Supplement Analysis
for the
Columbia River System Operations Environmental Impact Statement
(DOE/EIS-0529/SA-02)

Bonneville Power Administration
Department of Energy

Background

In September of 2020, Bonneville Power Administration (Bonneville) along with the U.S. Army Corps of Engineers (Corps) and Bureau of Reclamation (Reclamation) issued a Record of Decision (ROD) for the Columbia River System Operations Environmental Impact Statement (CRSO EIS) (DOE/EIS-0529) and associated consultations under the Endangered Species Act. The CRSO EIS, dated July 2020, addressed the ongoing operations, maintenance, and configuration of the 14 federal Columbia River System (CRS) projects on the Columbia and Snake rivers. The 14 projects are Libby, Hungry Horse, Albeni Falls, Grand Coulee, Chief Joseph, Dworshak, Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, The Dalles, and Bonneville. The co-lead agencies (Corps, Reclamation, and Bonneville) share responsibility and legal authority for managing the CRS. These three co-lead agencies coordinate the operation and maintenance of the CRS and worked together to develop the EIS. The co-lead agencies identified the Preferred Alternative, as described in detail in Chapter 7 of the Final EIS, as the Selected Alternative in the ROD.

As part of the CRSO EIS, the agencies considered six alternatives to CRS operations, maintenance, and configuration. The agencies analyzed the effects of these alternatives on the human environment, including environmental, economic, and social impacts. Multiple-Objective Alternative 3 (MO3) evaluated effects that would result from a suite of operational measures as well as a measure that included breaching the four lower Snake River dams: Lower Granite, Little Goose, Lower Monumental, and Ice Harbor. The CRSO EIS analyzed various affected resources, including effects from potential replacement energy resource portfolios to provide the lost energy services from the four lower Snake River dams.

On February 28, 2020, the co-lead agencies released for public comment the Draft CRSO EIS describing the effects of these alternatives and identifying the agencies' Preferred Alternative. The 45-day public comment period ended on April 13, 2020, and the agencies reviewed and responded to these comments in the Final CRSO EIS. The co-lead agencies released the Final EIS on July 28, 2020, and the agencies issued a joint Record of Decision on September 28, 2020.

In October 2021, Bonneville completed a supplement analysis (SA-01) documenting that proposed modifications to operational measures would not result in substantial modifications to the Selected Alternative and were consistent with the effects described in the Final CRSO EIS.

No further changes in the implementation of the Preferred Alternative adopted in the ROD are proposed at this time, therefore there is no substantial change in the proposed action relevant to environmental concerns that would trigger supplementation under the National Environmental Policy Act.

In 2022, Bonneville contracted with Energy and Environmental Economics, Inc. (E3) to conduct an independent analysis of the energy-system value of the four lower Snake River dams. This supplement analysis evaluates whether the resulting report, titled "*BPA Lower Snake River Dams Power Replacement Study*,"[1] hereinafter "E3 study," presents significant new circumstances or information relevant to environmental concerns not addressed in the Power Generation and Transmission analysis of CRSO EIS (Section 3.7 and Appendix H) regarding the future value of the four lower Snake River dams, such that it would warrant the need for a supplemental EIS.

Analysis

The E3 study captures updated assumptions that bear on the analysis of replacement-resource scenarios and costs if the four lower Snake River dams were breached. Specifically, the E3 study focuses on key assumptions that affect the four lower Snake River dams' replacement cost: the clean-energy policies in Oregon, Washington, and California; revised load-growth scenarios that assume high electrification; and additional options for clean-energy replacement portfolios including options enabled by emerging technologies (e.g., hydrogen-combustion, nuclear small modular reactor, natural-gas capture and storage, and offshore wind).

The CRSO EIS considered two resource replacement portfolios to maintain an adequate and reliable regional power supply: a conventional least-cost portfolio selecting the lowest-cost natural-gas-fired resources; and a zero-carbon portfolio selecting among the lowest-cost wind, solar, demand response and energy-storage options (battery and pumped storage). The CRSO EIS acknowledged uncertainty with the specific resources and additional means to maintain power generation and transmission reliability over time; and the influence that costs, technical feasibility, and regional greenhouse gas emissions policies have on resource availability (see Section 3.7, pp. 3-862 to 3-877; 3-882; Appendix H Section 2.2 pp. H-2-3 to H-2-24). It further acknowledged that the CRSO EIS's consideration of resource-replacement portfolios broadly addressed available resource options and resulting costs (Appendix H Section 2.2.2.1, p. H-2-5). As discussed in detail below, the E3 study provides information on resource optimization using updated assumptions generally consistent with or building on the CRSO EIS Power and Transmission analysis.

The following discussion evaluates information in the E3 study relative to the information evaluated in the CRSO EIS to determine whether it represents significant new circumstances or information relevant to environmental concerns:

1. Regional Clean Energy Policies and Regional Resource Adequacy

[1] Energy and Environmental Economics, Inc (E3). *BPA Lower Snake Dams Power Replacement Study*. July 2022. Available at: https://www.bpa.gov/energy-and-services/power/hydropower-impact (last accessed July 20, 2022).

The E3 study uses an optimization model, RESOLVE, to identify optimal capacity expansion scenarios with and without the four lower Snake River dams' generation, and to assemble lowest-cost resource-replacement portfolios responsive to state policy and legislation in west coast states that limit greenhouse gas emissions. This includes implementation of Washington's Clean Energy Transformation Act (CETA), Washington's cap-and-invest program (Climate Commitment Act), and Oregon's 100% clean energy electricity standard. These programs are expected to phase out coal generation, limit natural-gas generation due to pricing of carbon emissions, and drive deep emissions reductions in the electricity sector by 2045. As discussed below, the model also includes economy-wide electrification resulting in electric load growth in annual energy and peak demand.

The RESOLVE optimization model also includes a constraint for resource adequacy that captures the ability of the Northwest power system to reliably serve peak load when facing extreme weather events and low-flow conditions. Specifically, the RESOLVE resource-adequacy modeling constraint requires generating capacity to meet peak demand with an additional 15% planning-reserve margin (E3 study p. 24). This modeling constraint accounts for limitations in certain technologies to serve load in times of system stress—periods of high loads, low renewable generation, and low hydropower output—that challenge power system reliability.

The CRSO EIS analyzed impacts under a range of possible future scenarios that account for the evolving greenhouse gas policies in the region and corresponding reductions in fossil fuel-based generation. In Section 3.7.3.1, the CRSO EIS explained that base-case impact findings in the CRSO EIS Power Generation and Transmission analysis assumed that fossil fuel-based generators, including natural-gas and coal plants, would still be available to meet regional power system needs. This assumption relied on the best available information when analyzing the base case in 2017: the Northwest Power and Conservation Council's (Council) 2022 Resource Adequacy Forecast (p. 3-848; Appendix H Section 2.2.2.3, p. H-2-7; see footnote 21, p. H-2-24).

To update this base-case assumption upon CETA's enactment and coal plant retirement announcements arising during CRSO EIS preparation in 2019, the impact analysis separately considered "additional sensitivity analysis and other regional cost pressure" accounting for potential closures of coal plants in both a limited coal retirement and no-coal scenarios (p. 3-848; see table 3-123 on p. 3-876; pp. 3-874 to 3-877; Appendix H Section 1.3.6, p. H-1-9 and Section 2.3 pp. H-2-24 to H-2-32). As the CRSO EIS explained, "these two scenarios provide an updated understanding of the differences between the CRSO EIS alternatives and costs of zero-carbon replacement scenarios by modeling LOLP [loss of load probability] in light of the additional coal plant retirements" (p. 3-877). In addition, the sensitivity analysis addressed the potential for other costs related to clean energy policies in California, Washington, and Oregon, including carbon compliance costs (pp. 3-873 to 3-877; Appendix H Section 4.1.4, pp. J-4-12 to J-4-14).

On the related issue of resource adequacy, the CRSO EIS recognized the growing regional resource adequacy need and its direct relationship to coal retirements. The CRSO EIS cited a 2019 E3 report highlighting that retiring coal plants supplying the region could create an electric power supply shortage of up to 8,000 megawatts (MW) by 2030 (pp. 3-876).[2] Accordingly, the CRSO EIS sensitivity analysis considered a growing regional resource adequacy need driven by coal retirements and the potential implications for replacement resources to meet that need (pp. 3-951 to 3-952).

The CRSO EIS explained that updated assumptions related to clean energy policy and coal plant retirements entered into the evaluation of CRSO EIS alternatives and the costs of zero-carbon replacement (p. 3-877; Appendix H Section 4.1.4, p. J-4-12). Specifically, the CRSO EIS coal sensitivity analysis estimated additional resources to maintain reliability and address resource needs in light of developments related to regional clean energy policies and regional resource adequacy (pp. 3-875 to 3-877). Because the CRSO EIS used these updated assumptions in its sensitivity analysis to enhance the understanding of base case power and transmission impacts, and because these assumptions for clean energy policy developments and resource adequacy needs are generally consistent with those in the E3 study, the E3 study does not present significant new circumstances or information relevant to environmental concerns related to regional clean energy policies not already considered in the CRSO EIS.

2. Clean Energy Resource Replacement Scenarios for the Four Lower Snake River Dams

The E3 study evaluates clean energy resource replacement scenarios to replace the four lower Snake River dams' generating services such as energy, firm peaking capacity, and operational flexibility (ramping). These portfolios include updated assumptions on energy pricing, load-growth scenarios, and the clean energy resource options based on emerging technologies in addition to those in the "zero-carbon" portfolio analyzed for MO3 in the CRSO EIS (see SA Appendix A for a side-by-side comparison). The CRSO EIS MO3 analysis examined the resources to restore the No Action Alternative's level of reliability, which did not include replacing all generation capabilities of the dams. The CRSO EIS also conducted a sensitivity analysis, the "Lower Snake River Full Replacement" analysis, to assess what resources might be needed to replace all the attributes of the four lower Snake River dams' generation (pp. 3-944 to 3-952).

The E3 study explores the influence of emerging technologies on resource replacement. To that end, "mature technologies" modeled in all E3 scenarios included solar, wind, battery storage, pumped hydro storage, demand response, energy efficiency (EE), small hydro, and geothermal; and varying levels of emerging technology availability modeled across scenarios as follows:

1. **Baseline technologies**: mature technologies and dual fuel natural gas + hydrogen combustion plants.
2. **Emerging technologies**: mature technologies, dual fuel natural gas + hydrogen combustion plants, small modular nuclear reactors, natural gas with carbon capture and storage, and floating offshore wind.
3. **No new combustion**: mature technologies and floating offshore wind.

E3's RESOLVE optimization model assumes that increased load growth will result from electrification across all sectors due to carbon reduction measures. Specifically, it uses a base

[2] E3. *Resource Adequacy in the Pacific Northwest.* March 2019. Available at: https://www.ethree.com/wp-content/uploads/2019/03/E3_Resource_Adequacy_in_the_Pacific-Northwest_March_2019.pdf (last accessed July 20, 2022).

forecast for Northwest wholesale loads (from the Council's 2021 8th Power Plan) embedding increases in energy efficiency and customer solar. For decarbonization scenarios, it uses a "high electrification" load-growth forecast that assumes electric load growth will accelerate across sectors to support carbon reduction goals in a pattern consistent with the Washington State Energy Strategy that meets a net-zero emissions goal by 2050. This assumes high electrification results in loads 28% higher than the base forecast (i.e., Council's 8th Power Plan) by 2045 and winter-peak demand increasing by an additional 68% (E3 study p. 12).

The first scenario that the E3 study models, **100% Clean Retail Sales (S1),** retains some natural gas generation to ensure grid reliability, while constraining carbon emissions to 85% below 1990 levels. This scenario assumes regional power resources generate a sufficient level of clean power on an annual-average basis to meet 100% of all retail electricity sales. In addition, as noted above, it assumes regional load growth continues on a "business-as-usual" trajectory based on the Council's 8th Power Plan Load Forecast.

The E3 study models a second scenario, **Deep Decarbonization (S2)**, across three sub-scenarios: a baseline with mature technologies (S2a), one with emerging technologies (S2b), and one with mature technologies and no new combustion (S2c). These select resource replacement portfolios would maximize decarbonization outcomes. The sub-scenarios assume zero carbon emissions by 2045, high-electrification load growth to reduce emissions across multiple sectors including buildings, transportation, and industrial loads; and in some sub-scenarios, assumes the availability of specific emerging technologies to provide carbon-free firm power.

The E3 RESOLVE optimization model finds a range of economic impacts from replacing the power system value of the four lower Snake River dams with clean energy resources. Across the above-described clean energy replacement-portfolio scenarios, the E3 study finds that replacing the four lower Snake River dams would require between 2,300 to 12,000 megawatts of additional replacement resources at an annual cost of $415 million to about $3.2 billion by 2045. Scenarios S1, S2a, and S2b assume emerging technologies are available and find the resulting costs to public power retail customers could result in an annual per household cost of $100 to $230 (upward rate pressure of 8% to 18%). At the upper end of the E3 scenarios (S2c), which assumes replacement without any emerging technologies and requires very large renewable resource additions, the resulting costs to public power retail customers could result in an annual per household cost of $450 to $850 (upward rate pressure of 34% to 65%) unless Congress provides support (E3 study p. 37).

The E3 study acknowledges high uncertainty in the wide range of 2045 replacement portfolio costs under economy-wide decarbonization scenarios because the costs depend on the commercial availability of emerging technologies. The study highlights that emerging technologies such as hydrogen, advanced nuclear, and carbon capture could limit the costs to achieve a zero-emissions electric system (see, e.g., E3 study scenario S2b) with the caveat that the pace of their commercialization still remains uncertain. Without such emerging technologies breaking through on a commercial scale under deep-decarbonization scenarios (see, e.g., E3 study scenario S2c), the E3 study acknowledges that resource replacement without new combustion would require "impractically high levels of additional onshore wind, offshore wind, and battery storage to meet firm capacity and carbon reduction needs, quadrupling the total installed MW of the Northwest grid by 2045." (E3 study pp. 42 to 44).

The CRSO EIS addressed the available options and the impacts of replacing the four lower Snake River dams' generation with zero-carbon energy resources. The CRSO EIS Power Generation and Transmission analysis (Section 3.7 and Appendix H) described the economic impacts that would result from replacing lost generating capacity and energy system services from the CRSO EIS Action Alternatives compared to the No Action Alternative (i.e., as relevant here, replacing lost generating capacity for breaching the lower Snake River dams in MO3). In CRSO EIS Section 3.7.3.5, Bonneville identified options for zero-carbon replacement to replace the four lower Snake River dams' energy, firm peaking capacity, and operational flexibility (ramping) (i.e., a "like-for-like" resource portfolio) to account for services that maintain regional electrical reliability and stability (pp. 3-944 to 3-952).

As noted above, the CRSO EIS analysis used a load forecast prepared by the Council and published in July 2017: the Pacific Northwest Power Supply Adequacy Assessment for 2022. Using this forecast, the CRSO EIS resource replacement analysis added resources on a least-cost basis to the Council's GENESYS model—a model solving for an alternative's LOLP based on the characteristics and constraints of available existing generators to meet regional power demand—until the regional loss-of-load probability (or LOLP—the Council's aggregated measure of the adequacy of the regional power supply used in the CRSO EIS) reaches the level of the CRSO EIS's No Action Alternative (Appendix H Section 2.1, pp. H-2-1 to H-2-3; Appendix H Section 3.4, pp. I-3-2 to I-3-3).

The CRSO EIS provided an overview of resource replacement options and estimated the costs of major categories of clean energy resources that could replace the capabilities provided by the four lower Snake River dams, including solar, wind, and batteries; energy efficiency; pumped storage; and small modular nuclear reactors (pp. 3-946 to 3-949). Section 3.7 in the CRSO EIS found that replacing the four lower Snake River dams with these zero-carbon resources would cost between $234 million and $405 million per year compared to the No Action Alternative (pp. 3-976 to 3-978), and potentially twice that due to cost uncertainties (p. 3-10; 3-976). The CRSO EIS also found that residential rate pressure under the MO3 base case alone, not accounting for regional coal retirements, would increase 8.2% to 21% on a weighted average; and that cost uncertainties could drive that rate pressure up to 50% (p. 3-10; 3-960).

The CRSO EIS evaluated many of the same clean energy replacement options in the E3 study and found a similar range and magnitude of impacts to replace the characteristics of the four lower Snake River dams' generation with zero-carbon resources. The E3 study evaluated emerging technologies in some scenarios (specifically, some E3 deep decarbonization scenarios included hydrogen-combustion options, natural-gas capture and storage, small modular nuclear reactor and floating offshore wind). The EIS considered, but did not include, emerging technologies in replacement portfolios, and acknowledged factors creating uncertainty such as technical feasibility and the need to scale out and commercialize any such emerging technologies (see p. 3-882; Appendix H Section 2.2.1, pp. H-2-4 to H-2-5). In addition, the CRSO EIS analysis supported identifying a Preferred Alternative using a simplified optimization process to develop potential replacement portfolios. Therefore, the EIS emphasized the need to pursue a detailed optimization analysis for a resource selection should replacement resources be needed (Appendix H Section 2.2.2.1, p. H-2-5). Because the CRSO EIS analysis considered zero-carbon replacement portfolio options and found a similar degree of impact in replacing the four lower Snake River dams as the E3 analysis, the E3 study does not include information that will "affect the quality of the human environment in a significant manner or to a significant extent not already considered."[3]

Based on review of potential new information or circumstances since the issuance of the Final CRSO EIS and ROD in 2020, Bonneville has not found new information or circumstances relevant to environmental concerns not already analyzed in the Final CRSO EIS that could warrant preparation of a supplemental or new EIS.

Findings

Bonneville finds that the information presented in the E3 study is consistent with the information analyzed in the Final CRSO EIS (DOE/EIS- EIS-0529 2021). Based on the analysis above, there are no substantial modifications in the EIS's Selected Alternative and no significant new circumstances or information relevant to environmental concerns bearing on the EIS's Selected Alternative or its impacts within the meaning of 10 CFR § 1021.314(c)(1) and 40 CFR §1502.9(d). Therefore, no further NEPA analysis or documentation is required.

/s/ Jeff Maslow
Jeff Maslow
Senior Environmental Protection Specialist

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Digitally signed by KATEY GRANGE
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Katey Grange
NEPA Compliance Officer

[3] Marsh v. Oregon Natural Resources Council, 490 U.S. 360, 374 (1989).

Appendix A. Comparison of Lower Snake River Dam Resource Replacement Portfolios

Resource-Replacement Scenario	Clean Energy Resources Considered and Resource Replacement Portfolio Selections[1]	Load Growth Assumption	Cost of Replacement Resource Portfolio	Land Use[2]
CRSO EIS “Zero-Carbon” for MO3	Solar, energy storage (batteries), demand response (DR); energy efficiency; pumped storage; and nuclear small modular reactors (see CRSO EIS pp. 3-946 to 3-949; Appendix H 2-31). Base case: • 600 MW DR • 1,960 MW solar • 980 MW energy storage Limited coal: • 3,200 MW solar • 1,000 MW energy storage No coal: • 6,000 MW solar • 1,000 MW energy storage	Council’s Pacific Northwest Power Supply Adequacy Assessment for 2022	$234 million to $405 million per year under the base case (p. 3-977). $76 million per year added to base case costs in a limited-coal scenario (see p. 3-963). $345 million per year added to base case costs in a no-coal scenario (see p. 3-963).	12,000 acres (18 square miles) for the base case portfolio (p. 3-943)
E3 Study: 100% Clean Retail Sales (S1)	Baseline resources (mature technologies and dual fuel natural gas + hydrogen combustion plants) in 2035: • 1,800 MW dual fuel natural gas + hydrogen combustion • 1,300 MW wind • 100 MW battery • –500 solar[†] Baseline resources in 2045: • 2,100 MW dual fuel natural gas + hydrogen combustion • 500 MW wind	Council’s 8th Power Plan Load Forecast (Base Forecast)	$434 million (in 2035) to $478 million per year (in 2045)	55,677 acres (87 square miles) 23,070 acres (36 square miles)

E3 Study: 100% Clean Retail Sales (S1-2024 dam breach)	Baseline resources (mature technologies and dual fuel natural gas + hydrogen combustion plants) in 2035: • 1,800 MW dual fuel natural gas + hydrogen combustion • 1,400 MW wind • 100 MW battery • –500 MW solar[†] Baseline resources in 2045: • 2,100 MW dual fuel natural gas + hydrogen combustion • 500 MW wind	Base Forecast	$466 million (in 2035) to $509 million per year (in 2045)	60,147 acres (94 square miles) 23,070 acres (36 square miles)
E3 Study: Deep Decarbonization (S2a)	Mature technologies (solar, wind, battery storage, pumped hydro storage, demand response, energy efficiency, small hydro, and geothermal) in 2035: • 2,000 MW dual fuel natural gas + hydrogen combustion • 600 MW wind • 100 MW battery Mature technologies in 2045: • 2,000 MW dual fuel natural gas + hydrogen combustion • 300 MW battery • 400 MW wind • 50 MW Energy Efficiency • 1.2 Terawatt (TWh) hydrogen-fueled generation	High Electrification	$496 million (in 2035) to $860 million per year (in 2045)	27,506 acres (43 square miles) 18,556 acres (29 square miles)
E3 Study: Deep Decarbonization (S2b)	Emerging technologies (mature technologies, dual fuel natural gas + hydrogen combustion plants, small modular nuclear reactors, natural gas with carbon capture and storage, and floating offshore wind) in 2035: • 1,700 dual fuel natural gas + hydrogen combustion • 600 MW nuclear small modular reactors Emerging technologies in 2045: • 1,500 MW dual fuel natural gas + hydrogen combustion • 700 MW nuclear small modular reactors	High Electrification	$415 million (in 2035) to $428 million per year (in 2045)	613 acres (0.9 square mile) 550 acres (0.9 square mile)

E3 Study: Deep Decarbonization (S2c)	Mature technologies and no new combustion (mature technologies and floating offshore wind) in 2035: • 9,100 offshore wind • 100 MW wind • 1,000 MW solar • 300 MW geothermal • 1,500 MW battery Mature technologies and no new combustion in 2045: • 10,600 MW wind • 1,400 MW solar	High Electrification	\$1.953 billion (in 2035) to \$3.199 billion (in 2045)	757,250 acres (1,183 square miles) 482,360 acres (754 square miles)

† While most scenarios reflect the additional resource builds required without the four lower Snake River Dams, in E3's scenarios with negative values for solar, the optimal capacity-expansion modeling required 500 MW less solar. The table reflects the cost of these scenarios and their land-use conversions.

[1] To provide a snapshot of the mid-term replacement portfolio selections and costs, the E3 study included a 2035 portfolio in addition to those presented for the longer-term 2045 portfolio. The E3 study explained the difference between the 2035 and 2045 portfolios as follows: "Replacement resources are calculated by comparing the 'with LSR dams' RESOLVE portfolio to the 'without LSR dams' RESOLVE portfolio. This means some resources may be built in 2035, such as 0.3 GW of geothermal in scenario 2c, that are not built when the dams are included. However, those resources may have already been selected in the 'with LSR dams' case by 2045, hence do not show up as additional resource replacement needs in 2045. This explains the different resource changes between 2035 and 2045" (E3 study p. 30).

[2] Land-use conversions estimate footprints for all resource builds except for battery facilities. Conversion data from the National Renewable Energy Laboratory, "Land Use by System Technology," available at https://www.nrel.gov/analysis/tech-size.html; Natural Gas Supply Association, "The Footprint of Energy: Land Use of U.S. Electricity Production," available at: https://docs.wind-watch.org/US-footprints-Strata-2017.pdf; NuScale Energy, "Cost Competitive Energy,"available at: https://www.nuscalepower.com/newsletter/nucleus-spring-2019/cost-competitive-energy#:~:text=A%20proposed%20720%20MWe%20NuScale,would%20require%20nearly%20600%20acres; National Renewable Energy Laboratory, "2021 U.S. Geothermal Power Production and District Heating Market Report," available at: https://www.nrel.gov/docs/fy21osti/78291.pdf (URLS last accessed July 20, 2022).