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Submitted by Electronic Mail to records@utc.wa.gov

RE: Comments of Absaroka Energy
Docket No. UE-160918 – Puget Sound Energy 2017 Integrated Resource Plan

Introduction

Absaroka Energy is developing the Gordon Butte Pumped Storage Hydro Project (Gordon Butte), a 400 MW, closed-loop pumped storage hydro project with 3,200 MWh of storage capability to be interconnected to the Colstrip 500 kV transmission lines near Martinsdale, Montana. Gordon Butte will employ the latest ternary pump/turbine technology to provide fast-ramping flexible capacity ideally suited for integrating intermittent renewable resources into the Western US transmission grid. Gordon Butte coupled with Montana's robust wind resources provides a reliable, cost-competitive, and carbon-free solution for replacing the capacity and energy from Colstrip 1&2 when those units are retired no later than 2022.

On December 14, 2016 the Federal Energy Regulatory Commission issued the Original License for Gordon Butte (FERC Docket No. P-13642) to construct and operate the project for a 50-year period. Puget Sound Energy's (PSE) 2017 Integrated Resource Plan (IRP) discusses the long lead times and permitting challenges faced by most pumped storage hydro projects [IRP, pages 6-59 and D-41]. However, Gordon Butte has already completed these development activities and is construction-ready. Additional information on the Gordon Butte Project can be found at: http://gordonbuttepumpedstorage.com/.

Absaroka Energy participated in the meetings of the PSE IRP Advisory Group (IRPAG) during the development of the 2017 IRP. Through the IRPAG process, Absaroka Energy was able to learn about PSE's energy supply situation and its planning processes, and was also able to offer its comments and suggestions as the 2017 IRP was being developed. Absaroka Energy appreciates the opportunity to participate in the process and to contribute toward the exchange of ideas on how best to meet the future energy supply needs of PSE's customers.

In developing the 2017 IRP, PSE considered large amounts of information and conducted extensive analysis. In this process, many significant issues were considered. PSE's efforts to assess and address these topics certainly leads to an improved understanding of these topics. However, as will be discussed further below, PSE's analysis falls short in some areas.

Near Term Capacity Additions

PSE is to be commended on its decision to move away from selecting long-lived gas-fired resources to fill its near-term capacity needs. The selection, instead, of demand response and energy storage projects properly recognizes the economic and environmental benefits of these less traditional, but more suitable resources.

Energy Storage vs. Gas-Fired Peakers

Figure 6-20 [IRP, page 6-42] portrays the levelized net capacity costs for gas-fired units and energy storage technologies considered in the 2017 IRP. In preparing this analysis, PSE began with gross capacity costs (capital and fixed O&M) and then adjusted for net market revenues (gross market revenues minus fuel costs), flexibility benefits and assumed T&D benefits. The results indicate that the lowest cost energy storage technologies (4-hour flow batteries and pumped hydro storage) are cost-competitive with all of the gas-fired options, with the possible exception of frame peakers.

However, this analysis may understate the cost-competitiveness of the energy storage technologies for two reasons. First, in this IRP, PSE did not assign carbon costs to gas peakers because carbon costs were modeled using the specific provisions of the EPA's then-proposed Clean Power Plan which applied only to baseload units. [IRP, pages 1-4, 2-11 and 4-15]

Addition of carbon costs to the gas peakers would improve the relative cost effectiveness of the energy storage technologies.

Second, PSE assumes in this IRP that it has enough intra-hour flexibility in its existing generation fleet that it does not need to add new flexible capacity resources. This is based on the analysis presented in Appendix H, Operational Flexibility. That analysis is based on PSE's current generation fleet and flexibility requirements. It does not include possible future increased flexibility requirements that could result from building new variable resources inside PSE's balancing area, or moving existing variable resources (such as Hopkins Ridge, Lower Snake River and Wild Horse) into PSE's balancing area. These possible future flexibility requirements cannot be effectively met by inflexible frame peakers.

While these future flexibility needs could conceivably be met by more flexible gas units such as aeroderivative CTs or reciprocating engines, energy storage technologies can perform these duties much more economically because their two-way capability (full output to full storage) effectively doubles their flexible operating range compared to nameplate capacity. For example, Gordon Butte is able to generate at 400 MW (+100%) and store energy through pumping at 400 MW (-100%) giving it a flexible operating range of 800 MW. Absaroka Energy commissioned E3 Consulting to compare ternary pumped storage hydro technology against gas peakers (aeroderivative CTs, reciprocating engines and frame CTs) for various flexible capacity products. The results of this study are provided as Attachment A and demonstrate that pumped storage hydro provides these flexible capacity products at a significantly lower cost.

Pumped Storage Hydro vs. Batteries

The 2017 IRP selects a 4-hour flow battery as the preferred energy storage technology for meeting near-term capacity needs. This choice is based on the economics portrayed in Figure 6-20 [IRP, page 6-42] which shows a levelized net capacity cost of $93/kw-year, the lowest among the energy storage options evaluated. Pumped storage hydro comes in next lowest with a net capacity cost of $105/kw-year. However, the net capacity cost for all of the battery options is highly dependent on the assumed T&D benefits which are $103/kw-year for a 4-hour flow battery. [IRP, page 6-41 and Figure 6-20, page 6-42] Without this assumed T&D benefit (which depends largely on an assumption that batteries will be placed in locations that will defer or eliminate significant T&D investments), the 4-hour flow battery's net capacity cost increases to $196/kw-year, nearly twice the cost for pumped storage hydro. In fact, a reduction in the assumed T&D benefit of only 12%[1] results in price parity between the 4-hour flow battery and pumped storage hydro, while a 50% reduction in the assumed T&D benefit results in a 37% higher cost[2] for the battery.

The Energy Storage Sensitivity [IRP, pages 6-58 and 6-59] concludes that replacing the 50 MW flow battery in PSE's Resource Plan portfolio with 50 MW of pumped storage hydro raises the portfolio's NPV by $8 million. However, this result is again heavily influenced by the substantial T&D benefit assumed for the battery. If the assumed T&D benefit is reduced by 50%, the pumped storage hydro results in an NPV savings of $13 million[3]. If there is no T&D benefit for the battery, the pumped storage hydro NPV savings would increase to $34 million[4].

The generic T&D benefits assumed for batteries in the IRP drives the selection of the 4-hour flow battery as the preferred energy storage technology. The T&D benefits for actual battery installations on PSE's system could be much smaller.

Battery Degradation and Impacts on Lifecycle Costs

In addition to its superior economics, pumped storage hydro is a mature technology with all of the ramping speed and flexibility, but none of the technology risks associated with utility scale batteries.

The most obvious of these technology risks is degradation of batteries with age and use. It is known that batteries degrade and lose storage capacity over their lifetimes.[5] The exact extent of this degradation is influenced by the type of battery, operation of the battery, and operating environment among other factors. However, due to the complex nature of the aging processes

[1] From $103/kw-year to $91/kw-year.
[2] $144.5/kw-year for 4-hour flow battery vs. $105/kw-year for pumped storage hydro
[3] 50% of NPV calculated in footnote 4.
[4] 50 MW * $58.81/kw-year T&D benefit (2018) with 2.5% annual escalation over 54 years at 7.77% discount rate with costs beginning in Year 5 = $42 million NPV
[5] Fortenbacher, P., & Andersson, G. (2017). *Battery Degradation Maps for Power System Optimization and as a Benchmark Reference.* Zurich: Power Systems Laboratory. *https://arxiv.org/pdf/1703.03690.pdf*

and the large number of variables, nearly all of the existing battery capacity degradation models rely heavily on empirical data[6]. Other factors such as ambient temperatures, nature of the energy cycling, and depth of discharge all can negatively affect the batteries performance, increasing the overall lifecycle cost of the battery system.

Studies have shown that lithium-ion batteries have some very real impacts from degradation. Tests on these batteries have demonstrated that they have a typical life of anywhere between 500-1200 cycles. A group from the University of South Carolina also performed research into the capacity fade of lithium-ion batteries subjected to high discharge rates[7]. The research concluded that lithium-ion batteries that undergo rapid charging and discharging (as would be the case if the battery was used for grid regulation) would experience a capacity reduction of 16.9% (resulting in a reduced total capacity of 83.1%) after only 300 cycles.

As noted above, the 2017 IRP has selected a 4-hour flow battery as the preferred energy storage technology. Though flow batteries do not have many of the problems that accompany lithium-ion batteries, they still have their drawbacks. These batteries also suffer from degradation, although less research is available on the degradation rates, causes, and effects for flow batteries leading to less conclusive information available about their life expectancy.

A recent the study found that the capacity of a vanadium redox flow battery was reduced to 60% of its original capacity after only 50 cycles. This capacity was then mostly restored by replacing the electrolyte and reversing the polarity of the battery[8]. This is an important finding since this indicates that, although flow batteries are generally expected to have long lifetimes (beyond 10,000 cycles), they would experience significant maintenance costs over their lifetimes. The findings of this study suggest that the electrolyte would need to be replaced entirely or restored in some way to extend the life of the battery to a reasonable number of

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[6] Smith, K., Neubauer, J., Wood, E., Jun, M., & Pesaran, A. (2013, April 15). *Models for Battery Reliability and Lifetime.* Retrieved from NREL.gov
[7] Ning, G., Haran, B., & Popov, B. (2002, December 20). *Capacity fade study of lithium-ion batteries cycled at high discharge rates.* Retrieved from Sciencedirect.com: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.704.1039&rep=rep1&type=pdf
[8] Derr, I., Bruns, M., Langner, J., Fetyan, A., Melke, J., & Roth, C. (2016, September 1). *Degradation of all-vanadium redox flow batteries (VRFB) investigated by electrochemical impedance and X-ray photoelectron spectroscopy: Part 2 electrochemical degradation.* Retrieved from Sciencedirect.com: http://www.sciencedirect.com/science/article/pii/S037877531630742X

cycles[9]. This is corroborated in a Harvard article that describes research into a new type of flow battery[10]. The article plainly states that today's flow batteries are a promising solution, but suffer degraded energy storage capacity and require periodic maintenance of the electrolyte. Overall, vanadium redox flow batteries are still a developing technology with some promising attributes as well as some distinct drawbacks.

As PSE continues to refine its approach for comparing energy storage technologies, technology risk and degradation impacts on life-cycle costs for batteries should be fully considered.

Packaging Montana Wind with Pumped Storage Hydro

The Gordon Butte Pumped Storage Hydro Project is located approximately six miles from its planned interconnection point with the Colstrip 500 kV transmission lines. Gordon Butte is a natural complement to Montana wind in a package to cost-effectively replace PSE's share of Colstrip 1&2 while leveraging PSE's investment in the Colstrip transmission lines. Montana wind and pumped storage hydro could share PSE's Colstrip transmission rights freed up by the retirement of Colstrip 1&2 with the pumped storage resource optimizing the use of this transmission capacity. Absaroka supports Orion Renewables Energy's (Orion) comments regarding the proper treatment of Colstrip transmission costs in this IRP and future procurement processes and the need for PSE to work diligently to resolve issues related to dynamic transfers into and across the BPA transmission system. Those points are well made by Orion, so will not be repeated here.

PSE's 2015 IRP selected Washington wind over Montana wind as PSE's next renewable resource. Following the 2015 IRP, Absaroka commissioned a study by E3 Consulting of carbon-free replacement options for PSE's share of Colstrip 1&2. That study, which is provided as Attachment B to these comments, showed a substantial savings to PSE by procuring a package

[9] Derr, I. et al., 2016
[10] Burrows, L. (2017, February 9). *Long-lasting flow battery could run for more than a decade with minimum upkeep.* Retrieved from Harvard.edu: https://www.seas.harvard.edu/news/2017/02/long-lasting-flow-battery-could-run-for-more-than-decade-with-minimum-upkeep

made up of Montana wind and pumped storage hydro rather than a package made up of Washington wind and gas peakers.

PSE's 2017 IRP selects Washington solar over Montana wind for PSE's renewable energy needs and batteries over pumped storage hydro for capacity. Absaroka has not had sufficient time to prepare a detailed study comparing a package of Montana wind and pumped storage hydro to a package of Washington solar and batteries. However, a straightforward comparison of capital costs for replacing PSE's Colstrip 1&2 capacity (300 MW) and energy (250 aMW) has been prepared using cost and other parameters from the 2017 IRP [Figure 4-18, page 4-32 and Figure D-20, page D-43]. As shown in the tables below, the Montana wind and pumped storage hydro alternative results in a capital cost savings of 50% or $1.4 billion and an additional 100 MW of effective capacity.

Colstrip 1&2 Carbon-Free Replacement Alternatives

Montana Wind and Pumped Storage Hydro							
Resource	Nameplate Capacity	Capacity Factor	Energy	Capacity Credit	Effective Capacity	Capital Cost	Capital Cost
	(MW)		(aMW)		MW	($/kw)	$million
MT Wind	543	46%	250	49%	266	$ 2,055	$ 1,117
PSH	134			100%	134	$ 2,400	$ 322
Total	677		250		400		$ 1,438

Washington Solar and Batteries							
Resource	Nameplate Capacity	Capacity Factor	Energy	Capacity Credit	Effective Capacity	Capital Cost	Capital Cost
	(MW)		(aMW)		MW	($/kw)	$million
WA Solar	962	26%	250	0%	0	$ 2,041	$ 1,963
Batteries	395			76%	300	$ 2,324	$ 917
Total	1356		250		300		$ 2,880

2018 All-Source RFP

Absaroka supports moving ahead with an All-Source Request for Proposals (RFP) following Commission review of the 2017 IRP. An RFP will allow PSE to test the market and compare specific resource proposals to the generic resource assumptions relied upon in the IRP.

However, the Commission should provide specific direction to PSE regarding certain aspects of the RFP and any subsequent resource procurement:

1. PSE should not move forward on the procurement of any gas-fired peaking units until PSE has complete a thorough assessment of its future needs for flexible capacity.
2. In evaluating batteries, PSE should develop estimates of T&D benefits for specific locations on PSE's system rather than relying on a generic estimate of T&D benefits.
3. In evaluating batteries, PSE should fully consider technology risk and degradation impacts on life cycle costs.
4. As discussed in Orion's comments, PSE's costs for the Colstrip transmission lines and the BPA Montana Intertie should be treated as sunk in the evaluation of Montana resources.
5. As discussed in Orion's comments, if Montana resources appear to be cost-effective resource assuming adequate dynamic transfer capability, PSE should not move to procure alternative resources until the BPA/Montana Forum and GRC Settlement Process activities have been completed and PSE has an improved understanding of transmission issues related to Montana exports.

Conclusion

In the 2017 IRP, PSE properly identifies demand response and energy storage as the best options to meet its near-term capacity needs. However, the IRP selection of batteries over pumped storage hydro as the preferred energy storage technology is heavily dependent on generic assumptions about significant T&D benefits assigned to the batteries. If the assumed T&D benefits for batteries are overstated, pumped storage hydro is the least-cost energy storage technology. In addition to being the most cost-effective energy storage alternative, pumped storage hydro is the most mature and widely-deployed energy storage technology available with none of the technology risks and degradation issues associated with batteries.

Montana has tremendous wind resources, the only construction-ready modern pumped storage facility in the Western Interconnection, and a high-voltage transmission connection to PSE's transmission system. The combination of Montana wind and ternary pumped storage hydro will provide a low-cost, carbon-free alternative for replacing PSE's share of Colstrip 1&2, while continuing the beneficial use of PSE's investment in the Colstrip transmission lines.

The Gordon Butte Pumped Storage Hydro Project is fully-licensed, construction-ready resource that will provide value to PSE's customers by providing 1) an extremely flexible, low-cost, carbon-free resource to meet a portion of PSE's capacity needs, or 2) in combination with Montana's robust wind resources, a reliable, low-cost, carbon-free resource package to replace PSE's Colstrip 1&2 generation.

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