  - ❑ **lowering system production cost - $182M + $62M reduction for both plants**
  - ❑ **reducing CO_2 emissions - 1.8 + 0.5 million tons removed for both plants**
  - ❑ **minimizing thermal unit cycling**
  - ❑ **avoiding renewable curtailment - up to 4.8 TWh unlocked at high RE penetration**
- ✓ The metric and service determines the highest PSH system value in any grid scenario.
- ✓ Even in high storage scenarios, gas was not fully displaced.
- ✓ PSH plant profits vary significantly based on the grid characteristics where they are installed. Operating profits are larger for:
  - ❑ **higher renewable penetration levels**
  - ❑ **higher natural gas prices**
  - ❑ **lower hydro generation levels**
  - ❑ **lower system storage levels**

Pumped Storage Hydropower can provide critical grid support & services to fulfill grid operational & performance needs

STUDY RESULTS AND CONCLUSIONS

- Constructed **a detailed model** of the Western US Interconnect for 2028 to evaluate PHS, consisting of wind & solar providing 50% of annual energy.
- **Reserve Adequacy**: PSH has substantial capacity value even with short duration.
  - 4+ hours of storage typically lead to capacity values of 100% of nameplate capacity
  - 2 hours of storage are valuable for cases when solar power penetration is high
  - Solar & storage penetration have the largest impact on storage capacity value.
- **Grid Resiliency**: A 2GW VSPSH plant in Arizona in *pumping mode* was able to markedly improve the frequency response by 50mHz in the US Western Interconnect.
- A **novel PSH Scheduling tool** was developed and for the first time incorporated the impact of variable height differences between reservoirs ('head') and variable speed machine behavior.
- **Positive impact** on reducing production cost, CO_2 emission and curtailment of other renewables.
- Two **new VSPSH stability models** have been created and incorporated into PSLF grid planning software so grid operators can assess their benefits.





PSH provides value to support power grid needs for generation adequacy, balancing, resiliency and stability.

New tools and methods are now available and being deployed to unlock that value.