MEMORANDUM

TO:       Power Committee
FROM:    Gillian Charles
SUBJECT:  Pumped Storage Reference Plant for draft 2021 Power Plan

BACKGROUND:

Presenter:  Gillian Charles

Summary:   As part of the development of inputs for the draft 2021 Power Plan, staff develops generating resource reference plants as resource options – along with energy efficiency and demand response – for the Council’s power system models to select to fulfill future resource needs. A generating resource reference plant is a collection of characteristics that describe a realistic and likely implementation of a given technology within the region. It includes estimates of costs, operating and performance specifications, and developmental potential.

Staff presents reference plants for review and discussion with the Generating Resources Advisory Committee (GRAC) and incorporates feedback (when necessary) before bringing the reference plant to the Council for review.

At the December Council Meeting, staff will present the reference plant for pumped storage

Relevance: Development of inputs for the 2021 Power Plan

Workplan:  A.4.1 Develop generating resource reference plants for 2021 Power Plan
Pumped Storage Reference Plant for the 2021 Plan

December 10, 2019 Power Committee
Gillian Charles
Reminder: Council Input on Reference Plants

- Staff develops candidate reference plants
- Staff engages GRAC to solidify draft reference plants
- Staff brings draft plants to Council
- Reference plants are incorporated into models

Two important points:
- Most reference plant details are “just the facts” and are presented to the Council as background
- Some characteristics are a matter of judgement and are presented to the Council for discussion and direction taking
# Proposed Resources for 2021 Plan: What you’ve seen so far and what’s next

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<tr>
<th>Primary</th>
<th>Secondary</th>
<th>Emerging/Long-term</th>
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<tr>
<td>October P4</td>
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<td>Enhanced Geothermal Systems</td>
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<td></td>
<td>Solar PV</td>
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<td>November P4</td>
<td>Conv. Geothermal</td>
<td>Small Modular Reactors</td>
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<td>Onshore Wind</td>
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<td>Jan/Feb P4</td>
<td>Offshore Wind</td>
<td>Carbon Capture &amp; Sequestration</td>
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<td>Gas CCCT</td>
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<td>Gas SCCT - Frame</td>
<td>Hydro Upgrades</td>
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<td>October P4</td>
<td>Distributed Generation*</td>
<td>Hydrogen Gas Turbine</td>
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<td>Battery storage (Li-ion)</td>
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<td>October P4</td>
<td>Biomass</td>
<td>Allam Cycle Gas</td>
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<td>Solar + Storage</td>
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<td>Today! P4</td>
<td>Power-to-Gas</td>
<td>Wave, Tidal</td>
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<td>Pumped Storage</td>
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<tr>
<td>Jan/Feb P4</td>
<td>Small Hydro</td>
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<td></td>
<td>Reciprocating Engine</td>
<td>Combined Heat and Power</td>
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<td></td>
<td>Gas SCCT - Aeroderivative</td>
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* DG will also be included in the load forecast

Omitted: Advanced nuclear, coal, large hydro, CAES
Pumped Storage

Image source: https://www.energy.gov/eere/water/pumped-storage-hydropower
Treatment in the Seventh Power Plan

• Analyzed qualitatively as an emerging technology and recognized in the action plan through two specific action items
  • ANLYS-14, ANLYS-16

• Council considered pumped storage as emerging, despite it being an established and commercially mature technology, because

  “...new advances in technology have expanded its role from primarily shifting energy to providing ancillary services and capabilities that are beneficial in today’s power system...”

  • E.g. Adjustable speed vs. traditional fixed speed pumping units
ANLYS-16 Research and develop a white paper on the value of energy storage to the future power system. [Council, Generating Resources Advisory Committee] The Council should convene a subgroup of subject matter experts from its Generating Resources Advisory Committee to assist in the research and development of a Council white paper on the full value stream of energy storage and its role in the power system, including transmission, distribution, and generation. In addition, the white paper should investigate the existing need for frequency and voltage regulation and balancing reserves in the regional power system. The Council should author the white paper with help from industry experts, or lead a request for proposals and select a consultant to write the paper. The white paper should be completed in advance of the Eighth Plan.

One of the potential constraints to extensive storage development is the ability of the developer and/or investor to capture and aggregate the full value of the storage system’s services in a non-organized market and transform interest and overall system need into revenue streams and project funding. Many of the benefits of large scale storage are the portfolio effects for an optimized regional system, not just solely to a specific power purchaser, utility or end-user, and therefore it can be difficult to raise funds and seek cost-recovery for storage projects if the purchaser is not directly benefiting from all of the services, or is paying for a service that benefits others who are not also contributing funds. The white paper should clearly identify the issues and barriers and provide useful information that would be beneficial to the region’s decision makers, power planning entities and integrated resource planning processes.

ANLYS-14 Monitor and track progress on the emerging technologies that hold potential in the future Pacific Northwest power system. [Council, Generating Resources Advisory Committee] The Council should continue to monitor on an ongoing basis the emerging technologies identified in the Seventh Plan as potential resources of the future regional power system. There are several emerging technologies which could play an important role in the operation of the future power system, including:

- Distributed power with and without storage (Solar PV, CHP)
- Utility Scale Solar PV with battery storage
- Enhanced geothermal systems (EGS)
- Offshore wind
- Wave and tidal energy
- Small modular reactors (SMR)
- Energy Storage
  - Pumped storage with variable speed technology
  - Battery storage
  - Other
Benefits of Pumped Storage

• Large scale, carbon-free resource in a region with clean policy standards and goals
• Ability to provide flexible capacity and energy balancing to the grid
• Augment renewable generation and reduce renewable curtailment
• Energy arbitrage and ancillary services such as reserves and frequency control
• Longer duration energy discharge (as compared to short(er)-term battery storage)
Challenges of Pumped Storage: Barriers to New Development

- Capital-intensive, challenges to long-term financing, and regulatory risk
- Long permitting, construction, and lead time
- Monetary valuation of benefits that don’t yet provide direct compensation/revenue streams
America’s Water Infrastructure Act of 2018*

1. Extends the preliminary permit terms and start of construction deadlines for new construction projects
2. Promotes new, small conduit hydropower facilities
3. Promotes hydropower development at existing non-powered dams
4. Promotes development of closed-loop pumped storage projects
5. Incentives investments and modernization projects at existing hydropower facilities

* Signed into law on October 23, 2018
DOE EERE Techno-Economic Study of Pumped Storage

• Water Power Technologies Office issued a NOTA (Spring 2018) to perform techno-economic studies to evaluate the long-term value of two pumped storage projects
  • Goal to provide developers the ability to estimate the long-term value of proposed projects, guidance on financial revenue streams under current market conditions, and additional system benefits (e.g. transmission, portfolio effects)

• Council wrote letter of support for selection of a site located in the Pacific Northwest, stating that
  “understanding and capitalizing on the potential revenue streams from a specific pumped storage hydropower project within the regional market and existing portfolio of resources could go a long way towards making pumped storage cost-effective and competitive... in addition, information produced by the DOE’s analysis could help regional modeling and analysis of large-scale storage opportunities and unite interested parties and service providers to consider strategic investments in long-term storage solutions like pumped storage hydropower”

• December 2018 – DOE selected two projects as case studies
  • Goldendale (1200 MW, National Grid) and Banner Mountain (400 MW, Absaroka Energy)
Operating and Planned Pumped Storage Projects in the U.S.

In operation: ~22,000 MW
Planned: ~40,000 MW
Operating and Planned Pumped Storage Projects in the Region

- Swan Lake, 393 MW
- Cat Creek, 720 MW
- Owyhee, 500 MW
- Goldendale, 1200 MW
- Gordon Butte, 400 MW
- Two Dot Butte, 280 MW
- Banks Lake, 500 MW
- Swan Lake, 393 MW
- Hydro Battery Pearl, 5 MW
- Badger Mountain, 300 MW
- John W. Keys III (Grand Coulee), 314 MW

Planned

Operating
# Proposed Projects in the Region

Project-specific information received from developers, Fall 2019 (thank you!)

<table>
<thead>
<tr>
<th></th>
<th>Swan Lake</th>
<th>Goldendale</th>
<th>Gordon Butte</th>
<th>Banks Lake</th>
<th>Badger Mountain</th>
<th>Owyhee</th>
<th>Seminoe</th>
<th>White Pine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity/Storage</td>
<td>393MW/9hr</td>
<td>1200MW/12hr</td>
<td>400MW/8.5hr</td>
<td>500MW/6.5hr</td>
<td>300MW/8hr</td>
<td>600MW/8hr</td>
<td>750MW/10hr</td>
<td>750MW/8hr</td>
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<tr>
<td>Est. Earliest COD</td>
<td>2025</td>
<td>2028</td>
<td>2025</td>
<td>2026</td>
<td>2025</td>
<td>2026</td>
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<tr>
<td>Configuration</td>
<td>Closed-loop</td>
<td>Closed-loop</td>
<td>Closed-loop</td>
<td>Open-loop</td>
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<td>Closed-loop</td>
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<tr>
<td>Location</td>
<td>Klamath Cty, OR</td>
<td>Klickitat Cty, WA</td>
<td>Meagher Cty, MT</td>
<td>Grant Cty, WA</td>
<td>Douglas Cty, WA</td>
<td>Malheur Cty, OR</td>
<td>Carbon Cty, WY</td>
<td>White Pine Cty, NV</td>
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<tr>
<td>FERC Status</td>
<td>FERC Permit</td>
<td>FERC Prelim Permit</td>
<td>FERC Permit</td>
<td>FERC Prelim Permit</td>
<td>FERC Prelim Permit</td>
<td>Application for FERC Prelim Permit</td>
<td>FERC Prelim Permit</td>
<td>FERC Prelim Permit</td>
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<tr>
<td>Cost Estimate*</td>
<td>$866M</td>
<td>$2.14B</td>
<td>$975M</td>
<td>$1.44B</td>
<td>$675M</td>
<td>$1.2B</td>
<td>$1.6B</td>
<td>$1.5B</td>
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<tr>
<td>Capital Cost Estimate*</td>
<td>$2,203/kW</td>
<td>$1,783/kW</td>
<td>$2,437/kW</td>
<td>$2,880/kW</td>
<td>$2,250/kW</td>
<td>$2,000/kW</td>
<td>$2,133/kW</td>
<td>$2,000</td>
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<tr>
<td>Source (Developer)</td>
<td>National Grid/Rye</td>
<td>National Grid/Rye</td>
<td>Absaroka</td>
<td>Kleinschmidt Associates</td>
<td>GridFlex</td>
<td>GridFlex</td>
<td>GridFlex</td>
<td>GridFlex</td>
</tr>
</tbody>
</table>

* Assume nominal 2019 dollars
• PacifiCorp considered pumped storage in IRP, not selected in preferred portfolio, but in some other portfolios (such as no new gas)
• NorthWestern Energy’s draft 2019 IRP identifies peaking capacity needs and plans to solicit competitive proposals from variety of sources (including pumped storage) starting in 2022 in increments of 200 MW capacity/year
• Idaho Power modeled pumped hydro but did not select it in preferred portfolio (near-term action is solar PPAs)
• Avista’s draft IRP identifies 150 MW pumped storage in 2026, around the time the Lancaster PPA expires and following the exit from Colstrip 3, 4
• Puget Sound Energy included pumped storage in resource options; draft 2019 IRP yet to be released
• Snohomish PUD exploring pumped storage in its resource plan as well
Integrated Resource Plan – Round-up (2)

Portland General Electric, 2019 IRP (filed July 2019)

• Identified need for near-term dispatchable capacity resources over range of future conditions

• Preferred portfolio includes both pumped storage and battery storage in the action plan period (through 2025)

• Capacity procurement actions could allow for numerous outcomes to support future capacity needs – this could result in selection of existing capacity resources or new non-emitting capacity resources (including pumped storage and batteries)

• Oregon PUC staff has raised some concerns about the timing of PGE’s planned procurement process and its potential misalignment with the permitting and construction process for a longer-lead time resource like pumped storage
Pumped storage capital costs are very site specific

- Open-loop vs. closed loop
- Man-made reservoir vs. natural reservoir
- Access to water source, availability of existing infrastructure and transmission
- Site geology, environmental considerations
- Various technology options to select from, with varying equipment costs (e.g. configuration, single vs. variable speed, etc.)
- Project size, head and capacity
Generating Resources Advisory Committee Discussion and Feedback

• September 25
  • Regional project developers provided status updates on projects
    • Swan Lake & Goldendale, National Grid and Rye Development
    • Gordon Butte, Absaroka
    • Banks Lake, Kleinschmidt Associates

• October 29
  • Staff presented status and background of pumped storage technology and a draft pumped storage reference plant
  • Discussion on size, duration of storage (hours), overnight capital cost
Capital Cost Estimates for Pumped Storage

Overnight Cost of Pumped Storage - 2016$/kW

- Swan Lake - 393 MW/9hr, COD 2025
- Gordon Butte - 400 MW/8.5hr, COD 2025
- Badger Mountain - 300 MW/8hr, COD 2025
- Seminole - 750 MW/10hr, COD 2026
- E3 - Pumped Storage
- 2019 PGE IRP - 1200MW/8hr, COD 2024
- 2019 PGE IRP (High) - 1200MW/8hr, COD 2024
- 2019 NWE Draft IRP (High) - 500MW/9hr, COD 2025
- 2019 PAC Draft IRP - 1200MW/14hr, COD 2029
- HydroWire Avg
- HydroWire High

- Goldendale - 1200 MW/12hr, COD 2028
- Banks Lake - 500 MW/6.5hr, COD 2026
- Owyhee - 600 MW/8hr, COD 2026
- White Pine - 750 MW/8hr, COD 2026
- 2019 PSE Draft IRP - 500MW/8hr, COD 2025
- 2019 PGE IRP (Low) - 1200MW/8hr, COD 2024
- 2019 NWE Draft IRP (Low) - 500MW/9hr, COD 2025
- 2019 PAC Draft IRP - 400MW/9.5hr, COD 2025
- 2019 Avista Draft IRP - 100MW/16hr share, COD 2025
- HydroWire Low

NORTHWEST POWER PLAN
## 2021 Plan Reference Plant: Pumped Storage

<table>
<thead>
<tr>
<th>Configuration &amp; Technology</th>
<th>400 MW, 8hr, Variable Speed Pump, Closed-loop System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity (MW)</td>
<td>400</td>
</tr>
<tr>
<td>Energy (MWh)</td>
<td>3,200</td>
</tr>
<tr>
<td>Round Trip Efficiency</td>
<td>80%</td>
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<tr>
<td>Financial Sponsor</td>
<td>IOU</td>
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<tr>
<td>Economic Life (years)</td>
<td>50</td>
</tr>
<tr>
<td>Overnight Capital Cost ($/kW)</td>
<td>$2,300/kW</td>
</tr>
<tr>
<td>Fixed O&amp;M Cost ($/kW-yr)</td>
<td>$14/kw-yr</td>
</tr>
<tr>
<td>Earliest Commercial Online Date</td>
<td>2025</td>
</tr>
<tr>
<td>Development Time</td>
<td>4 years</td>
</tr>
<tr>
<td>Construction Time</td>
<td>5 years</td>
</tr>
<tr>
<td>Potential</td>
<td>4,000 MW (equiv. 10 reference plants); staggered availability and development time over planning period</td>
</tr>
</tbody>
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Next Up

• January/February P4: Natural gas reference plants
• February P4: Geothermal reference plant
• Timing TBD: Emerging technology analysis