April 2007

BPA analysis

Replacing lower Snake River dams would cost Northwest $413 million to $565 million annually

Note: This report presents expanded analysis and background on the costs reported in an earlier BPA fact sheet entitled "The costs of breaching the four lower Snake River dams," published in March 2007. The comparable numbers in the earlier fact sheet were rounded. Actual figures are used here. That fact sheet can be found at: www.bpa.gov/corporate/pubs/fact_sheets/07fs/fs030207.pdf.

Over the years, there have been multiple calls from various groups to remove the four lower Snake River dams. A recent effort came in the shape of a Nov. 15, 2006, report called *Revenue Stream – An Economic Analysis of the Costs and Benefits of Removing the Four Dams on the Lower Snake River.* The report, issued by a coalition of environmental and sport fishing groups, made the following conclusion relative to power costs:

> "A NW Energy Coalition analysis estimates that replacing the power from the dams with a mix of energy efficiency and wind power would increase electrical utility costs $79 million to $170 million per year for the next 20 years."

The *Revenue Stream* report did not seek input from the Bonneville Power Administration about power and reliability impacts and costs. *Revenue Stream* also does not document how power cost conclusions were reached. Based on subsequent conversations with contributors to the report and the information in *Revenue Stream*, BPA is concerned that the *Revenue Stream* report significantly underestimated the costs to replace the energy and capacity capability of the projects.

BPA is not alone in these concerns. On Feb. 25, 2007, the Independent Economic Advisory Board completed a broader critique of the Revenue Steam report and also took issue with the report's conclusions. IEAB concluded that *Revenue Stream* has "a number of deficiencies that raise serious questions about its acceptability as an alternative to the *Corps of Engineers Lower Snake* EIS (*environmental impact study*)." The findings of the Corps' EIS are highlighted at the end of this report.

The IEAB review can be found on the Northwest Power and Conservation Council Web site: *www.nwcouncil.org/library/ieab/ieab2007-1.htm*.

Cost impacts to electric ratepayers analyzed

This fact sheet responds strictly to the power replacement cost estimate included in the *Revenue Stream* report, but unlike *Revenue Stream* it attempts to cover the major facets of actually replacing the emission-free power provided by the four dams. For example, this paper does not limit the power costs to the costs borne by the utility as *Revenue Stream* has done. Rather, it also includes the costs that will be borne by all ratepayers in the region. It also does not assume, as *Revenue Stream* did, that the subsequent investments have no cost of capital[1] but instead assigns a cost of financing to the upfront funds that would be required. Furthermore, *Revenue Stream* did not address or attempt to replace the capacity of the projects when developing replacement resources.

This report is not an integrated resource plan or a detailed loss-of-load analysis. However, it is an attempt to more properly address the actual costs of the power replacement issue raised in *Revenue Stream* while retaining as much comparability as possible with the *Revenue Stream* base case. It is not an exhaustive list of all costs that would be entailed in taking out such a substantial amount of the capability of the Federal Columbia River Power System.

---

1 *Revenue Stream* does not explicitly state how the cost of $79 million to $170 million per year was determined. In a subsequent e-mail, the authors stated they took the utility costs that they assumed would occur and divided them into 20 periods without providing for any financing costs.

In any case, the full power replacement costs are well in excess of those stated in *Revenue Stream* and by themselves reverse its conclusion that removing the Lower Snake dams would be an economic benefit to the region.

Using the assumptions contained in the Northwest Power and Conservation Council's Fifth Power Plan (Power Plan), BPA analysis shows it will cost between $413 million to $565 million a year[2] to replace all the capabilities[3] of the lower Snake River dams, not the $79 million to $170 million reported in *Revenue Stream*.

Reflecting the higher replacement costs of all the existing capabilities of these dams by itself is enough to change *Revenue Stream's* conclusion of a small regional net savings over 10 years into a significant net cost. *Revenue Stream's* net benefits become a net cost to the region of $1.6 billion to $3.9 billion over 10 years.

Earlier report ignores "capacity" needs

Revenue Stream addresses only the energy output of the four lower Snake River dams. These dams generate 1,022 average megawatts (aMW) of energy per year or 12 percent of BPA's annual hydro energy – an amount of emission-free electricity equivalent to that used by a city the size of Seattle in a year. The four dams are also part of an integrated hydro system that is used to meet customers' peak loads and to provide system reliability and deliver operating flexibility for needs such as integrating wind energy. *Revenue Stream* did not address the costs associated with replacing any of those capabilities.

Capacity is the maximum electricity output that a dam's generator can provide under existing service conditions when running at full throttle. While dams do not normally run under these conditions, the ability to do so is important to ensure reliable power delivery to meet peak power conditions (for example, very cold or very hot weather) or to make up for loss of other generation.

The term is most frequently used to refer to the amount of energy that can be called on for short periods to meet peak loads. The four lower Snake River dams can produce 3,483 MW for several hours or, more conservatively, in excess of 2,650 MW over a sustained period[4] even under low-water conditions.

This is extremely significant in the event of something unexpected, such as the sudden loss of output from a thermal generation plant or a disruption of imports on a major transmission intertie. With other resource types, this kind of capability is either not feasible (nondispatchable renewables and conservation) or very expensive to recreate (idling gas turbines and other thermal resources).

The loss of this energy and capacity cannot be made up easily. According to the Council's Power Plan, expected load growth and resource firming needs in the region over the next 20 years will require new resources at considerable cost. Removing the lower Snake River dams would exacerbate the situation.

Council's Power Plan provides context

The authors of the *Revenue Stream* report addressed the energy replacement cost from the lower Snake River dams by selectively using numbers from other studies to support their case. A more appropriate method is to look at resource replacement in the broader context of regional loads and resources as comprehensively outlined in the Council's Power Plan. The Council's plan is subject to broad public review and, under the Northwest Power Act, provides guidance to BPA in the acquisition of conservation, renewables and other resources.

---

2 Cost is after accounting for $38 million in annual O&M savings. This is equivalent to a net cost with a range of $46 to $63 per megawatt-hour. Note that this replacement cost figure was rounded in BPA's March 2, 2007, press release.

3 In the industry, the use of the term "power" is often intended to encompass both the energy and capacity aspects of electricity supply. In the remainder of this document that definition of power applies to both aspects, and the terms "energy" and "capacity" are used when speaking of them separately.

4 This example is based on low winter flows supplemented by upstream draft and measures the capability to sustain an operation for 10 hours per day over five consecutive days.

Revenue Stream does not adequately consider the regional load growth forecast in the Power Plan. Under a medium load-growth scenario, loads will grow by 5,343 average megawatts (aMW) annually by 2025. If the 1,022 aMW from the lower Snake River dams are removed, the region will have a bigger resource deficit to fill of 6,365 aMW.

The Power Plan outlines a strategy to acquire all cost-effective conservation, estimated at 2,500 aMW annually, and install more than 1,830 aMW of wind energy (6,100 MW of capacity) for a total of 4,330 aMW. This falls short of what is needed to cover the expected annual load growth of 5,343 aMW.

Thus, removal of the lower Snake dams would only accelerate and increase the need for more costly resources. Some of these resources might be additional wind, other renewables and conservation, but there would also be a need for carbon-based resources, both for firming renewable resources and to meet base load.

Three scenarios are considered

In an attempt to consider *Revenue Stream's* claims and to keep the replacement cost within the context of the Power Plan, BPA has penciled out three hypothetical scenarios for replacing the lower Snake River dams. These scenarios seek to replace the energy production and the capacity value of the projects. BPA would expect that a combination of resource types would be used if the Northwest needed to replace resources on the scale discussed in *Revenue Stream*. Therefore, these scenarios are combined to ultimately arrive at a power replacement cost estimate.

Scenario 1: Using wind power to replace the dams

Replacing 1,022 aMW of energy would require 3,407 MW of installed wind capacity. That's because wind is a low-generation factor resource. The Power Plan estimates that the capacity factor for a better quality wind resource in Washington, Oregon, Idaho and western Montana is 30 percent. The capacity factor is the ratio of average generation to the installed capacity of the wind farm. A typical wind turbine is sized at 1.5 MW, which would require the installation of 2,277 wind turbines. Conservative estimates would place the capital costs of this wind capacity at $3.23 billion.[5]

Although this wind farm could replace the average annual energy generated by the lower Snake River dams, it cannot replace the ability to shape the generation to load or provide other services, because wind is an uncontrollable intermittent resource. Therefore, to fully replace the lost energy, peaking capacity, load-following, reserves-carrying and wind-integration attributes of the lower Snake River dams, the wind turbines would still require capacity from gas-fired combustion turbines. Gas may be the most cost-effective (and less polluting) alternative resource with those attributes.

Costs

- Based on Power Plan estimates, the capital costs of installing 3,500 MW of gas-fired generation and 3,407 MW of wind turbines would conservatively cost $5.23 billion dollars. Amortizing $5.23 billion over 20 years at 6 percent would cost $455 million a year.
- The cost to firm the intermittent wind energy is estimated at $41 million per year.
- Annual operating costs are estimated to be $107 million per year. This is without considering the cost of natural gas to run the combustion turbines when the wind resources are not matched to load.

> Annual costs to replace the lower Snake River dams with wind would be at least $603 million.

Scenario 2: Using the Power Plan supply curve to determine the replacement resource.

Assuming that regional loads grow by 5,343 aMW annually, the Power Plan supply curve assumes the next most cost-effective resources that could be developed to replace the lower Snake River dams' generation are completing the 926 MW Mint Farm and Grays Harbor combustion turbines. The average levelized costs of these resources are estimated to

5 "Benchmark" cost estimate from the Power Plan in year 2006 dollars.

be $39.9 to $73.2 per megawatt-hour (higher prices reflecting gas supply forecast risks), or $323 million to $593 million per year. These costs would only replace slightly less (926 MW) than the energy and capacity associated with the average annual energy production of the lower Snake dams and would not include replacement costs for the additional 2,574 MW capacity that the current dams provide. Conservative Power Plan estimates of installing 2,574 MW of gas turbine capacity would cost $1.47 billion. Amortizing $1.47 billion over 20 years at 6 percent would cost $128 million a year.

Annual costs to replace the lower Snake River dams with gas-fired plants would be $451 million to $721 million, including additional capacity replacement costs.

Scenario 3: Using conservation to replace the lower Snake dams

Revenue Stream counts on conservation efforts for 90 percent of the replacement energy, and it includes only those costs borne by the utility (which are approximately one half the total costs of the measures). In addition, *Revenue Stream* does not consider that the most cost-effective conservation will already be developed to address load growth over the next 20 years.

A more appropriate approach would be to price the incremental conservation that is not already committed in the Power Plan. To fully address the cost and quantity of this conservation, the Council's Portfolio Model would have to be re-run, but the costs can be estimated with information from the Power Plan.

Conservation comes in two varieties: discretionary programs and lost opportunity resources that can only be captured at a specific point in time (e.g. when a building is constructed or an appliance is purchased). The Power Plan supply curve contains about 580 aMW annually of discretionary programs not developed over the 20 years of the plan. These programs have a weighted average levelized cost of about $90 per megawatt-hour.[6]

The lost opportunity resource supply curve can be increased by about 375 aMW[7] annually over 20 years at an average levelized cost of about $100 per megawatt-hour.[8] If combined, these types of conservation would have a weighted average cost of $94.56 per megawatt-hour, and the total is almost large enough to replace the average annual energy from the lower Snake River dams. Since conservation is absorbed at site with the load, the Power Plan credits conservation for transmission loss savings in order to allow for a comparison with more traditional generation resources. BPA understands that this effect has been captured in the figures above.

If there is enough conservation to replace the average energy from the lower Snake River dams (at just under $95 per megawatt-hour), it would cost $846 million per year. While conservation is nondispatchable and cannot provide reliability or emergency services, it may be shaped toward higher demand periods and therefore have a capacity contribution. The Power Plan estimates the load factor of conservation as .35, which would result in an additional capacity resource of almost 1,900 MW. Accounting for this resource and the base 1,022 MW of average energy still would leave a need for almost 600 MW of incremental capacity. Using the same pricing assumptions as Scenario 2, this capacity would cost $331 million in capital costs, which would amortize to $29 million per year at a rate of 6 percent over 20 years.

Annual costs to replace the lower Snake River dams with conservation and capacity additions would be approximately $875 million per year.

Costs of replacing the dams summarized

The low end of the undeveloped conservation in the Power Plan is competitive with the ranges of levelized costs captured in Scenarios 1 (wind) and 2 (gas). In addition, the cost estimate for wind is less than the high end of the gas case. Therefore, a combination approach can be estimated conservatively as having costs between the low end of the gas scenario and the estimate from the wind scenario

6 Programs ranged from $48 to $112 per megawatt-hour.

7 25 MW of incremental conservation per year over 20 years with a 25 percent reduction for ramp-up issues.

8 Increments ranged from $58.9 to $112.8 per megawatt-hour

(see table below). This would result in a range of power replacement costs between $451 million and $603 million dollars per year. Subtracting the operations and maintenance savings associated with no longer maintaining the lower Snake River dams would arrive at a net cost between $413 and $565 million per year.

Range of power replacement costs	Estimates ($ millions per year)
Scenario 1 – Wind energy and gas capacity	$603
Scenario 2 – Gas energy and capacity	$451 to $721
Scenario 3 – Conservation and gas capacity	$875
Conservative range of costs	$451 to $603
Net cost after $38 million in O&M savings	$413 to $565

Capacity affects replacement costs

When looking at a hydro facility's capacity value, there are numerous measures that reflect the ability to provide different services, ranging from long-term sustained capacity for meeting peak loads to sub-hourly capacity services for frequency regulation, load following and wind integration. In this analysis we elected to measure the capacity based on the short-term peaking capability of the projects, which is almost 3,500 MW. While these levels sometimes can be sustained for only a few hours, they represent the full value of the projects in terms of their ability to meet peak loads, provide reserves and other reliability products, and to respond to an emergency condition on the electrical system.

Replacing less than this full capacity would leave the Northwest electrical grid with less capability than currently exists with the lower Snake River dams. Because of conservative assumptions with regard to capacity costs, the economics would be largely unchanged if sustained capacity were used as the measurement for replacement.

There is a reasonable debate over whether the full capacity value or the sustained peaking capacity is the appropriate metric when gauging the replacement of the lower Snake River dams. The full capacity ensures that all the capabilities of the dams are replaced, but it may create additional value if the replacement resource has greater sustained peaking capacity than the dams. If faced with replacing this full capacity, the region may decide that it is too costly and prefer to forego the incremental value provided.

On the other hand, the existing system has this capability, and limiting the peaking capacity to a sustained value would result in a system that offers lower value to the region. This is because, unlike most other resources, the dams can exceed their sustained capacity for shorter periods, allowing the region to have a lower risk of load loss and thus to forgo costly capacity additions.

Regardless of that choice, however, the economics of the scenarios outlined in this paper are largely unchanged. In order for a combustion turbine to provide sustained capacity, it must have access to fuel. The scenarios in this paper using full capacity replacement do not include the reservation fees necessary to ensure an adequate fuel supply (fixed fuel costs) or variable fuel costs to run the combustion turbines when they are needed.

Variable fuel costs are contingent on the operating pattern of the resource, which would require much more complex modeling than applied here. Therefore, the costs were ignored in the interest of conservatism and time. Fixed fuel costs were excluded in the full capacity replacement case as an offset to the potential additional economic value that combustion turbines could achieve via a greater sustained capability than the lower Snake River dams. Including those costs only when replacing sustained capacity would outweigh the savings associated with building a smaller resource base.

The following example outlines how each of the resource scenarios would change if the capacity addition were lowered to the sustained peaking capability of the dams, while also accounting for fixed fuel costs:

- Reduction in capacity additions if only replacing sustained capability – 830 MW.
- Amortized capital savings of the reduction – $41 million per year in Scenarios 1 and 2, $29 million in Scenario 3 (the savings in Scenario 3 are capped by the size of the addition).
- Fixed fuel cost from the Fifth Power Plan for simple cycle turbine ($32- $34/kW/yr) applied to the remaining sustained capacity additions to arrive at the cost column.

Impact of a change to sustained capacity analysis and addition of fixed fuel costs
(in millions of dollars)

	Savings	Costs	Net Cost (Benefit)
Scenario 1 – Wind	$41	$85-91	$44-50
Scenario 2 – Gas	$41	$53-56	$12-15
Scenario 3 – Conservation	$29	0	$ (29)

In the analysis, the conservation scenario was not ultimately a driver in the overall cost estimate and would not be even with a $29 million reduction. The wind and gas scenarios would be somewhat higher in cost and would therefore increase the overall range of costs slightly in the event a sustained capacity analysis were used instead of a full capacity analysis with simplifying cost reductions.

Previous research on dam removal holds

In 2002, the U.S. Army Corps of Engineers released a seven-year, independent, peer-reviewed environmental impact statement that evaluated dam breaching and three other alternatives to helping juvenile salmon get past the four lower Snake River dams. This EIS remains the most comprehensive evaluation of dam breaching.

The Corps EIS found that breaching the lower Snake River dams would cost Northwest ratepayers $373 million annually and generate $106 million annually in benefits and avoided costs (1998 dollars) over a 100-year period.

Since that EIS was released, the estimated cost of replacement energy has increased substantially. Updating the energy replacement costs in the Corps EIS to reflect higher prices would increase the costs for breaching the lower Snake River dams in that analysis by roughly twofold. BPA recognizes that comparisons of replacement costs outlined in this paper are not "apples to apples" since the Corps' EIS ran complex modeling to determine what would have to be replaced as opposed to replacing all attributes of the projects as this paper does. However, the EIS costs if updated for current fuel prices would appear to be in the same range or higher than those presented here.

Conclusion

As mentioned at the outset, this analysis is not an integrated resource plan. It is an attempt to better reflect the power replacement costs depicted in the *Revenue Stream* report using the Power Plan as a consistent underpinning for resource costs. These estimates also appear to be consistent with results that would be expected from updating the power replacement cost forecasts in the Corps' EIS. While further analysis would result in a more precise estimate, the costs here and in the Corps' EIS are sufficient to invalidate the *Revenue Stream* conclusion of net benefits from lower Snake River dam removal.