July 5, 2023

MEMORANDUM

TO: Power Committee Members

FROM: Annika Roberts, Dylan DSouza

SUBJECT: Emerging Trends in Battery Storage

BACKGROUND:

Presenter: Dylan DSouza, Annika Roberts

Summary: The new energy landscape we find ourselves in, defined by clean policies, heavy renewable builds, and electrification, necessitates a system that can be flexible, works with intermittent resources to ensure reliability, and doesn’t overload transmission. Storage resources fulfill many of those needs. Both regional utility IRPs and state/national energy policy have acknowledged the important role storage will need to play in the country’s energy transition, devoting considerable resources into their further development. This presentation will focus on utility scale battery storage, as it is a rapidly developing technology presently garnering a lot of interest and attention, though there are other forms of storage that can provide similar benefits. Staff will describe the policies shaping storage adoption, outline the existing and planned storage resources in the region and nationally, and will then summarize the technologies available now and emergent technologies to watch for the future.

Relevance: In the 2021 Power Plan there were a number of recommendations in the research and development section to look more closely at battery storage. Both as an emerging technology with potential in the region, as well as a non-wires alternative to help address existing transmission capacity
challenges. Battery storage is showing up in most regional utilities integrated resource plans in some capacity and is poised to play a greater role in the regions electric mix than it has historically.

Workplan: Track emerging technologies, both supply and demand side, providing periodic updates to the Council.

Background: In the 2021 Power Plan the Council developed generating resource reference plants for utility-scale battery storage, pumped storage, and utility-scale solar PV + battery storage which may provide useful context for how the Council has considered storage in the past and the assumptions surrounding storage that went in to the most recent power plan.
Emerging Trends in Battery Storage

July Power Committee
Annika Roberts, Dylan DSouza
Agenda

• Overview of energy storage in the 2021 Plan
• Policy Drivers for Battery Storage
• Existing & Planned Energy Storage (Nationally/Regionally)
• Storage Technology Overview
• Short Duration Storage
• Emerging Technologies
Battery Storage in the 2021 Plan

• Resource Strategy
  – Lots of new renewables necessitate resources that provide flexibility and reliability, & transmission
• Battery storage selected in decarbonization scenario in 2021 PP
  – Stand alone (800 MW) and co-located with solar (2,100 MW)
• Recommendations for R&D:
  – In a directive to explore alternative approaches to power system operation, transmission, and non-wires alternatives the Council recommended the region consider the role of battery storage, targeted demand response, and other demand-side resources to address existing transmission capacity challenges
  – Research and explore the regional resource potential of supply side emerging technologies including energy storage
Storage Policy Drivers
Federal Policy

**IRA**

Expanded the ITC for renewable energy projects to standalone and co-located storage systems
- Applies to battery, thermal or hydrogen energy storage projects with a nameplate capacity of at least 5 kWh
- Tax credit starts at 6% of project development cost, can increase to 30% if certain labor practices are used. Additional 10% available if project meets domestic content requirements
- Also allows for cash payments in lieu of tax credits available to tax-exempt organizations including state/local governments and tribes

**IIJA**

Supply of critical minerals
- Advanced Manufacturing Production Tax Credit directs nearly $30 billion to the domestic production of critical components—including rare earth minerals and their substitutes
- Portion of the $500 million reserved for the DOD is intended to support domestic mining of critical minerals and to explore potential alternative minerals that would reduce demand on the few existing sources of rare earth minerals

PNW Pumped Storage Hydropower Development Act
- Streamlines permitting processes for pumped storage for non-federal pumped storage development at federally owned reserves
- Introduced by WA congressmember intended to encourage pumped storage development at some of the Federal Columbia River Power System dams in the region

Appropriated $505 million for the development of grid-scale, long-duration energy storage demonstrations
National focus

Department of Energy’s Energy Storage Grand Challenge:

- Develop and domestically manufacture energy storage technologies that can meet all US market demands by 2030
- 3 strategic goals (innovate here, make here, deploy everywhere) and supported by quantitative targets
- Designed to ‘create and sustain American leadership in energy storage’
Policy

Oregon

- HB2193: Storage mandate for the two largest IOUs of 5 MWh each by 2022 at a minimum, and up to 1% of 2014 peak load
- Directs OR PUC to develop analytical guidelines for evaluating energy storage.

Washington

- UTC released policy statement directing the study of energy storage as a candidate non-wires alternative for T&D upgrades,
- WA Clean Energy Fund has provided $14.3 million in matching funds for development of 4 utility-scale storage projects.

Montana

- MT PSC issued Order 7621b allowing distributed storage to be used in net metering & directed its IOUs to investigate pumped storage in its next IRP

Idaho

- No storage specific directives at this time. Idaho Power announced plans for the state's largest utility scale Battery storage project at 120 MW of storage to be online by June 2023.
Storage Buildout: Existing & Planned
National Battery Storage Capacity

- Utility-scale battery storage capacity is likely to reach 30.0 GW by the end of 2025
- US battery storage capacity is outpacing even the early growth of the country's utility-scale renewable capacity
- Battery storage projects are becoming increasingly larger in capacity:
  - Pre to 2020: 40 MW
  - Currently: 409 MW (FL's Manatee Energy Storage)
- Developers have scheduled more than 23 large-scale battery projects, ranging from 250 MW to 650 MW, to be deployed by 2025.
U.S. utility-scale battery storage and co-located generator power capacity

Existing capacity (2020) gigawatts:
- Standalone batteries (not co-located)
- Batteries co-located with solar
- Fossil fuels
- Wind

Planned capacity (2021–2024) gigawatts:
- Battery capacity

Capacity of co-located technologies
Figure 3: U.S. Large-Scale Battery Storage Cumulative Power Capacity, 2015-2023

Source: U.S. Energy Information Administration, Dec 2020 Form EIA-860M, Preliminary Monthly Electric Generator Inventory
In Region Storage: *Announced and Operating*

![Bar chart showing storage capacity for Idaho, Montana, Oregon, and Washington.](chart.png)
## In Region Storage: Operating

<table>
<thead>
<tr>
<th>Power Plant</th>
<th>Nameplate Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salem Smart Power Center Battery Storage (Battelle Memorial Institute)</td>
<td>5</td>
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<tr>
<td>Wheatridge Battery Storage Project</td>
<td>30</td>
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<tr>
<td>Wheatridge II Battery Storage Project</td>
<td>30</td>
</tr>
<tr>
<td>Arlington Microgrid Solar &amp; BESS Battery Storage</td>
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<tr>
<td>Horn Rapids Battery Storage and Training Project</td>
<td>1</td>
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<tr>
<td>Innovation 2 Battery Storage Project</td>
<td>4</td>
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<tr>
<td>PSE 2 MW Glacier Battery Storage</td>
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<tr>
<td>Snohomish PUD - MESA 2 Battery Storage</td>
<td>2.4</td>
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<tr>
<td>SNOPUD MESA 1 (Battery Storage) Project</td>
<td>2</td>
</tr>
</tbody>
</table>

*Oregon*

*Washington*
### In Region Storage: Announced

<table>
<thead>
<tr>
<th>State</th>
<th>Power Plant</th>
<th>Year in Service</th>
<th>Nameplate Capacity (MW)</th>
</tr>
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<tbody>
<tr>
<td>IDAHO</td>
<td>Bluebunch Battery Storage Project</td>
<td>2024</td>
<td>150</td>
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<td></td>
<td>Desert Ridge Battery Energy Storage System</td>
<td></td>
<td>250</td>
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<tr>
<td></td>
<td>Downey Populus Battery Storage Project</td>
<td></td>
<td>350</td>
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<tr>
<td></td>
<td>Franklin BESS (Twin Falls)</td>
<td>2024</td>
<td>60</td>
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<tr>
<td></td>
<td>Black Mesa BESS</td>
<td>2023</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Hemingway BESS</td>
<td>2023</td>
<td>80</td>
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<tr>
<td>MONTANA</td>
<td>Beaver Creek I Battery Storage Project (I-IV)</td>
<td>2025</td>
<td>240</td>
</tr>
<tr>
<td></td>
<td>Broadview I &amp; III Battery Storage Project</td>
<td>2024</td>
<td>200</td>
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<tr>
<td></td>
<td>Haymaker Ranch Battery Storage</td>
<td>2027</td>
<td>100</td>
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<tr>
<td></td>
<td>Meadowlark Solar Battery Storage</td>
<td>2024</td>
<td>25</td>
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<tr>
<td></td>
<td>Beartooth Battery Storage Project (EsVolta)</td>
<td>2024</td>
<td>50</td>
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<tr>
<td>OREGON</td>
<td>Cedar Island Battery Storage Project</td>
<td>2025</td>
<td>80</td>
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<tr>
<td></td>
<td>Madras Solar Energy Facility Battery Storage</td>
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<td>63</td>
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<td></td>
<td>Muddy Creek Battery Storage Plant</td>
<td>2025</td>
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<tr>
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<td>Nolin Hills Solar Battery Storage Project</td>
<td>2026</td>
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<td>Port Westward Generating Battery Storage Project</td>
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<td>Stateline (OR) Battery Storage Project</td>
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<td>Evergreen Battery Storage Project</td>
<td>2024</td>
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<td>Obsidian Battery Storage Project</td>
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<td>Seaside Battery Storage Project</td>
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<td>Troutdale Battery Storage Project</td>
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<td>Wheatridge East Battery Storage Project</td>
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<tr>
<td></td>
<td>Bakeoven Battery Storage Project</td>
<td>2026</td>
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<tr>
<td>WASHINGTON</td>
<td>Badger Mountain Energy Battery Storage</td>
<td>2024</td>
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<td></td>
<td>Hop Hill Battery Storage Project</td>
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<tr>
<td></td>
<td>Horse Heaven Hybrid Battery Storage Project</td>
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<tr>
<td></td>
<td>Ostrea Battery Storage</td>
<td>2025</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>High Top Battery Storage</td>
<td>2025</td>
<td>40</td>
</tr>
</tbody>
</table>

- **930 MW** in Idaho
- **615 MW** in Montana
- **1443 MW** in Oregon
- **1430 MW** in Washington
### Storage in Regional IRPs

This list is not comprehensive but an illustration of how much of the region is considering storage in their planning.

<table>
<thead>
<tr>
<th>Utility</th>
<th>Utility Scale</th>
<th>Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>PacifiCorp (2023 IRP)</td>
<td>7,560 MW Li-Ion battery by 2028 35 MW pumped storage by 2028 (+350 MW by 2036)</td>
<td></td>
</tr>
<tr>
<td>Avista (2023 IRP)</td>
<td>52 MW by 2039 195 MW by 2045 (primarily long duration iron oxide batteries)</td>
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<tr>
<td>Portland General Electric (2023 IRP)</td>
<td>176-503 MW by 2030 (4-hour Li-Ion batteries)</td>
<td></td>
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<tr>
<td>Idaho Power (2021 IRP)</td>
<td>1685 MW by 2040 (large storage projects + 17 selections of 5 MW grid-located storage projects for T&amp;D deferral)</td>
<td></td>
</tr>
<tr>
<td>NorthWestern Energy (2023 IRP)</td>
<td>25-700MW battery (4-hour) 200-400MW pumped storage (through 2042)*</td>
<td></td>
</tr>
<tr>
<td>Puget Sound Energy (2023 IRP)</td>
<td>1,000 MW by 2030 1,800 MW by 2045 (4-6 hour Li-Ion batteries and 8 hour pumped hydro)</td>
<td></td>
</tr>
<tr>
<td>Tacoma Power (2022 IRP)</td>
<td>10 MW Demand Response in preferred portfolio though identified utility-scale battery storage as supply-side alternative</td>
<td></td>
</tr>
<tr>
<td>Snohomish (2021 IRP)</td>
<td>35-70 MW 8-Hour Storage by 2031**</td>
<td></td>
</tr>
</tbody>
</table>

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*NorthWestern’s IRP does not identify a preferred portfolio among the 20 scenarios.

**Snohomish’s IRP does not specify an underlying technology of the storage resource, the study focuses on specific characteristics to meet the PUD’s needs.*
Storage Technology Overview
Utility-Scale Energy Storage

LDES technologies can be used for inter-day and multi-day use cases at a variety of scales

- **More detail follows**

**Codifying the technology**

1. **Short duration**: Durations up to 10 hours
2. **Inter-day LDES**: Sometimes called “diurnal”
3. **Multi-day / week LDES**: Commonly called “seasonal”
4. **Seasonal shifting**: Generally included in “seasonal”, but distinct in that this does function as a conventional, storable fuel
Energy Storage Technologies

Mechanical
Kinetic storage; most common: flywheel and compressed air
- Flywheel
- Vacuum Enclosure
- Cylindrical Rotor
- Motor
- Upper Magnetic Bearing
- Lower Magnetic Bearing

Electrochemical
Battery storage; most common: lithium-ion and lead
- Battery Racks
- Cells
- Fire Suppression
- Grid-scale battery
- Cooling Vents

Thermal
Energy stored as heat or cold; most common: controllable water heaters
- Control Panel
  - Utility turns heater on and off
  - Regulates and shifts load
  - Lowest-cost energy-storage method

Gravitational
Storage using moved mass; most common: pumped hydropower
- Upper Reservoir
- Lower Reservoir
- Pumping
- Generating
- Turbine
power capacity
megawatts

annual additions
250

cumulative capacity
1000


4% 2% 1% 1%

92%

Source: U.S. Energy Information Administration, 2019 Form EIA-860, Annual Electric Generator Report

energy capacity
megawatthours

annual additions
600

cumulative capacity
1,800


4% 1% 1%

93%

lithium-ion
nickel-based
sodium-based
flow
other
Short Duration Battery Storage
Lithium-ion (Li-ion) Battery Technology

• Dominant option for short duration storage
• Efforts are continuing to expand duration of Li-ion
• Fit for flattening the curve
• Discharge rate and frequency
• Supply chain concerns and constraints
• Common uses: cell phones, electric vehicles, utility-scale storage
Capacity Factor, Round Trip Efficiency and LCOS

• Capacity Factor
  – A 4-hour device has an expected capacity factor of 16.7% ($4/24 = 0.167$), and a 2-hour device has an expected capacity factor of 8.3% ($2/24 = 0.083$)

• Round-Trip Efficiency
  – Round-trip efficiency is the ratio of useful energy output to useful energy input. For 2022 NREL adopted 86% as a representative round-trip efficiency for these battery systems

• Levelized Cost of Storage
  – According to the same 2022 NREL study, ranging from $428/kWh down to $333/kWh cost decreases with size and duration changes
Supply Chain and Other Hurdles

- Supply Chain constraints
- Interconnection
- Policy
- Regulation
Emerging Technologies
**Flow Batteries**

- A flow battery is a rechargeable battery in which electrolyte flows through one or more electrochemical cells from one or more tanks.
- With a simple flow battery, it is straightforward to increase the energy storage capacity by increasing the quantity of electrolyte stored in the tanks.
- The electrochemical cells can be electrically connected in series or parallel, so determining the power of the flow battery system.
- This decoupling of energy rating and power rating is an important feature of flow battery systems.
- ESS Eastern Oregon factory and Iron-Air Batteries by Form Energy.
Emerging Utility-Scale Storage Technologies

• Flow Batteries
  – Iron-Air Batteries
• Hydrogen Storage
  – Ammonia
• Compressed Air Energy Storage (CAES)
  – Study done in 2013 by PNNL in conjunction with BPA
Pilots and Research In-Region

• Washington Clean Energy Fund Grid Modernization Projects
• PNNL and Washington Clean Energy Testbeds