PSM(-E24

Role of Hydropower to Meet Regional requirer PSM(-E22 s

+ **Hydropower resources provide unique system benefits to support system needs in California and the Northwest**

System Benefit	Hydropower Capabilities	Value Over Time
Capacity for Resource Adequacy	• Hydropower provides significant RA capacity through its maximum expected generation (CA) or sustained peaking capability (NW)	• RA will be ***highly valuable across the planning horizon***
Carbon Free Energy	• Hydropower's carbon-free energy comes at low-cost without any new transmission needs or development risk • Hydro energy also provides the financial benefit of avoiding natural gas fuel costs	• Carbon-free energy will be ***increasingly valuable*** to both CA and the NW as clean energy policy targets become more stringent
Reserves and Flexibility	• Hydro provides a zero-emissions source of ancillary services (spin, regulation, etc.) and ramping capabilities to integrate variable renewable energy • Flexibility may change as a function of time of year and water availability	• Renewable integration value will be ***increasingly valuable***, though batteries can provide some similar services
Essential Reliability Services (ERS)	• Hydro also provides key reliability services (reactive power, inertia, blackstart, etc.), including some that cannot currently be provided by asynchronous generators	• ERS will be ***increasingly valuable*** as other synchronous generators retire

Lower Snake River Dams

- **The lower snake river dams:**
  - Are ~10% of the Northwest regional hydropower capacity
  - Provide relatively low-cost and flexible carbon free power

Plant	Nameplate Capacity (MW)*	50-year Forecasted Costs** (real 2022 $/MWh)
Lower Granite	930	$22.69
Little Goose	930	$15.71
Lower Monumental	930	$12.58
Ice Harbor	693	$15.84

Total = 3,483

* Nameplate capacities from BPA White book

** Costs provided by BPA based on the CRSO EIS, including sustaining capex, O&M, and fish + wildlife related costs PSM(-E5

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Comparison to the recent NWEC study

- The Northwest Energy Coalition study incorrectly describes the nameplate capacity of the four lower Snake River dams as 1,000 MW, when in fact, the capacity is more than 2,000 MW.
  - Although output averages at 1,000 MW, the region draws on the nameplate capacity of 2,000 MW often to avoid power shortages, such as during heat waves or cold snaps.

PSM(-E14

PSM(-E33

PSM(-E34

- The NWEC study understates the benefits that the four lower Snake River dams provide in terms of grid stability –the services required to keep the lights on.
  - For example, Bonneville is required to keep reserve power to avoid blackouts if a generator trips offline (this is not hypothetical – it happens). PSM(-E37
  - Obtaining these services would add to the cost of replacing the output of the dams, which is not articulated in the NWEC study.

Placeholder for graphic showing capacity of four Lower Snake River dams

- Baseline for the NWEC study assumes that Bonneville purchases 300 MW from the market to provide firm power.
  - By statute, Bonneville relies on the federal hydrosystem to provide firm power to its public power customers PSM(-E35
  - BPA typically purchases market power when the hydrosystem can't produce enough to serve its customers during emergencies

Important note about dam output

- By law, Bonneville can only provide **firm** sales of electricity (reliable energy that is available at all times) to its public power customers.
- That means the agency can only commit to providing the amount of electricity produced from a **low water year**, because that's the only amount of electricity that can be assured – high water years provide a "bonus," or surplus.
- If Bonneville committed to providing the amount of electricity produced from an average or high water year, there would be a **power shortage** during low water years.
- During extremely low water years, or during emergencies such as cold or heat snaps, Bonneville purchases power on the market to avoid a power shortage. PSM(-E38
- During average or high water years, Bonneville sells the surplus on the secondary market to help keep public power rates low.

PSM(-E17

PSM(-E28

Assumptions, or “dials” in the modeling

Element	Study Approach	Impact on Dams Replacement Needs
Study Years	• 2025 through 2045, including fuel price forecasts and declining renewable + storage costs	Considers long-term needs
Clean Energy Policy Scenarios	• Aggressive OR+WA legislation reflected, including coal retirements + carbon pricing • Two electric emissions scenarios considered: 1. 100% clean retail sales (~85% carbon reduction*) 2. Zero-emissions (100% carbon reduction)	Clean energy policy requires long-term **replacement of LSR dams with GHG-free energy**
Load Growth Scenarios	• Two load scenarios: 1. **Baseline** (per NWPCC 8th Power Plan) 2. **High electrification** load growth (to support economy-wide decarbonization)	Higher load scenarios **increase the value of LSR dams energy + firm capacity**
Reliability Needs PSM(-E39	• Modeling ensures reliability needs during extreme conditions (e.g. high loads + low hydro) Captures ability (and limits) of renewables, battery storage, and demand response to support system reliability	Reliability needs require **replacement of LSR dams firm capacity contributions**
Consideration of Emerging Technologies	• Broad range of dam replacement technology options considered • **Baseline technologies**: solar, wind, battery + pumped storage, energy efficiency, demand response, dual fuel natural gas + hydrogen combustion plants • **Sensitivities:** • **Emerging technologies** • **No New Combustion**	**Technology available for LSR dams replacement** determines cost + feasibility
Distributed Energy Resource Options	• Energy efficiency, demand response, and customer solar embedded into modeling inputs • Additional energy efficiency and demand response can be selected	**Demand resource can help replace LSR dams**, though low-cost supply is limited

* A 100% clean retail sales target allows emissions for electric generation beyond that needed to serve "retail sales", i.e. losses during transmission to retail loads and exported energy.

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Two clean energy scenarios – both consider emerging tech availability and the *increased* electricity use from *decreased* fossil fuels on the grid

- **Scenario 1: 100% Clean Retail Sales (S1)**
  - 100% of retail sales met with clean energy by 2045, ~85% carbon reduction
  - Business-as-usual load growth
  - Can be achieved using existing mature technologies
- **Scenario 2: Deep Decarbonization**
  - Zero carbon emissions remain in 2045
  - High electrification load growth consistent with economy-wide carbon abatement scenarios
  - Emerging technologies are key to meeting higher winter reliability needs with carbon-free power

Electric Load Growth and Carbon Emissions

Emerging Technologies Considered

Emerging "Clean firm" technologies

Technology	Description	S1 100% Clean	S2a Deep Decarb Baseline	S2b Deep Decarb Emerging Tech.	S2c Deep Decarb No New Combustion
Hydrogen (existing gas retrofits)	Burn green hydrogen (produced off-grid) in existing gas plants				
Hydrogen (new dual fuel gas + hydrogen)**	Burn either natural gas or green hydrogen (produced off-grid) in new gas plants				
Nuclear (small modular reactors)	Firm, dispatchable zero-GHG generation using advanced modular construction				
Gas w/ Carbon Capture and Storage	Firm, dispatchable zero-GHG generation with 100% carbon capture + storage (allam cycle)				
Offshore Wind (floating)	High output wind farms floating in deep offshore waters				

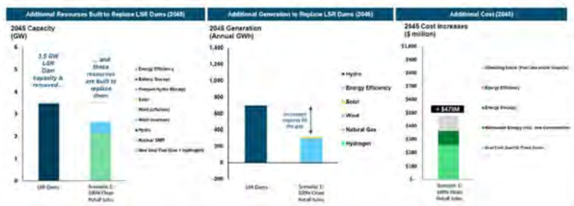
* Load based on 2021 NWPCC Power Plan; shown as retail sales (after assumed growth in customer PV)
** Scenario 1 builds dual fuel gas + hydrogen, but no hydrogen is utilized in this scenario

Energy+Environmental Economics 4

PSM(-E20

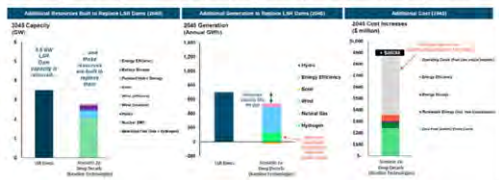
Scenario 1: 100% clean retail sales to replace lower Snake River dams

- **Capacity replaced with dual fuel natural gas + hydrogen turbines**
- **Energy replaced by wind and net imports**



Scenario 2: deep carbonization (baseline technologies) to replace lower Snake River dams

- Capacity replaced with dual fuel natural gas + hydrogen turbines, energy efficiency, and energy storage
- Energy replaced by wind, reduced exports, energy efficiency, and increased hydrogen generation



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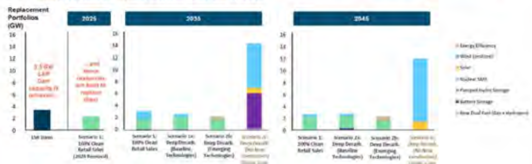
PSM(-E18

Across all scenarios: replacing four Lower Snake River dams capacity

- **Capacity replacement for additional scenarios and years is shown below:**
  - **Scenario 1 (100% Clean Retail Sales, 2024 LSR Dam removal)**: similar to scenario 1, but with dual fuel natural gas + hydrogen turbine replacement in 2025
  - **Scenario 2b (Deep Decarbonization, Emerging Technologies)**: small modular nuclear reactors replace LSR capacity and energy, instead of additional wind power
  - **Scenario 2c (Deep Decarbonization, No New Combustion)**: very high replacement need as wind and solar alone struggle to replace LSR dam firm capacity and zero-carbon energy output



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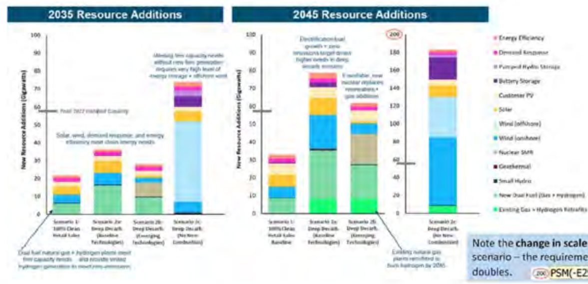
All scenarios show large levels of new resource additions



Note the **change in scale** for the last scenario – the requirement almost doubles.

PSM(-E25

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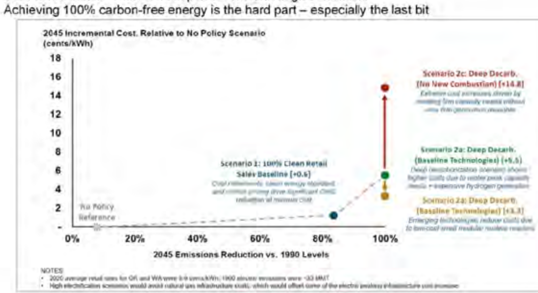
Even before we consider taking out the four lower Snake River dams…

- Regional policy requirements and legislation to reduce emissions is removing resources fossil fuel resources from the grid. This is happening now.
- Consequently, with retiring coal and gas plants, the region is ***already*** facing resource adequacy issues.
- Loss of the four lower Snake River dams, or reductions in their flexibility, while there are still fossil fuel generators on the grid will increase the timeframe and costs associated with shifting to a carbon-free electricity sector.

Placeholder for graphic showing coal retirements

Cost of carbon reductions

- Significant carbon reductions are possible at modest cost
- Cost to reach zero emissions depends on technologies available
- Achieving 100% carbon-free energy is the hard part – especially the last bit



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Increased costs and requirement for resources

- RESOLVE model determines replacement needs and cost by optimizing regional requirements with the dams, and then again without the dams
- The model does not consider **essential reliability** services for the transmission grid, such as voltage, reactive power, inertia, black start, etc.
- The RESOLVE model shows that, without the four lower Snake River dams, the region will experience increased costs and increased requirement for resources.

Electric Grid Benefit
GHG-free Energy Output (MWh) GHG-free energy displaces the costs and carbon emissions of NW coal + gas generation or imported power
Reliable Capacity (MW) Firm capacity contributions towards resource adequacy
Flexibility and Operating Reserves (MW) Sub-hourly ancillary service provision and renewable integration benefits

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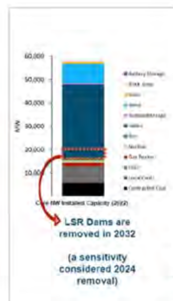

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The cost of replacing power

- Replacing the greenhouse gas-free energy, capacity, and operational benefits of the dams requires investment in new resources at increased total system costs
  - Cost differences between scenarios driven by 2045 greenhouse gas PSM(-E26rgy replacement and the availability of "clean firm" emerging technologies
- Costs are expected to fall on Bonneville Power Administration's public power customers
  - Could **increase public power costs** by 8% (best case scenario with emerging tech) to 65%
  - Could **raise residential electricity costs** by ~$100 –850 per year

	Total Costs	Annual Cost Increase			[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Scenario 1: 100% Clean Retail Sales	$3.3 billion	—	$434 million	$478 million	[illegible]
Scenario 1: 100% Clean Retail Sales (2024 dam removal)	$7.2 billion	[illegible]	[illegible]	$509 million	[illegible]
Scenario 2a: Deep Decarb. (Baseline Technologies)	[illegible]	—	[illegible]	$860 million	1.5 cents/kWh (+18%)
Scenario 2b: Deep Decarb. (Emerging Technologies)	$3.0 billion	—	$415 million	$408 million	0.7 cents/kWh (+8%)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

NOTES:
- Cost increases account for replacement energy, capacity, and reserves as well as avoided LSR capital + expense, but do not include any costs for breaching the dams, which would be an additional cost.
- NPV and annual cost increase are shown for the Northwest Region as a whole, but the incremental costs are calculated relative to the BPA Tier I annual sales for public power customers.
- % increase versus average rates assumes OR + WA average retail rates are ~8.5 cents/kWh. This does not include additional rate increases driven by higher loads of clean energy needs that increase regional rates as shown in the earlier 2045 incremental cost chart
- Annual residential customer cost impact assumes 1,200 kWh/month for average residential customers in Oregon and Washington (current ~1,000 kWh/month average + 20% from electrification load growth)

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Land use considerations

PSM(-E7

- Replacing the lost power with new solar-power resources would require roughly X acres (about X square miles) of land. PSM(-E36
- Such a large build out of solar capacity would likely result in additional, but currently unknown impacts to natural and cultural resources, which may include vegetation, wildlife habitat, archeological resources, and traditional cultural properties (such as sites or land features that are important to tribes).

4. Impact of differing operating patterns on capacity value of Diablo Canyon

Conclusion and summary

- The study considers two important factors in replacing power from the four lower Snake River dams:
  - Power must **provide firm capacity** (reliable energy that is available at all times) to avoid power shortages
  - Power must be **free of greenhouse gasses** to meet regional carbon policies
- Policies and laws to decarbonize the region will **increase electricity use** (electric cars, replacing gas appliances, etc.)
- Acquiring replacement resources could require **building renewable resources at an unrealistic level**.
  - This would also require building transmission to bring the power from new resources to utilities
- Replacing the dams comes at a **substantial cost** for new resource replacement
  - This would have a meaningful impact on the rates of Bonneville Power Administration's public power customers.
- The **availability of emerging technology** is a factor in achieving replacement recourses that are free of greenhouse gasses.

Thank you slide