Lower Snake River Dams Power Supply Replacement Analysis

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Study Goals

Use long-term, production cost model to compare two policy futures:
  – Meet existing policy goals assuming Lower Snake River Dams* (LSRD) are not removed.
  – Meet existing policy goals with LSRD removal.

Measure impacts associated with LSRD removal:
  – Generating capacity mix required to meet clean energy laws with and without LSRD.
  – Compare cost, timing, and emission impacts associated with LSRD removal.

* Lower Snake River Dams: Lower Granite, Little Goose, Lower Monumental, Ice Harbor
High Level Findings

• Significant capacity additions are required to meet clean energy laws (160 GW by 2045 in WPP).
• Replacement of LSRD requires an additional 14.9 GW of new renewable capacity.
• Cost of capacity to replace LSRD: $15 Billion NPV.
• If you double historical installation rates, clean energy targets cannot be met unit late 2050’s to 2070’s.
• Replacement capacity for LSRD is in addition to capacity required to meet existing laws. Replacing LSRD would further delay meeting clean energy laws by 3 to 5 years.
• Removal of LSRD in 2030 would result in increased carbon emissions until replacement resources are built in the 2050's to 2080's timeframe.
Approach
### Clean Energy Targets

<table>
<thead>
<tr>
<th>State</th>
<th>Target</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>100%</td>
<td>2045</td>
</tr>
<tr>
<td>Colorado</td>
<td>100%</td>
<td>2040</td>
</tr>
<tr>
<td>Nevada</td>
<td>100%</td>
<td>2050</td>
</tr>
<tr>
<td>New Mexico</td>
<td>100%</td>
<td>2045</td>
</tr>
<tr>
<td>Oregon</td>
<td>100%</td>
<td>2040</td>
</tr>
<tr>
<td>Washington</td>
<td>100%</td>
<td>2045</td>
</tr>
</tbody>
</table>

All policy goals implemented in model as Renewable Portfolio Standard, thereby less stringent in each case.

Linear glide path used for implementation from current state to future policy compliance

Additional annual emission constraint applied in Oregon and Washington
Production Cost Model

• Zonal Least Cost Optimization
  – Least cost solution to meet load subject to constraints such as:
    • Planning Reserve Margin (PRM)
    • Zonal transmission constraints
    • Renewable goals
    • New generator options
  – Widely used throughout the industry
    • PSEI, PGE, etc. use same commercial software (i.e., Aurora)
Study Approach

- (a) Study Case w/o LSRD
- (b) Base Expansion w/ LSRD

Impact of Removing LSRD = (a) – (b)
“Pool” Topology for Capacity Sharing

• WECC wide model with five pools where:
  – Min. PRM defined
  – Commitment decisions

• Captures WRAP capacity sharing program

• Matches NERC reliability regions
“Zone” Topology for Energy

- 41 zones broadly representing each Balancing Authority
- Transmission limits applied between zones
- Additional granularity in PNW separating East/West WA/OR; PacifiCorp East, and California
## Generator Candidate Options

<table>
<thead>
<tr>
<th>Region-Technology</th>
<th>Size (MW)</th>
<th>Duration (hr)</th>
<th>Capacity Factor (%)</th>
<th>2023 Cost ($/kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>West-Solar</td>
<td>100</td>
<td>-</td>
<td>16%</td>
<td>1,508</td>
</tr>
<tr>
<td>East-Solar</td>
<td>100</td>
<td>-</td>
<td>24%</td>
<td>888</td>
</tr>
<tr>
<td>East-Wind</td>
<td>150</td>
<td>-</td>
<td>35%</td>
<td>1,237</td>
</tr>
<tr>
<td>MT-Wind</td>
<td>150</td>
<td>-</td>
<td>40%</td>
<td>1,237</td>
</tr>
<tr>
<td>West-Storage</td>
<td>100</td>
<td>4</td>
<td>-</td>
<td>1,147</td>
</tr>
<tr>
<td>East-Storage</td>
<td>100</td>
<td>4</td>
<td>-</td>
<td>1,147</td>
</tr>
<tr>
<td>Hybrid Solar + BESS</td>
<td>100</td>
<td>4</td>
<td>-</td>
<td>1,306</td>
</tr>
</tbody>
</table>

Source: EGPS, NREL ATB - [https://atb.nrel.gov/](https://atb.nrel.gov/); EIA AEO

Notes: Declining cost curves applied in modeling; Costs reflect ITC on solar and qualifying hybrid units.
Peak Capacity Credit

Notes: Wind/Solar peak credit determined by actual output in top 100 hours during simulation; Storage peak credit specified as input based on capacity additions; Peak capacity contribution sets the amount of capacity that can reliably serve the peak load.
Hydro Modeling

- Calibrated to 60-dam, historical hourly hydro production dataset in the PNW
  - Total annual generation based on 2020 actual production which was 100% of normal
  - Parsed annual generation into normal monthly generation by selecting a normal month for each month using data from the 2010 to 2021 time period.
  - Shape hourly generation based on shaping factors from historical hourly production (2018-2021)
- Outside PNW forecast is based on EIA 923
Representation of LSRD

- Lower Snake River Dams Characteristics:
  - Nameplate capacity: 2900 MW†
  - Peaking capacity: 1844 MW*
  - Annual generation: 6,672 GWh
  - Monthly shaping: Selected normal month from 2010-2021 time period.
  - Hourly shaping: calibrated to 2018-2021

† Based on EIA

* This is the estimated Effective Load Carrying Capability or Net Qualifying Capacity.
## Study Differentiators

<table>
<thead>
<tr>
<th>Input Assumption</th>
<th>EGPS; 2022</th>
<th>E3; 2022</th>
<th>Energy Strategies, 2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean Energy Laws</td>
<td>100%</td>
<td>100%</td>
<td>NA, historical</td>
</tr>
<tr>
<td>Load Growth</td>
<td>P50, BAU</td>
<td>Electrification</td>
<td>NA, historical</td>
</tr>
<tr>
<td>Peaking Capacity of LSRD</td>
<td>1,844 MW</td>
<td>2,300 MW</td>
<td>1,000 MW</td>
</tr>
<tr>
<td>Market Purchases for Capacity</td>
<td>NA</td>
<td>NA</td>
<td>Allowed</td>
</tr>
<tr>
<td>Footprint / Dispatch</td>
<td>WECC</td>
<td>WECC</td>
<td>NA, one-for-one capacity</td>
</tr>
<tr>
<td>Cost of new Regional Transmission</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Emerging Technologies</td>
<td>No</td>
<td>Yes†</td>
<td>No</td>
</tr>
<tr>
<td>Battery ELCC</td>
<td>80% declining to 50%</td>
<td>&lt;10%‡</td>
<td>100%</td>
</tr>
</tbody>
</table>

† Most comparable scenario to this study includes off-shore wind
‡ At over 5 GW battery penetration
Results and Discussion
Capacity Mix (with LSRD) in WPP

160 GW of new capacity additions in WPP by 2045
• 55 GW new wind
• 73 GW of new solar
• 32 GW new battery storage
Replacement Capacity

Additional Installed Capacity Required for LSRD Replacement (Study - Base)

<table>
<thead>
<tr>
<th>Year</th>
<th>Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2035</td>
<td></td>
</tr>
<tr>
<td>2045</td>
<td></td>
</tr>
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</table>

14.9 GW of new capacity additions to replace LSRD by 2045
- 3.3 GW new wind
- 8.7 GW of new solar
- 2.9 GW new battery storage
$19 Billion Nominal / $15 Billion NPV costs to replace LSRD from 2030 to 2045
Delay in Meeting Clean Energy Laws

Cumulative Capacity Additions vs. Historical Build Ratios

- 2X NWPP
- 2X California
- 2X ERCOT
- Requirement
## Delay in Meeting Clean Energy Laws

<table>
<thead>
<tr>
<th>Annual Average Renewable Capacity Additions in WPP to meet Study Case</th>
<th>Using WPP Historic Buildout Pace</th>
<th>Using CA Historic Buildout Pace</th>
<th>Using ERCOT Historic Buildout Pace</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual average renewable capacity additions from 2007 – 2021 (MW)</strong></td>
<td>1512</td>
<td>1661</td>
<td>2326</td>
</tr>
<tr>
<td><strong>Estimated achievement of clean energy laws if double the historic pace of capacity additions (Year)</strong></td>
<td>2076</td>
<td>2071</td>
<td>2057</td>
</tr>
<tr>
<td><strong>Added emissions due to delay (MMT)</strong>‡</td>
<td>136</td>
<td>114</td>
<td>55</td>
</tr>
<tr>
<td><strong>Estimated achievement of clean energy laws and replacement of LSRD if double the historic capacity additions (Year)</strong></td>
<td>2081</td>
<td>2076</td>
<td>2060</td>
</tr>
<tr>
<td><strong>Added emissions due to delay for replacement of LSRD (MMT) ‡</strong></td>
<td>8.5</td>
<td>8.5</td>
<td>5.1</td>
</tr>
</tbody>
</table>

‡Based on average emission rate from 2030 to 2045
Study Assumptions Which Understate Replacement Capacity and Costs

• Load growth will likely be higher.
  – Electrification is very likely to cause higher load growth

• Capacity contribution of LSRD may be higher.
  – WPP WRAP estimates of peak capacity contribution for hydro is likely higher than the 1844 MW modeled.

• Capacity contribution of batteries may be over-stated.
  – Battery peak capacity contribution is likely lower than assumed in this study.

• Cost of new regional transmission
  – E3 found a significant cost driver and uncertainty was cost of new regional-scale transmission
  – We did not consider regional transmission expansion and associated costs
Study Assumptions Which Overstate Replacement Capacity and Costs

• New generating technology
  – Not-yet commercial technology such as off-shore wind, hydrogen, small nuclear reactors were not considered.
High Level Findings

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Thank you