Northwest Overgeneration:
An assessment of potential magnitude and cost

Introduction

Electric loads and resources must always instantaneously balance to avoid significant reliability risks. When generation exceeds regional loads, the difference must be exported, reduced, turned off or, in the case of hydroelectric power, spilled to avoid destabilizing the grid. High seasonal river flows are known in the Pacific Northwest for occasionally generating more hydropower than needed to meet regional demand. While the regional power system has long coped with such temporary “overgeneration” conditions due to large spring runoff events, the rapid growth of wind energy has added a new variable.

Wind power can at times compound overgeneration conditions, causing the Bonneville Power Administration to reduce the output of hydroelectric dams and spill additional water. Nevertheless, that additional spill can increase dissolved gas levels in the Columbia River and its tributaries that pose a danger to federally protected fish. BPA is working with the region to explore a wide variety of options that may reduce this risk by increasing the consumption or export of as much surplus renewable energy as possible during high-water periods.

BPA is obligated to manage the Federal Columbia River Power System to store, sell, and spill as much surplus hydro energy as possible and to reduce as much federal non-hydro generation as possible, without risking its return to service, before requiring other resources in the region to reduce generation. A last resort in such situations is to temporarily curtail wind generation to reduce overgeneration and replace the wind energy with free hydropower. Nevertheless, wind power producers may then lose the value of renewable energy credits and production tax credits available only when their projects actively generate electricity.

This report

Recent discussions about options to address the temporary oversupply of power raised questions about the potential amount of overgeneration the Northwest may experience and the potential costs of lost energy and tax credits. This report estimates the magnitude of seasonal overgeneration that could be expected in 2012 under a range of conditions affecting the Northwest power system. It also estimates the costs of displacing wind power as an option of last resort, based on the known values of renewable energy credits and production tax credits. The figures in this report represent initial approximations under reasonably foreseeable weather, river flows, power demand, and market conditions in 2012. It does not represent an absolute or exhaustive analysis of all possible outcomes.

The purpose of this report is to inform public discussion of options for addressing the temporary oversupply of power, not to advocate solutions.

The estimates outlined in this report were developed by BPA staff in response to questions and dialogue at public meetings and related discussions in late 2010 and early 2011 about the overgeneration issue. The estimates use recent and historic data on wind generation, river flows, load and other power system conditions under a range of scenarios and are focused on spring months when overgeneration conditions are most likely to occur. The methodology was discussed with and reviewed by independent experts from the Pacific Northwest National Laboratory (PNNL) and the National Renewable Energy Laboratory (NREL). Their input was considered and incorporated into the report and/or attached for future consideration.

Background

The Federal Columbia River Power System is operated for multiple public purposes, including flood control, irrigation, power production, navigation, recreation and municipal water supply. A high priority in the operation of the system is the protection of the river's fish, including salmon, steelhead, sturgeon and bull trout listed as threatened or endangered under the Endangered Species Act.

High flows in the Columbia River system are frequent due to years with above average snowpack and/or early warming periods that result in rapid snowmelt. The most recent event occurred during a period of heavy precipitation in early June 2010, which created overgeneration conditions for most of the month. The chance of such high flows occurring in any one year and lasting for a month or more is about one in three. Columbia River flows fluctuate widely, with historic maximum flows 35 times greater than historic minimum flows. That compares to maximum flows on the Mississippi River that are just five times greater than minimum flows. Given the extraordinarily wide range of potential flows on the Columbia, flood control is a significant purpose of many of the Northwest's federal dams. The destructive Vanport Flood of 1948 spurred reservoir development in the upper Columbia and was a major impetus for the Columbia River Treaty with Canada in 1964, which doubled Columbia reservoir storage. Even when combined with Treaty reservoirs, the federal system can store less than 40 percent of an average year's 134 million acre-feet of runoff.

Water that cannot be stored necessarily travels downstream, increasing river flows in spring and early summer. Since the 1970s, BPA and other Northwest hydropower producers have routinely sold surplus power produced during high flows at very low rates to utilities in the Northwest and California. Such sales encourage operators of coal, oil, natural gas and other power plants to reduce the output of their plants and replace their energy with low-cost renewable hydropower when available. The quantity of surplus hydro generation, and now other surplus generation such as wind in the Bonneville balancing authority area that can displace thermal generators in California, the Pacific

Northwest or other parts of the West is limited by the transmission available to carry the surplus to the loads served by the thermal generators.

In recent years, several new factors have affected this overgeneration supply situation in the Bonneville control area.

1. The wholesale power market was deregulated in the 1990s, and power generation was functionally separated from wholesale transmission. This added numerous market participants, such as independent power producers, that have built generation in the region not directly associated with load in the region.
2. Flow augmentation requirements for Columbia and Snake River salmon and steelhead listed under the Endangered Species Act dramatically changed the way the reservoirs are managed, generally reducing storage space available to manage high spring flow events.
3. As of February 2011, about 3,400 megawatts of wind power generation has connected to BPA's transmission grid in the Columbia River Basin, adding highly variable renewable generation to the hydroelectric base of the Columbia River system.
4. The rapid increase in wind power in the Northwest has significantly increased the power system's total energy generation output. At the same time wind generators require balancing reserves, which now consume a significant portion of the operating flexibility of the FCRPS.
5. The lingering effects of the recession have resulted in demand for energy in the Northwest being lower than expected.

In light of these developments and the high flows and overgeneration conditions in June 2010, BPA began a public dialogue on options to address overgeneration conditions when necessary to manage spill to safeguard fish from harmful levels of dissolved gas. At public workshops BPA announced its intent to substitute federal hydropower for other generation, including wind power, in BPA's balancing authority area as a last resort when necessary to be consistent with Clean Water Act and Endangered Species Act limitations on total dissolved gas (TDG). This practice is called "environmental redispatch" because it replaces one generating resource with another for environmental reasons.

There is some debate whether it is appropriate for BPA to pay parties that are asked to curtail generation. On one hand, BPA is proposing to replace their planned energy production with free, carbon-free hydro generation. BPA has also stated that it will turn to environmental redispatch only as a last resort to be consistent with Clean Water Act and other environmental obligations. On the other hand, some parties that could be asked to curtail generation are receiving production incentives to generate renewable energy and could lose these payments or credits to the extent production is curtailed. Discussion of these issues and their consequences prompted questions about the potential magnitude and costs of overgeneration at stake, which this report is intended to address.

General methodology

The fundamental approach of this high-level analysis is to compare anticipated load, generation and power exports under a variety of conditions in a region generally defined as the Pacific Northwest. When generation resources exceed load and the amount of power exported, overgeneration occurs. The amount of overgeneration and its consequences for increased spill and gas levels determine how much power may need to be displaced, which can then be used to estimate potential financial impacts. The region examined in this estimate is defined as the area south of the Northern Intertie to Canada, north of the AC and DC interties to California and west of the intertie to Montana.

The variability of river flows over the course of individual months and weeks and the way the hydro system can shape flows between high load hours (HLH) and low load hours (LLH) directly affect the amount and timing of hydro generation. Those factors are consequently very important in determining the degree of overgeneration that may occur. Nevertheless, because the operation and configuration of the hydro system changes from year to year in response to new restrictions or conditions, past generation data may not accurately represent generation in coming years. BPA therefore relies on hydro regulation models called the Hydro Simulation Program (HYDSIM) and Hourly Operating and Scheduling Simulator (HOSS) that depict the current configuration of the system. The models can calculate the anticipated power output of the current hydro system under a variety of past water conditions.

The models produce monthly HLH and LLH generation amounts for the federal hydro system based on varying flow conditions. Nevertheless, such monthly values alone do not provide sufficient detail to examine the likelihood of overgeneration, so weekly HLH and LLH values were also developed. To do this, BPA compared actual weekly federal hydro generation data from past years to actual monthly federal hydro generation to determine the ratios of weekly generation to monthly average generation under actual operating conditions. The ratios were then applied to the monthly HLH and LLH generation values obtained from the HYDSIM and HOSS models to produce weekly details of HLH and LLH generation to accompany the monthly values.

BPA used the same approach of developing weekly to monthly generation ratios to translate the monthly non-federal hydro generation into weekly values. The resulting weekly values were then shaped into HLH and LLH periods based on regression equations derived from actual hydro generation data for non-federal hydro projects for the period 2006 to 2010. The regression equations were created by comparing HLH hydro generation for non-federal projects to the average generation for non-federal projects and defining the relationship between the two values.

Inputs for the overgeneration estimates in this report include:

- Load in the region, represented as L
- Generation in the region, represented as follows:
    - Hydro: Federal (G_{Fh}) and non-federal (G_{Nh})
    - Thermal: G_t

    - Miscellaneous: G_m
    - Wind: G_w
- Intertie Loadings:
    - Northern, AC and DC to California and Montana
    - The sum of the intertie loadings, represented as E, is the amount of power the region is exporting

To calculate the balance between loads and generation resources, the following equation was used:

$$G_{Fh} + G_t + G_w + G_{Nh} + G_m = L + E$$

Any scenario that results in the generation side of this equation exceeding loads and exports is an overgeneration condition. This was the first step in the calculations, illustrated in Figure 1 below and defined as:

$$G_{ov} = \max(G_{Fh} + G_t + G_w + G_{Nh} + G_m - L - E, 0)$$

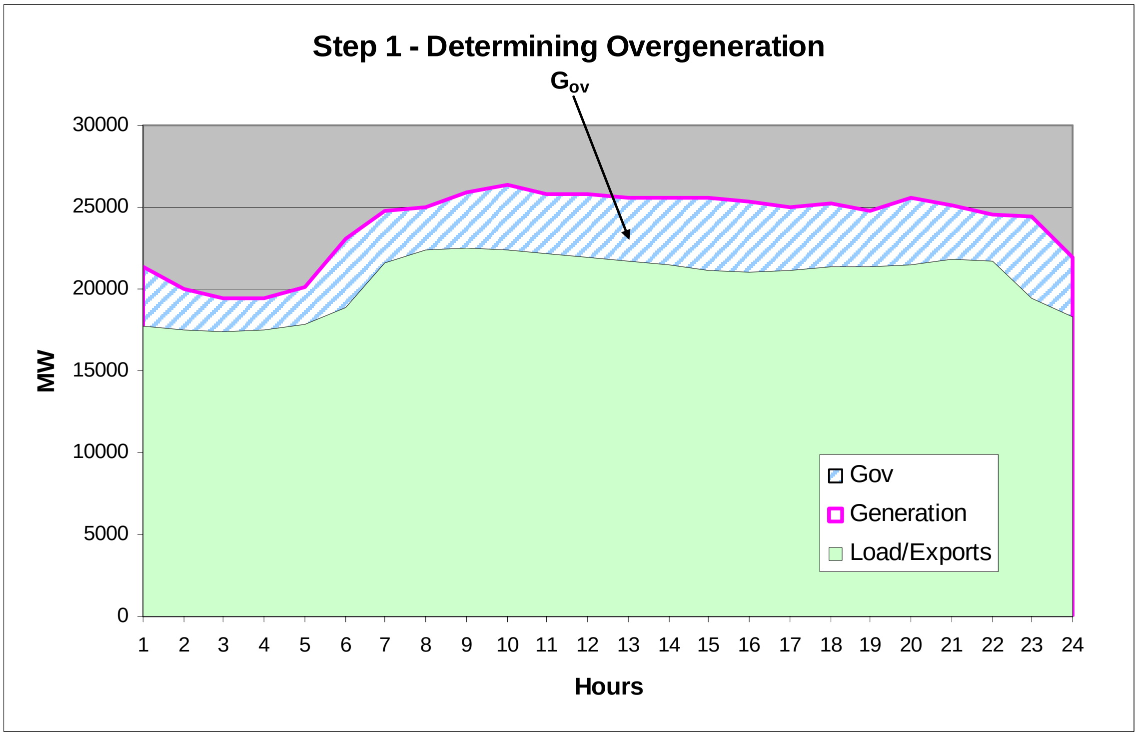


Figure 1

A portion of the overgeneration amount (G_{ov}) can be managed by spilling additional water, which reduces the flow through turbines that generates power. Nevertheless, the amount of spill is limited by maximum TDG levels (S_{max}). Any spill exceeding this maximum would require a generation resource to be displaced (G_{dis}), as illustrated in Figure 2 below and defined in the following equation:

$$G_{dis} = \max(G_{ov} - S_{max}, 0)$$

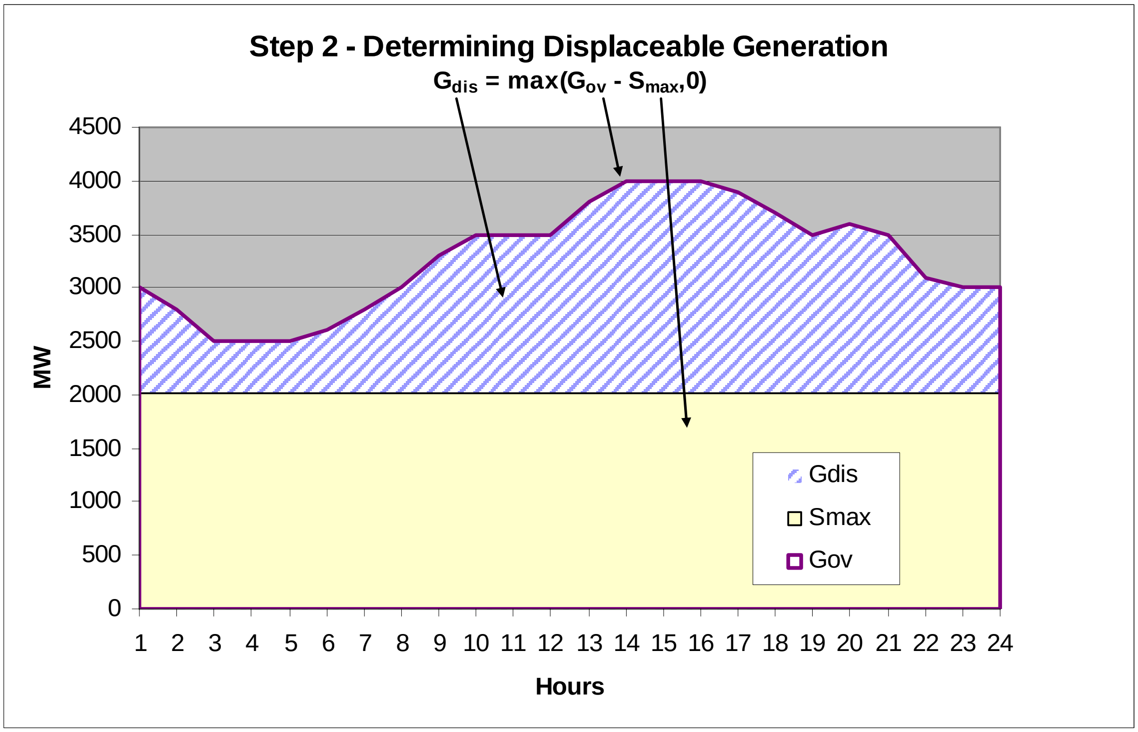


Figure 2 (Note that the shape of overgeneration in Figure 1 and Figure 2 is the same, but Figure 2 displays the data on a smaller scale so variations stand out.)

In these conditions, we assume that all available thermal generation has been taken off line in exchange for hydroelectric power, leaving wind generation (G_W) as the only remaining displaceable resource. The third step was the calculation of the amount of wind generation that is displaced ($G_{disWind}$) as illustrated in Figure 3 below and defined by the equation:

$$G_{disWind} = \min(G_{dis}, G_W)$$

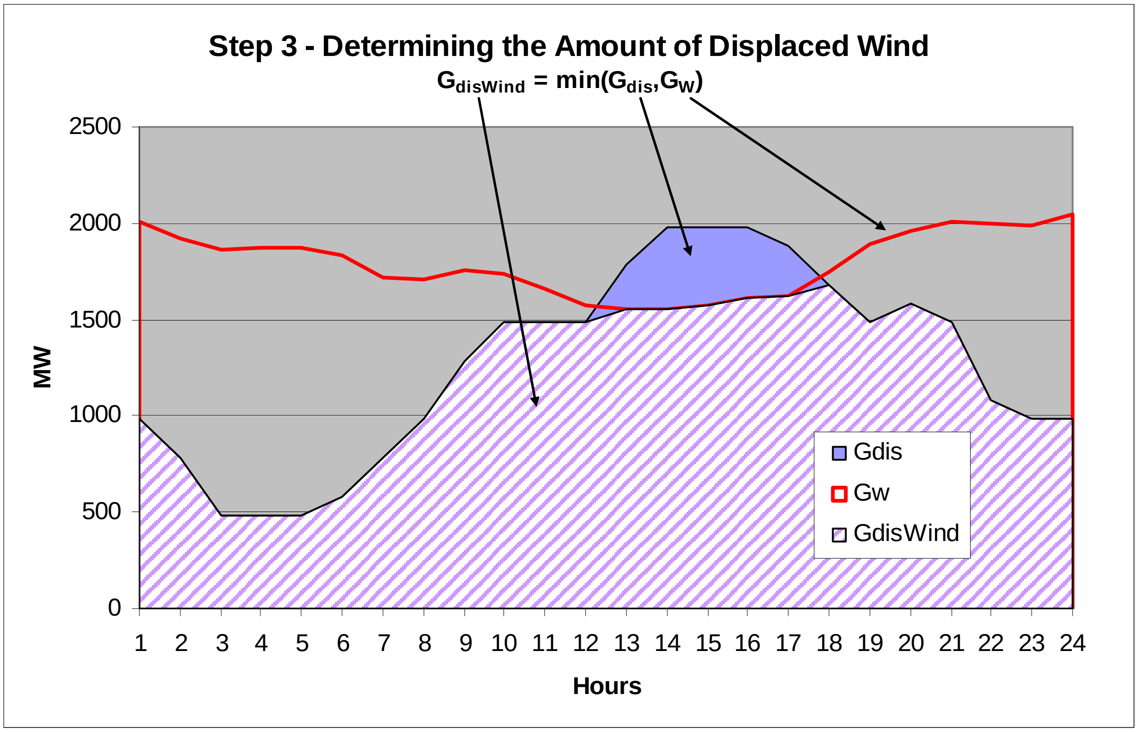


Figure 3

We are not aware of the specific contractual arrangements of wind generators and do not know whether they all receive renewable energy credit (REC) payments or have passed those payments or credits on to other parties. For purposes of this study we have assumed that the entire wind fleet receives renewable energy credits (P_{REC}) and only a percentage of the fleet ($PTC_{\%}$) receives production tax credits (P_{PTC}). We assume that the entire wind fleet would be displaced proportionately, independent of which projects receive production tax credits and which do not. Therefore the implied or estimated cost to wind generators (C_W) of displacement over time (t) is defined as:

$$C_W = (PTC_{\%} * P_{PTC} + P_{REC}) * G_{disWind} * t$$

Finally, note that scheduling error of wind generation and the associated deployment of balancing reserves are not considered in this methodology. Measuring the impact of balancing reserve deployment requires time resolution much finer than the weekly HLH/LLH time blocks described above. While a finer time resolution would provide greater precision, the coarser time blocks used in this methodology is sufficient for providing a general estimate of the amount of overgeneration in a given scenario.

This methodology forms the foundation of the following sections.

Scenario selection

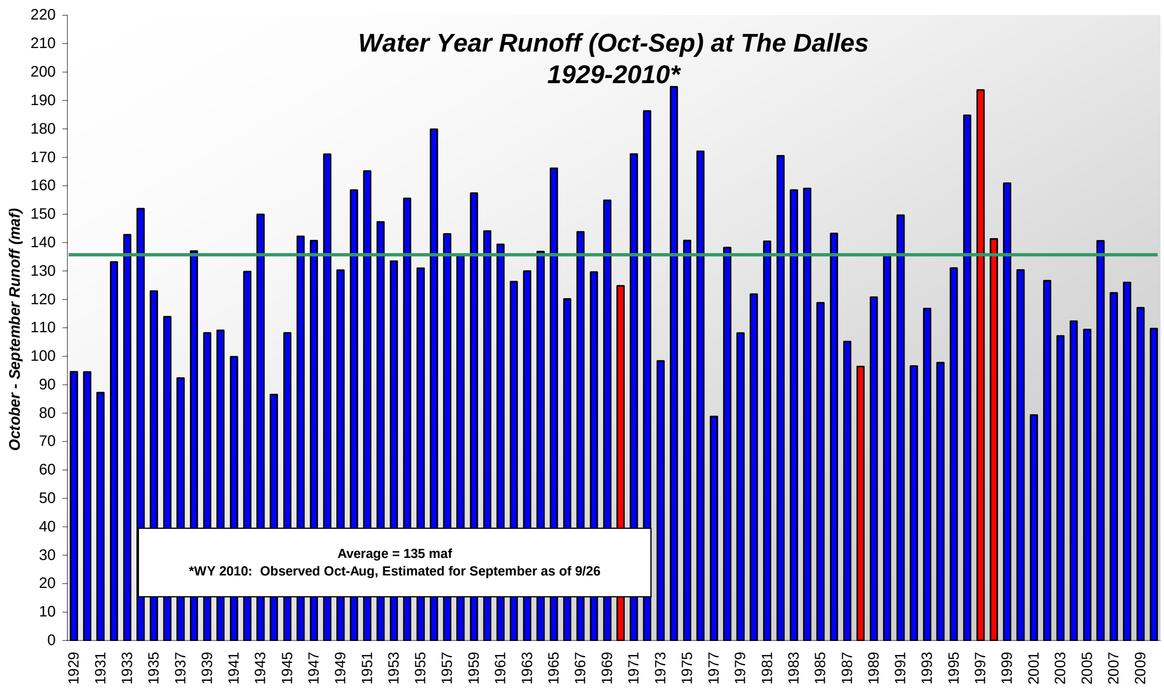
BPA assessed the amount and financial implications of overgeneration under a series of different scenarios for the period April to June 2012. We selected spring 2012 because it illustrated a near term period for which we had reasonable estimates of the expected size of the wind fleet, loads and transmission export capability. These scenarios are based on actual historic variations in river flow, hydro generation and wind generation that could be expected in future years and that can lead to the overgeneration conditions that are the subject of this report.

The following scenarios were examined to produce estimates for April to June 2012.

Hydro Generation

Four streamflow scenarios outlined in the 2010 rate case materials are examined in this analysis, utilizing the HYDSIM/HOSS models to assess generation outputs for these four flow conditions given the current system configuration.

1. 1997 conditions, with a water year volume much above average.
2. 1998 conditions, with a water year volume slightly above average.
3. 1970 conditions, with a water year volume slightly below average.
4. 1988 conditions, with a water year volume much below average.
    a. 1996 data was used for weekly shaping of 1970 and 1988 conditions because its shape was fairly smooth as compared to other weekly shapes that were studied.



Wind Generation

This analysis considered two different wind generation profiles selected from historical wind generation data in the BPA balancing authority from 2002 to 2010. Wind generation capacity in the BPA balancing authority has grown over that period from about 200 MW to nearly 3,400 MW. The intent was to select an average wind production month and an above average wind production month. The two profiles selected were:

1. Weekly HLH/LLH wind generation derived from the 50^{th} percentile of average monthly capacity factors (about 32 percent) applied to projected 2012 wind fleet capacity of 4,600 MW in April - June. The weekly HLH/LLH capacity factors range from 16-65 percent.
2. Weekly HLH/LLH generation derived from the 83^{rd} percentile of average monthly capacity factors (about 41 percent) applied to projected 2012 wind fleet of 4,600 MW in April - June. The weekly HLH/LLH capacity factors range from 20-73 percent.

An additional 1,200 MW of wind generation capacity was also included to reflect the wind fleet in Northwest balancing authorities other than BPA's. Nevertheless, the calculation of the amount of wind generation that is displaced ($G_{disWind}$) only considered the wind generation in the BPA balancing authority.

Other Parameters

The analysis also incorporated data representing other factors. Data was selected to represent conservative conditions in which thermal generation is significantly reduced and power exports are increased and likely understate the displacement needs. Data was selected as follows:

1. **Regional must-run thermal generation** was represented by the lowest seven-day period in June 2010: 977 aMW HLH; 852 aMW LLH
2. **Exports** were represented by the maximum seven-day period of exports in June 2010: 6,959 aMW HLH; 5,716 aMW LLH. These values represent approximately 90 percent of the available AC/DC intertie being utilized in HLHs and 70 percent in LLHs. Exports to Canada occupied approximately 25 percent of the northern intertie on both HLHs and LLHs, while exports to Montana filled less than 10 percent of the intertie space. These low levels of exports to Canada and Montana suggest either lack of demand or generation that could not be displaced.
3. **Regional loads** were represented by actual loads for 2010, factoring in 0.9 percent projected load growth in 2011 and 1.2 percent load growth in 2012 as the economy recovers.
4. **Maximum spill** was limited to the TDG levels consistent with the Clean Water Act, the limit that applied in June 2010 for Grand Coulee, Chief Joseph,

Dworshak and Willamette Valley projects. The analysis assumes that this level of spill is achieved in 90 percent of the hours examined.

5. **The percent of wind receiving PTC** is assumed to be 29 percent.

Basis for cost assessment

This report provides general estimates of the costs of displacing wind generation. Nevertheless, BPA cannot definitively determine the absolute costs of displacing wind power because the agency does not necessarily know and cannot predict how wind energy producers might value the right to curtail their wind generation.

This assessment accounts for such uncertainties by displaying the estimated total cost of displacing wind generation under the range of scenarios based on each $10 per megawatt-hour of potential cost. BPA understands the current value of RECs is approximately $16/MWh of power generated and the value of PTCs is $21/MWh generated, for a total of $37/MWh. BPA also understands that only 29 percent of the wind fleet receives PTCs. Therefore as an alternative approach, BPA estimated the total costs of displacing wind generation based on a weighted value of $22/MWh of lost generation, accounting for the proportion of the wind fleet that receives PTCs.

Although this analysis uses $10/MWh and $37/MWh wind displacement metrics to estimate the cost of environmentally redispatching wind to reduce regional overgeneration in spring 2012, the cost could vary significantly. Thermal plants in the region have historically found it economic to replace their generation with low cost hydro surplus generation during periods of overgeneration and have not required payment from BPA or other hydro based utilities to take energy. Nevertheless, a negative price market during overgeneration events could create the potential for payments to parties other than wind generators. In addition, this analysis does not speculate on potential future market design in the region. The cost of curtailing overgeneration supplies in the region could be tied to new market pricing structures in the future that could result in significant negative price conditions when it is expected that large hydro generators must sell energy to limit spill to comply with environmental requirements.

This is not an abstract possibility. A recent straw proposal by the California Independent System Operator suggests that prices in excess of the value of RECs and PTCs may be necessary to incent wind generators to displace in overgeneration conditions. To increase these incentives, the California ISO has proposed reducing the present price floor of -$30/MWh for decremental (DEC) bids to a new price floor of -$500/MWh in 2012 and lowering the floor again in two annual steps to -$750/MWh and later to -$1,000/MWh. Applying such costs of this magnitude to displace overgeneration supplies discussed in this analysis would produce dramatically higher total costs than we have described.

Scenario results: displacement amounts and costs

The following tables estimate wind displacement amounts and costs in 2012 based on the wind and flow scenarios outlined earlier and under two additional analyses examining how the figures would change with more or less hydro generation. The percentage of wind generation that is curtailed in these three months is included parenthetically.

The wind generation scenarios are shown as:

1. **P50**: Wind generation derived from the 50th percentile of average monthly capacity factors (about 32 percent) applied to projected wind fleet capacity of 4,600 MW in April – June 2012.
2. **P83**: Wind generation derived from the 83rd percentile of average monthly capacity factors (about 41 percent) applied to projected wind fleet capacity of 4,600 MW in April – June 2012.

MW-months of wind displacement and percentage of wind curtailment

		Flow condition			
		1997 (much above average)	**1998 (slightly above average)**	**1970 (slightly below average)**	**1988 (much below average)**
Wind Generation	**P50**	1590 (36%)	1033 (23%)	283 (6%)	0
	P83	2327 (41%)	1065 (19%)	132 (2%)	0

Cost of lost REC/PTC ($22/Mwh*) ($million)

		Flow condition			
		1997	**1998**	**1970**	**1988**
Wind Generation	**P50**	25.3	16.5	4.6	0.0
	P83	37.2	17.2	2.1	0.0

**Cost of lost REC/PTC assumes a REC value of $16/MWh and a PTC value of $22/MWh, with 29 percent of the wind fleet receiving PTCs.*

Cost per $10/MWh ($million)

		Flow condition			
		1997	**1998**	**1970**	**1988**
Wind Generation	**P50**	11.7	7.6	2.0	0.0
	P83	17.0	7.9	1.0	0.0

The results for 1970 showing less wind displacement with 83rd percentile wind than 50th percentile wind are a result of the coincidence of high wind and hydro generation. Even though the 83rd percentile wind scenario had higher month-average wind generation, the weekly shape of the 50th percentile wind more closely matches the weekly shape of the 1970 hydro generation.

The results also show that displacement is most likely to occur in May during LLHs.

Sensitivity analysis: additional hydro generation

Additional hydro generation rather than spill relieves the need to curtail wind. The following charts reflect the same scenarios assuming an additional 500 aMW of hydro generation is possible, either by further displacing thermal generation, additional demand driven by cooler temperatures or deliberate demand-side actions to increase load or additional export capability.

MW-months of wind displacement and percentage of wind curtailment

Flow condition

		1997 (much above average)	1998 (slightly above average)	1970 (slightly below average)	1988 (much below average)
Wind Generation	**P50**	1076 (24%)	788 (18%)	218 (5%)	0
	P83	1706 (30%)	637 (11%)	68 (1%)	0

Cost of lost REC/PTC ($22/Mwh*) ($million)

Flow condition

		1997	1998	1970	1988
Wind Generation	**P50**	17.2	12.6	3.5	0.0
	P83	27.2	10.3	1.1	0.0

**Cost of lost REC/PTC assumes a REC value of $16/MWh and a PTC value of $22/MWh, with 29 percent of the wind fleet receiving PTCs.*

Cost per $10/MWh ($million)

Flow condition

		1997	1998	1970	1988
Wind Generation	**P50**	7.9	5.8	1.6	0.0
	P83	12.5	4.7	0.5	0.0

Sensitivity analysis: reduced hydro generation

Reduced ability to generate power with high runoff can cause additional spill, pushing the hydro system closer to the TDG limits consistent with the Clean Water Act. The following charts reflect the same scenarios assuming 500 aMW less hydro generation, either because less thermal generation can be displaced, reductions in demand caused by milder temperatures, increased generation imports to the region or reduced exports caused by transmission limitations.

MW-months of wind displacement and percentage of wind curtailment

		Flow condition			
		1997 (much above average)	**1998 (slightly above average)**	**1970 (slightly below average)**	**1988 (much below average)**
Wind Generation	**P50**	2528 (57%)	1348 (31%)	347 (8%)	0
	P83	3170 (56%)	1504 (27%)	202 (4%)	0

Cost of lost REC/PTC ($22/Mwh*) ($million)

		Flow condition			
		1997	**1998**	**1970**	**1988**
Wind Generation	**P50**	40.2	21.6	5.6	0.0
	P83	50.5	24.2	3.3	0.0

**Cost of lost REC/PTC assumes a REC value of $16/MWh and a PTC value of $22/MWh, with 29 percent of the wind fleet receiving PTCs.*

Cost per $10/MWh ($million)

		Flow condition			
		1997	**1998**	**1970**	**1988**
Wind Generation	**P50**	18.5	9.9	2.6	0.0
	P83	23.1	11.1	1.5	0.0

Other considerations

Factors that would significantly increase the magnitude of this overgeneration supply problem include the projected interconnection of 6,000 MW of wind in the BPA control area alone by 2013. This could combine with the region's emphasis on conservation as the preferred resource to meet future loads to create higher probabilities of overgeneration conditions. In addition, the expanding need to reserve capacity of regional thermal plants to balance wind and other renewables may limit the ability of thermal plants to reduce generation. Finally, additional penetration of other non-dispatchable renewable generation could add to overgeneration situations.

The fact that the region may periodically face an oversupply of inexpensive carbon-free energy also presents an opportunity. The availability of such energy may incentivize creative responses to access the surplus. In addition, economic recovery could increase spring loads and potential expansion of interties around the region could allow export of larger amounts of surplus energy, reducing oversupply situations.

Finally, it is important to note that low water, higher loads and low wind conditions would create little or no need for environmental redispatch.

Conclusion

The estimates in this report provide only a snapshot of the potential extent and cost of overgeneration in 2012, when wind capacity in BPA's balancing authority area is projected to reach almost 4,600 MW, compared to about 3,400 MW today. BPA expects wind generation to continue its expansion beyond 2012, so the potential for occasional seasonal overgeneration may well continue to escalate. Our search for solutions must continue to do the same.

Under near-average water conditions in 2012 (the 1970 and 1998 data), BPA anticipates a likelihood of about 100 MW-months to 1,100 MW-months of overgeneration supply once BPA has managed the system to provide spill close to the TDG limits consistent with the Clean Water Act. Very limited sensitivity analyses show that this oversupply can drop to less than 100 MW-months or increase to about 1,500 MW-months with relatively modest changes in assumptions.

Whether produced by water or the wind, renewable energy represents a valuable Northwest resource. Because unpredictable factors such as runoff volume and shape, wind generation and loads all contribute to overgeneration, it is not surprising to find that the magnitude of overgeneration supply is also highly variable. Such wide variation must also be multiplied by the differing theories on how to best assess the cost of displacing enough generation to manage the overgeneration supply. Given so many variables, that cost could range from zero to very large values.

While the region cannot avoid exposure to this volatile overgeneration supply condition, stakeholders can work together to prepare for and minimize its consequences. BPA is exploring options for making maximum use of the abundance of renewable energy when overgeneration conditions occur and encourages others to do the same.