The Lower Snake River Dams Power Replacement Study

April 4, 2018

NW Energy Coalition

About the study

WHY?

The study was undertaken to investigate the technical feasibility and cost of replacing the four Lower Snake River Dams with a portfolio of clean and renewable resources that support a reliable and adequate regional power system while minimizing increases to greenhouse gas emissions.

HOW?

The study seeks to develop a deeper understanding of the options for replacing the grid services the Lower Snake River Dams provide to the regional power system, while also establishing an analytic framework that uses models and metrics familiar in the Northwest.

WHO?

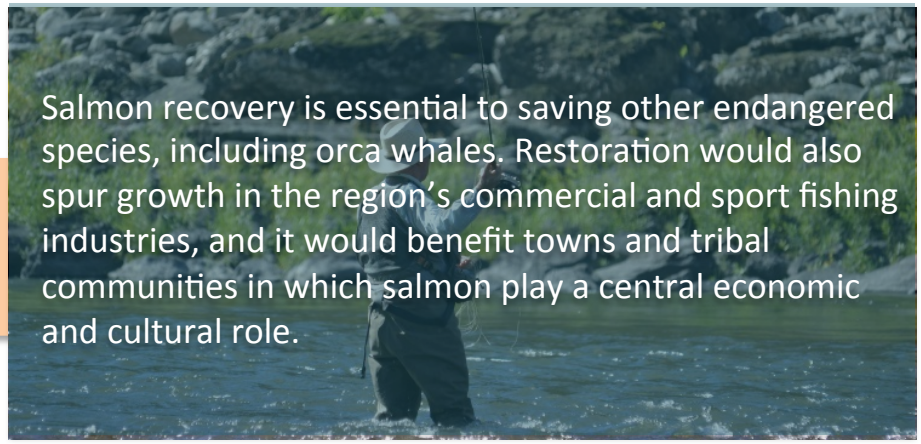
The study was commissioned by the NW Energy Coalition and conducted by Energy Strategies, an independent consulting firm founded in 1986 and based in Salt Lake City, Utah. Energy Strategies clients include power producers, transmission developers, utilities, and government agencies throughout North America.

The dams, the fish, and the opportunity

The Northwest Power and Conservation Council has said we need sustained return rates of 2%–4% for salmon survival and 4%–6% to move towards recovery. In the last 20 years, return rates for wild Snake River salmon have largely hovered between 0.5% and 1%—far below what's required for wild salmon to survive and thrive into the future.

Despite many efforts and great expense, fish populations are not recovering.

Restoration of fish populations holds great promise for the region and it's required by the Endangered Species Act.



Salmon recovery is essential to saving other endangered species, including orca whales. Restoration would also spur growth in the region's commercial and sport fishing industries, and it would benefit towns and tribal communities in which salmon play a central economic and cultural role.

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Summary findings

"The region can remove the four lower Snake River dams and replace the power they provide with a portfolio of conservation and renewable energy resources while maintaining grid and transmission reliability at levels equal to or better than the current system and with little or no increase in greenhouse gas emissions."

The Lower Snake River Dam Power Replacement Study, April 2018

- Balanced portfolios of clean energy resources, including solar, wind, energy efficiency, demand-response, and storage can replace the power the four LSR Dams contribute to the Northwest region.
- Clean portfolios were equal or superior to an All Gas alternative for adequacy, grid stability, and reliability.
- The costs of balanced clean replacement portfolios are small compared to the cost of the regional power system.
- A balanced clean replacement portfolio has only a minor impact on GHG emissions (about 1%). If implemented in conjunction with a regional GHG reduction policy, substantial reductions in GHG emissions can be achieved.
- New gas-fired generation is not required to address regional capacity needs.
- The study did not try to identify an optimal clean energy replacement portfolio. An effort to do so should produce even more cost effective and environmentally efficient outcomes than the portfolios considered in this analysis.

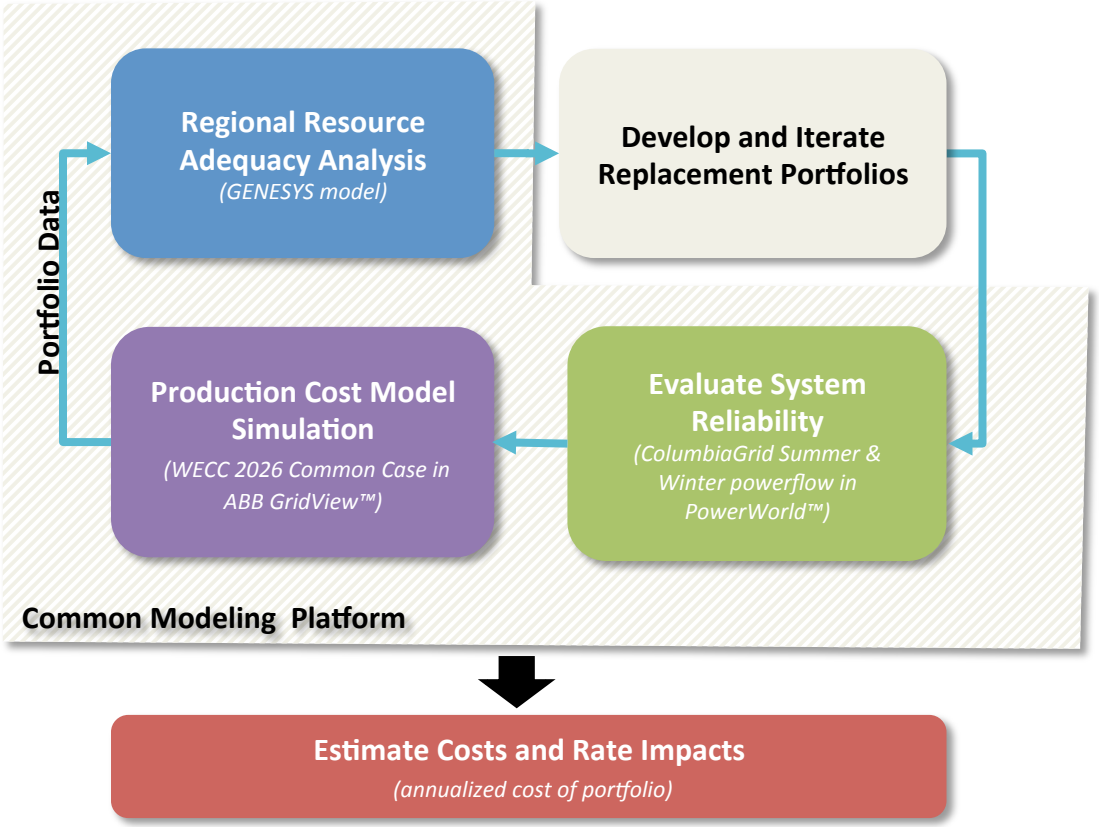
Process and structure

- The study was conducted in 3 phases:
  - Identification and quantification of grid services provided by the Lower Snake River Dams.
  - Development of replacement portfolios that meet or exceed reliability, energy, and adequacy needs.
  - Assessment of fixed and variable production and operating costs to implement the replacement portfolios and their effect on market prices and greenhouse gas emissions.

- The study started with a Reference Case in which the dams remain in operation under existing policies and in accordance with the Northwest Power and Conservation Council's 20-year Power Plan and 5-year Action Plan. It then considered three replacement portfolios, which all start with the 7th Plan assumptions for acquiring energy efficiency, demand response, and renewable energy resources. The portfolios then add resources as required.

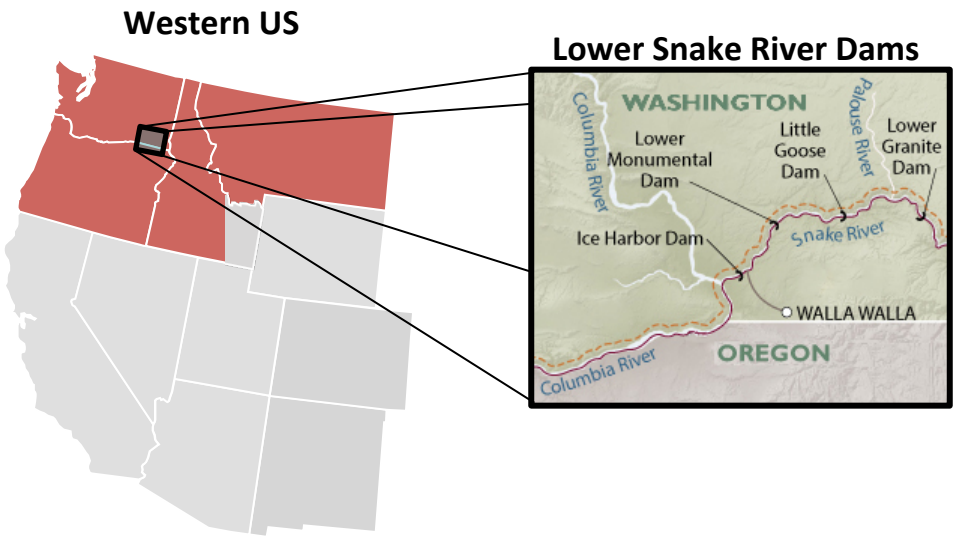
Non-Generating Alternative Portfolio	**Balanced Portfolio**	**All-Gas Portfolio**
Would replace power from the dams with feasible levels of demand response, energy efficiency, battery storage, and incremental market purchases of electricity	Would replace power from the dams with a combination of demand response, energy efficiency, and wind and solar generation	Would replace power from the dams with a mix of combined cycle and reciprocating engine natural gas-fired generators

Study framework



- Coordinated modeling framework used three modeling tools to look at replacement portfolio impacts to reliability, resource adequacy, operations, and cost.
- Initial portfolios were developed, tested, and adjusted iteratively.
- The clean replacement portfolios included “Plus” versions that ramped-up the level of clean energy resources.
- Modeling resulted in robust comparisons of all replacement portfolios with the Reference Case.

Geographic scope of the study



- Three models were used to evaluate Pacific Northwest region
  - Two models represent the entire WECC-footprint. The third represents ties and market purchases with neighboring areas.
  - British Columbia and Alberta are factored in all three models.
- Lower Snake River Dams are modeled explicitly.
- Replacement portfolios are modeled with high-granularity (e.g. new resources sited at specific substations, demand response assigned to appropriate load types).

The replacement portfolios

RESOURCE COMPOSITION OF THE REPLACEMENT PORTFOLIOS

The base Balanced and Non-Generating Alternative (NGA) portfolios were enhanced by the addition of extra resources to create "Plus" versions. The resulting portfolios as well as the All Gas portfolio were then modeled for their effects both under current law and under a scenario in which Northwest states adopt carbon pricing policies.

		Replacement Portfolios					GHG Reduction Policy Senstitivity		
		NGA	NGA Plus	Balanced	Balanced Plus	All Gas	NGA Plus	Balanced Plus	All Gas
Replacement Resources	Demand-side	~1,000 MW DR 320 aMW EE	~1,000 MW DR 880 aMW EE	~500 MW DR 160 aMW EE	~500 MW DR 160 aMW EE	-	~500 MW DR 160 aMW EE	~500 MW DR 160aMW EE	-
	Resource-side	-	-	500 MW wind 250 MW solar	1,250 MW wind 750 MW solar	500 MW NGCC 450 MW recip	500 MW wind 250 MW solar	1,250 MW wind 750 MW solar	500 MW NGCC 450 MW recip
	Capacity Market	100 MW	100 MQ	-	-	-	100 MW	-	-

Models, data sources, and assumptions

Resource adequacy was assessed using the Northwest Power and Conservation Council's GENESYS model. Reliability and power flow characteristics were modeled using PowerWorld. Production costs and grid stability were modeled using ABB's GridView. Wind, solar, and battery storage levelized costs were calculated using the 2017 WECC Capital Cost Model. Data for the study was provided by WECC, ColumbiaGrid, and the Northwest Power and Conservation Council.

Thermal Generation or Capacity Market Cost

Resource Type	Capital Cost ($/kW-ac)	Levelized Fixed Cost ($/kW-year)
Gas Combined Cycle	$1,498	$213
Gas Reciprocating Engine	$1,416	$206
Capacity Contract (Market)	$30/kW-year	---

Renewable/Storage Cost

Resource Type	Capacity Factor (%)	Installed cost ($/kW-ac)	Levelized Fixed Cost ($/kW-year)	Levelized Cost of Energy ($/MWh)
Wind (Montana)	44%	$1,639	$205	$53.24
Solar, Single-axis Tracking (Idaho)	26%	$1,440	$127	$59.10
Li-ion Battery (4-hr)	---	$753	$141	---

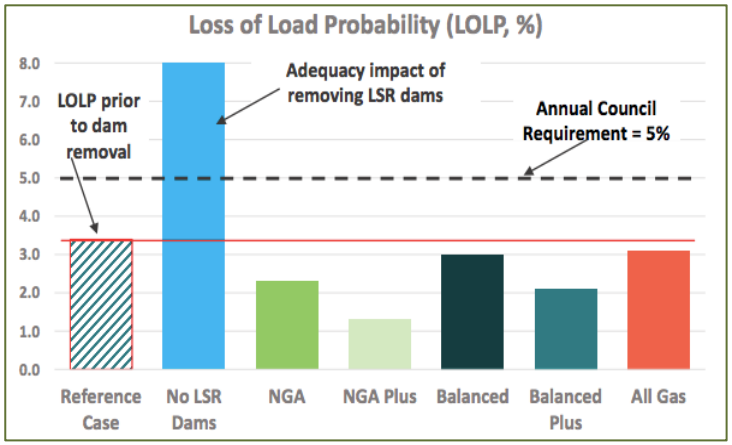
Demand-side Cost Assumptions

Resource Type (incremental to Reference Case)	Resource Potential	Average Levelized Fixed Cost ($/kW-year)	Average Levelized Cost of Energy ($/MWh)
"Cost Effective" Energy Efficiency	320 aMW	---	$28
50% of "Cost Effective Energy Efficiency	160 aMW	---	$24
"Technical Potential" Energy Efficiency	880 aMW	---	$132
"Cost Effective" Demand Response	~1000 MW	$68	---
50% of "Cost Effective Demand Response	~ 500 MW	$29	---

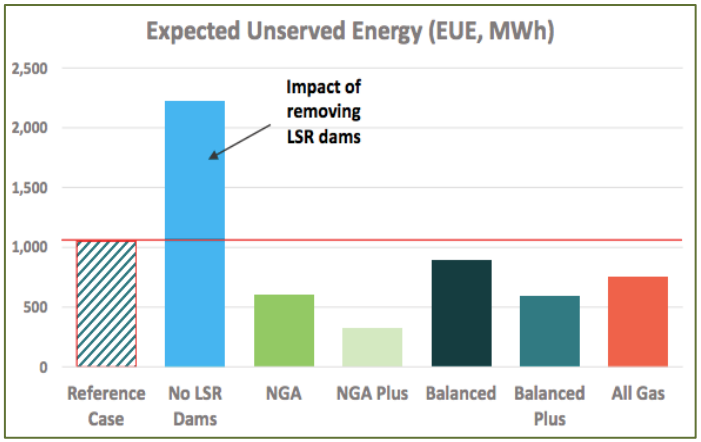
Findings: Adequacy & reliability

All three replacement portfolios reduced the likelihood of curtailments and the magnitude of load loss in the event of curtailments. The "Plus" portfolios were the best-performing in terms of system adequacy.

Probability of Curtailments



Magnitude of Curtailments



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Findings: Cost

- The Balanced Plus portfolio increases the system revenue requirement by 3% starting in 2026, which translates to a $1.28 per month increase for the average residential customer. The figure increases slightly to 3.21% or $1.38 per month if Northwest states implement greenhouse gas policies.

- The revenue requirement for the Balanced Plus portfolio is less than that of the All Gas portfolio.

- If costs for wind power, solar power, and storage continue their current declines, costs may be lower. This is reflected in the column titled, "Balanced Plus w/Low Renewable Cost Sensitivity".

All changes are relevant to Reference Case that retains the LSR dams		Replacement Portfolios						GHG Reduction Policy Sensitivity		
		NGA	NGA Plus	Balanced	Balanced Plus	Balanced Plus w/Low Renewable Cost Sensitivity	All Gas	NGA Plus	Balanced Plus	All Gas
Costs	Δ Total Ann'l Cost ($M/year)	$421	$1,191	$396	**$464**	**$399**	$535	$1,224	$501	$581
	Δ Region Revenue 2026 Requirement (%)	+2.7%	+7.6%	+2.5%	**+3.0%**	**+2.6%**	+3.4%	+7.6%	3.21%	+3.7%
	Δ Levelized Monthly Bill ($/Month)	$1.16	$3.28	$1.09	**$1.28**	**$1.10**	$1.47	$3.37	$1.38	$1.60

Findings: Greenhouse gas emissions

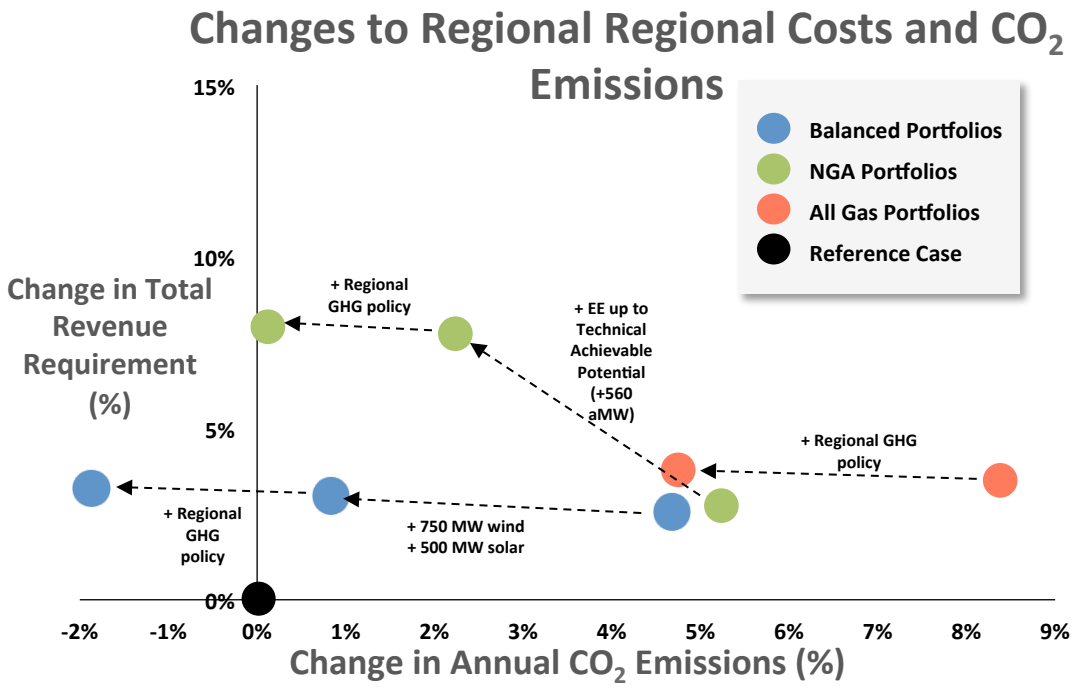
The Balanced Plus portfolio generates enough clean electricity to mitigate the impact on regional emissions to less than 1%.

When the Balanced Plus portfolio is combined with regional greenhouse gas policy, emissions decline by 2%.

Decreases in GHG emissions are feasible if the Lower Snake River Dams are replaced by clean energy portfolios that are implemented in parallel with a GHG reduction policy.

Portfolio	Total CO_2 Emissions Including Annual Gross Imports (Short Ton)	Δ (Short Ton, annual)	Δ (%)
Reference	43,299,426	0	0%
Balanced	45,327,168	2,027,741	5%
Balanced Plus	43,659,702	360,275	1%
Balanced Plus + GHG Policy	42,491,591	-807,836	-2%
NGA	45,566,562	2,267,136	5%
NGA Plus	44,267,489	968,063	2%
NGA Plus + GHG Policy	43,351,769	52,342	0%
All-Gas	46,928,920	3,629,493	8%
All-Gas + GHG Policy	45,357,456	2,058,030	5%

Costs and emissions summary



- When the Balanced portfolio was modified to include additional renewable resources and then modified further to include a regional GHG policy, carbon emissions are fully mitigated at a relatively low incremental cost .
- The All Gas portfolio started with much higher emissions and, when mitigated by GHG policy, was more costly and higher emitting than the Balanced portfolio.
- An optimized portfolio may result in lower costs without increases in GHG emissions.

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Policy implications

The Lower Snake River Dams Power Replacement Study has important implications for the court-ordered review process now being conducted by the federal agencies that own and operate the dams.

1. The study shows that removal of the dams and replacement of the energy they generate with clean and renewable resources is a viable, effective and affordable option. The study also offers a framework from which the federal agencies can draw as they develop a new plan for dam operations.
2. The clean energy portfolios developed in the study can be improved upon. Although this study demonstrates the viability of replacing power from the four LSR Dams with clean and renewable resources, it did not seek to identify the optimal clean energy solution. The court-ordered process offers a great opportunity for the federal agencies to identify more cost effective and environmentally efficient portfolios than those considered in this analysis.
3. A full study of dam removal needs to address factors beyond the scope of this study. These factors include the costs of decommissioning the dams as well as cost savings from dam removal, including the hundreds of millions of dollars that will be needed in the next few years to replace the dams' aging turbines.