Economic Study Request

Pumped Storage Hydro in Wyoming

Request

In March 2022, Black Canyon Hydro, LLC made a request for a regional Economic Study Request to be performed.

"Seminoe Pumped Storage Transmission and Economic Benefits Study 900MW x 10 hours pumped hydro energy storage facility, interconnecting at 500kV at Aeolus Substation, Carbon Co. Wyoming. Projected placed in service date of June 2029. The project would significantly enhance capacity of Gateway transmission to deliver additional highquality wind energy from WY to UT the PNW. The project can also reduce future congestion on the Gateway System, including at Aeolus, Clover/Mona while accommodating wind expansion in WY; provide shaping and firming of WY wind to meet capacity needs; provide shaping and firming of UT solar via the Clover/Mona area to meet capacity needs; provide system inertia that replaces lost inertia from coal retirements in WY and UT. The project has a wide range in generation and pumping, up to 900MW, dispatchable. The project will have 3 units of 300MW ea., variable speed generators that can provide maximum value and flexibility to the operations of the transmission system and integration of intermittent renewable energy generation. The ramp rate is up to 30MW /sec, 0 to full output in 30-60 seconds. The project can generate at full capacity, 900MW for 10 hours, and in pumping mode at 900MW for 13 hours. Additional technical information will be made available as needed."

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Study Plan for Economic Study Request: Pumped Storage at Aeolus Request

In March of 2022, Black Canyon Hydro, LLC submitted to the NorthernGrid planning region a request for economic analysis of the Seminoe Pumped Storage project. The high-level details are listed below.

1. 900 MW dispatchable pumping capability, 13-hour duration
2. 900 MW dispatchable generating capability, 10-hour duration
3. Proposed interconnection at the 500 kV Aeolus substation
4. Planned in-service date of June, 2029

The request states that the proposed project "can also reduce future congestion on the Gateway System, including at Aeolus, Clover/Mona while accommodating wind expansion in WY; provide shaping and firming of UT solar via the Clover/Mona area to meet capacity needs; provide system inertia that replaces lost inertia from coal retirements in WY and UT."

Study Scope

The study scope was developed to address the economic impact of the SPS project to the overall NorthernGrid region. Production cost modeling will be used to ascertain if the presence of the SPS changes congestion on selected WECC paths, allows for increased dispatch of renewable resources, or reduces the overall production cost of the transmission system.

Analysis

Production cost modeling analysis will be used to determine if the pumped storage project would result in a net reduction in total production cost to supply system load or reduced congestion. The production cost analysis will consist of the following:

1. Starting with the Anchor Data Set (ADS) from the Western Electric Coordinating Council (WECC), the topology will be modified to include 17 transmission projects submitted by the enrolled parties into the NorthernGrid 2022-2023 planning cycle as well as all submitted generation changes.
2. Production cost modeling will be run to establish the total production cost of the system over a year and identify areas of congestion
3. The pumped storage project will be modeled into the modified ADS
4. Production cost modeling will be run on the modified ADS and comparisons will be made to the initial production cost and congestion values.

The results section in the report will address how the introduction of the Seminoe Pumped Storage project results in changes to annual energy output from the Wyoming wind facilities, total production cost, and congestion.

Report

A report of the Economic Study Request, methodology, and findings will be complete by March 31, 2023, or other date agreed upon between the Parties. This economic study report will be a stand-alone report that will be included as an appendix to the Regional Transmission Plan. This report in no way constitutes an analysis for generation interconnection, load service, or transmission service; its findings may inform the regional transmission planning process.

Analysis

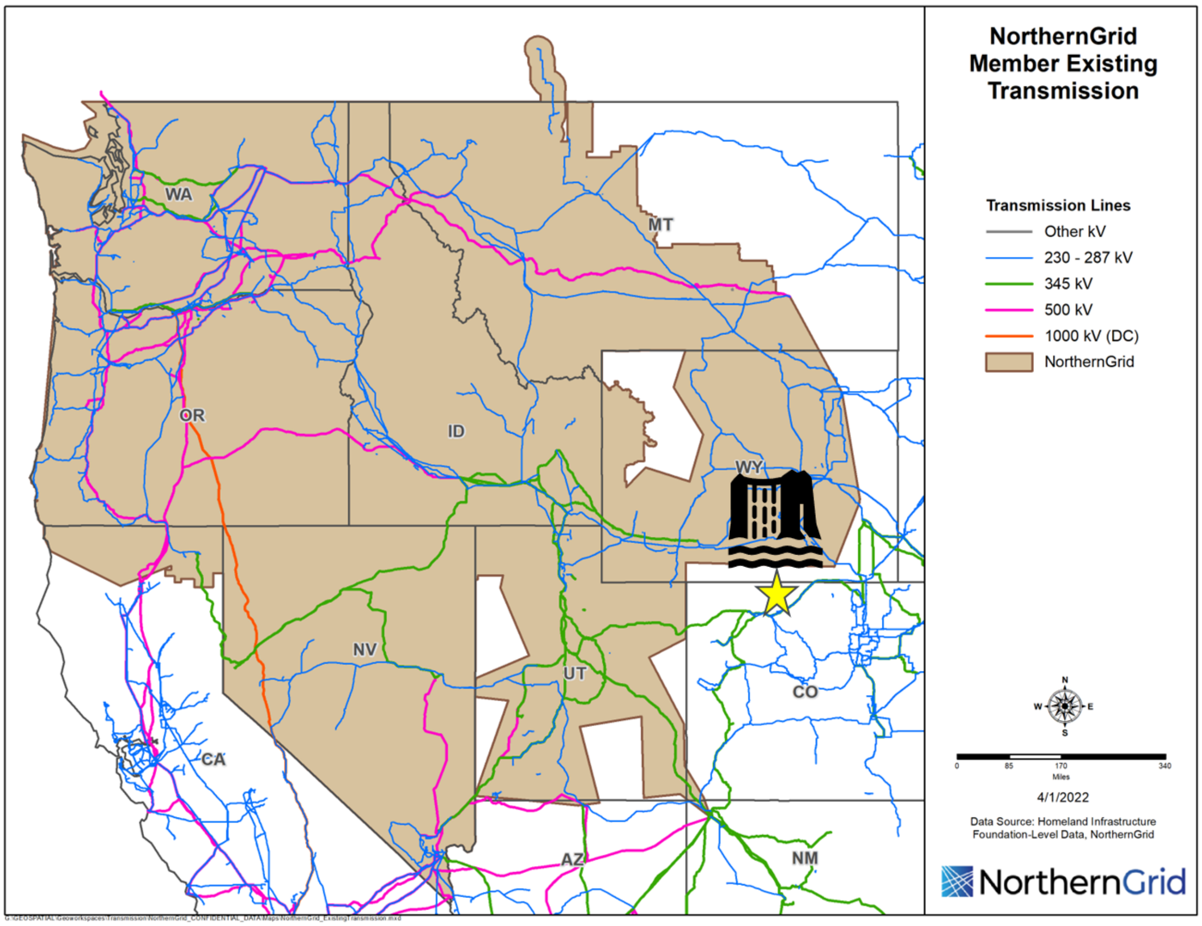

Figure 1: Representation of the SPS project

The SPS project was modeled into the 2032 Anchor Data Set (ADS) and production cost modeling was run. This production cost analysis assumes a point of interconnection at the Aeolus 500 kV bus with no additional transmission upgrades. The analysis in this report does not address the upgrades to the transmission system needed to support the point of interconnection. The analysis herein does not address the reliability or the assumed operations of this pumped storage project; it is a representation of study results bounded by the assumptions.

Results

The following set of plots represent the observed impact to the transmission system given the assumed installation of 900 MW of pumped storage generation at the 500 kV Aeolus substation and with no additional transmission system upgrades. Hitachi GridvView Version 10.3.44 was used to analyze the 2032 ADS, with and without the SPS and for the case with the SPS, the pumped storage simulation option used was that of, “Daily Scheduling on Price”. While GridView dispatches the system on an hourly basis given the fuel costs and transmission constraints of the transmission system, the results of GridView analyses should in no way be construed as operational instruction.

Using the Multi-Integer-Optimization (MIO) and the “Daily Scheduling based on Price” option, the GridView Pumped Hydro Storage (PHS) algorithm commits PHS in consideration of other system resources based on PHS pumping efficiency/plant volume/ramping rates to optimize and schedule the generation/pumping dispatch 24-hour forward. This option does not require iterating to determine a pre-price forecast. GridView allows the user to schedule PHS with the given storage target looking at weekly, daily or monthly schedules with consideration of load pattern, wind and solar patterns (these are fixed energy patterns). It supports modeling for high wind events for the chosen period by emptying storage or to prepare for rain days (or low solar generation for the period) by filling up storage over weekly or even longer period of time. The 2032 ADS has negative pricing for wind and solar (- $25), reflecting either an investment tax credit (ITC) or a production tax credit (PTC). Significant addition of utility-scale solar and behind-the-meter solar installations has changed the net load shape; in some areas, the net daily minimum load now occurs mid-day. Accordingly, Hydro generation is responding to the price signals, and had shifted its operation from “Peak” to “Load – Solar – Wind”. The daily ending storage targets from longer duration storage scheduling will guide how to best utilize storage plants in the daily optimization. The charge and discharge prices optimize over 24 hours with given initial storage and ending storage targets.

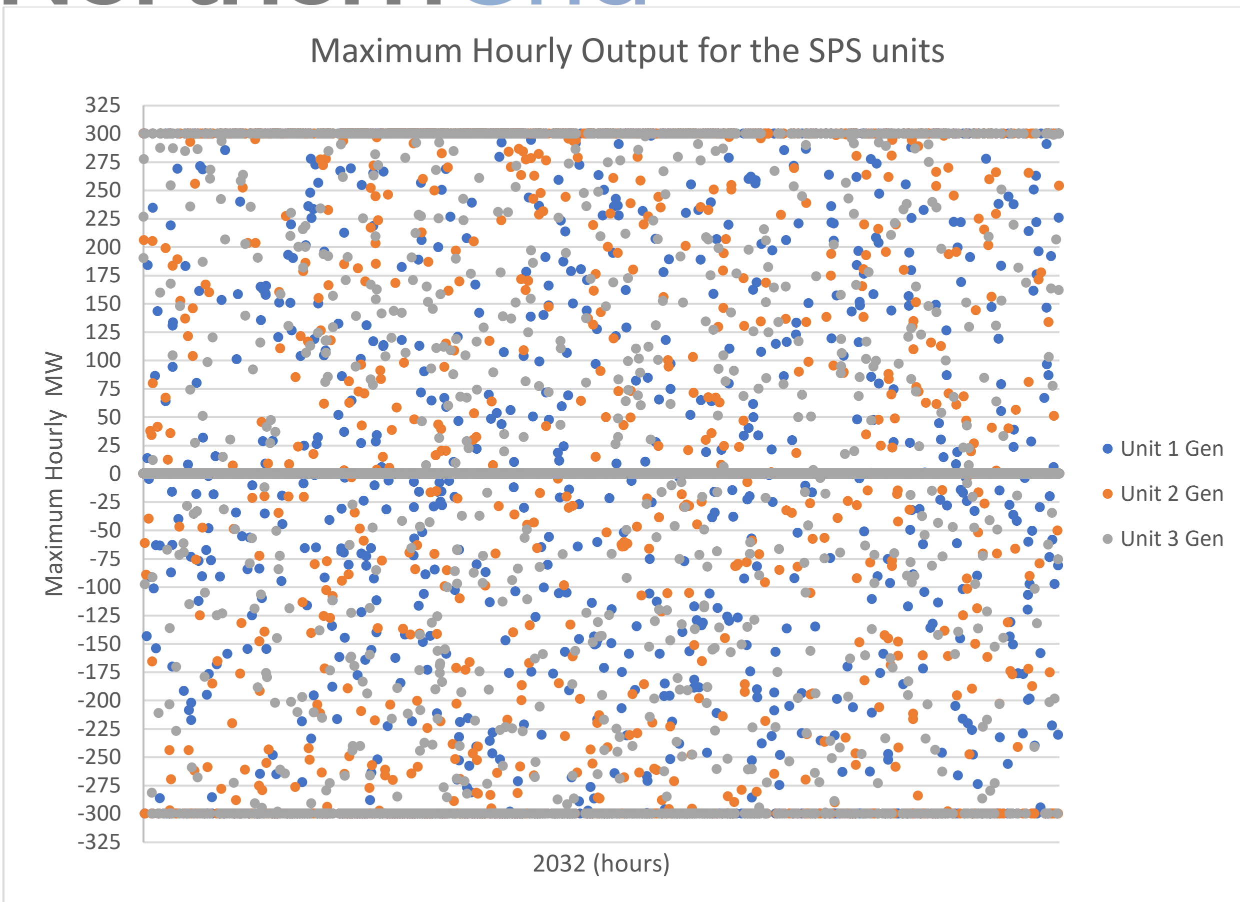

Figure 2: Maximum hourly output for the SPS units; negative values reflect pumping hours

Figure 2 shows the maximum hourly output for each of the individual 300 MW units. The units range from -300 MW (pumping mode) to +300 MW (generating mode). The ramp rate of the SPS units allow for very quick transitions between pumping and generating. The range indicates that the point of interconnection allows for maximum discharging and charging of the pumped storage units.

Analysis was conducted to ascertain if any of the units acted in conflict with one another. At no time did any one unit generate while either of the other two units pumped, and similarly, at no time did any one unit pump while either of the other two units generated.

Table 1: Number of Hours for three specific operating conditions

	P1	P2	P3
Number Hours at Full Output	1182	1078	954
Number Hours at Zero Output	5505	5857	6143
Number Hours at Full Load	1453	1300	1088

Table 1: Number of Hours for three specific operating conditions shows the number of hours at three operating points for each of the pumped storage units. There 8784 hours in 2032.

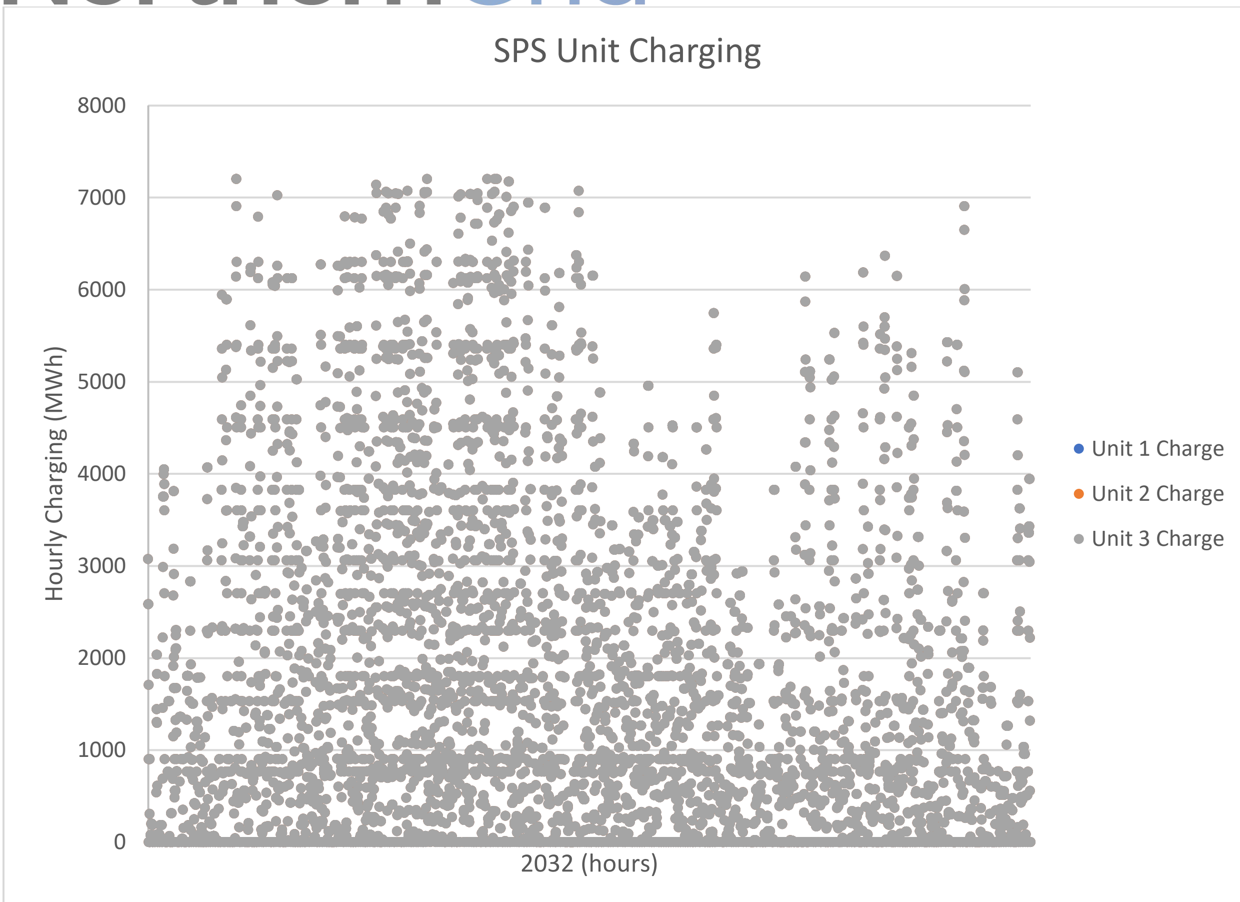

Figure 3: Hourly Charging for SPS Units

Figure 3 shows the hourly charging for the SPS units. The values are identical due to how GridView treats the collective pumped storage plant. For the SPS project, the three 300 MW pumped storage units were modeled with equal participation factors in the overall plant function. The storage component for each plant was one third of the overall plant. Each of the three units was able to experience full charging and did not reach any transmission system limitation.

This analysis explores if a regional impact of the installation of 900 MW at the 500 kV Aeolus substation can be observed by examining the real power flows and/or congestion of select Western Electric Coordinating Council (WECC) Paths.

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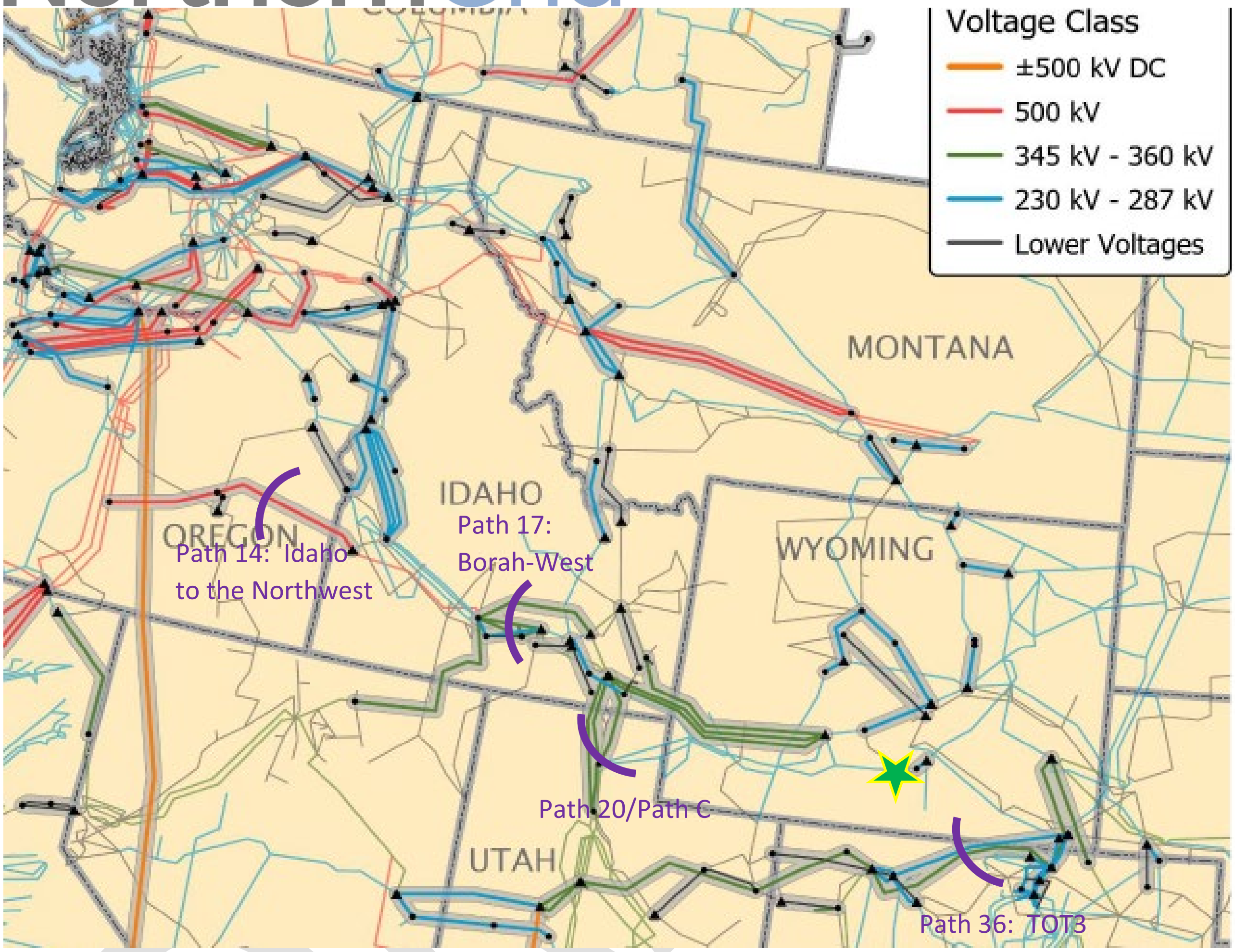

Figure 4: Select WECC Paths

Figure 4 shows the select WECC paths chosen for this report. In all Figures and Tables, the following acronyms are defined as:

ADS Anchor Data Set, the “pre” case

PSH Pumped Storage Hydro, specifically the Seminoe Pumped Storage project, the “post” case

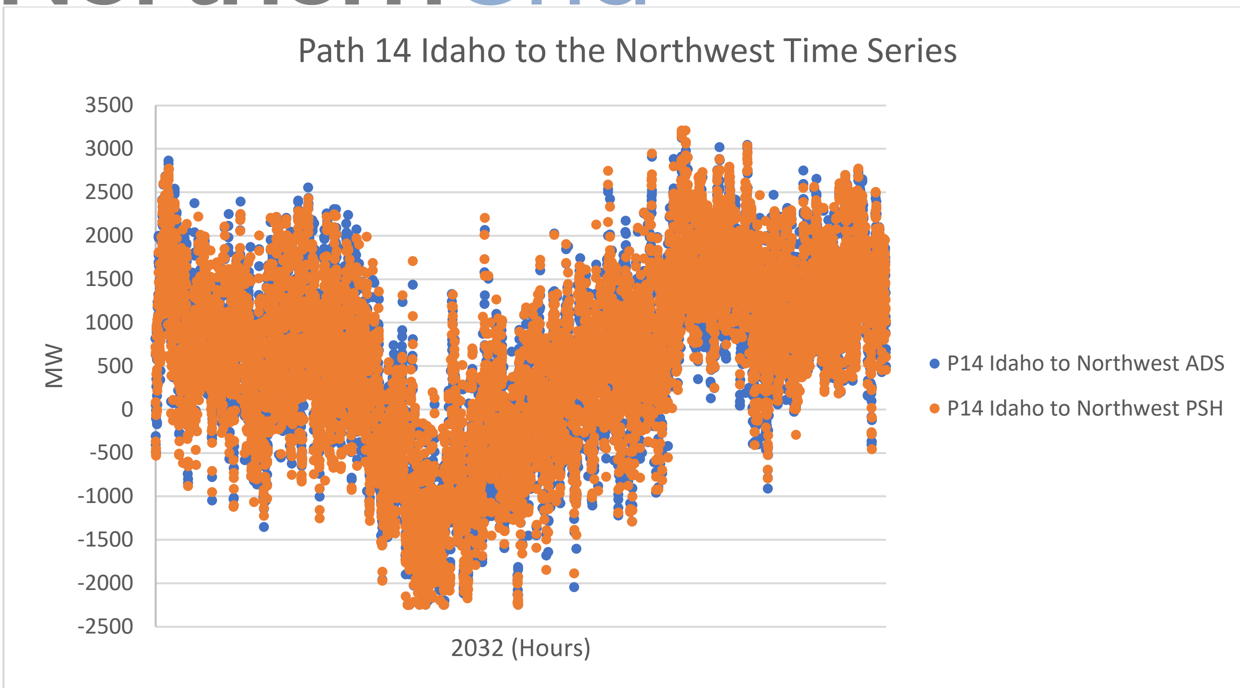

Figure 5: Path 14, Idaho to the Northwest, westbound prevailing

Figure 5: Path 14, Idaho to the Northwest, westbound prevailing demonstrates that the path behaves similarly with and without the pumped storage project, and further statical scrutiny revealed that the

average difference on the megawatts on Path 14 between the two different cases is 16 MW, which is negligible for the path.

There are times when the flows on the Path 14 reach either an upper or lower limit, resulting in congestion.

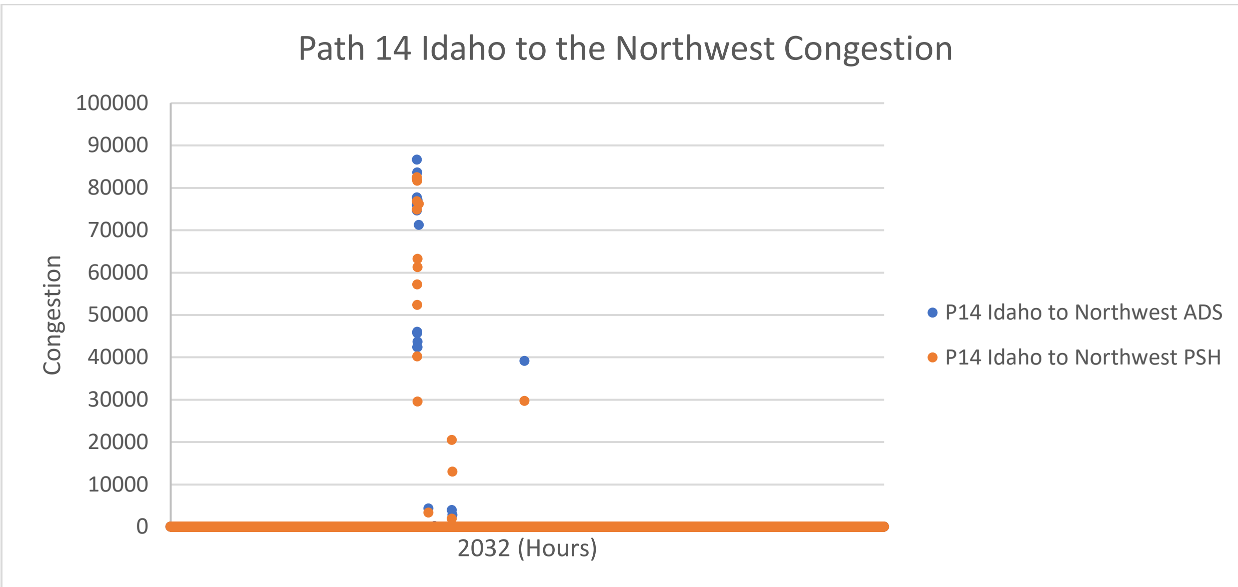

Figure 6: Path 14 Congestion

Figure 6: Path 14 Congestion confirms that the congestion on Path 14 occurs when the Path has hit its operating limits. The difference in congestion between the two cases was nearly zero, indicating that the pumped storage did not negatively contribute to the congestion on the path for this study.

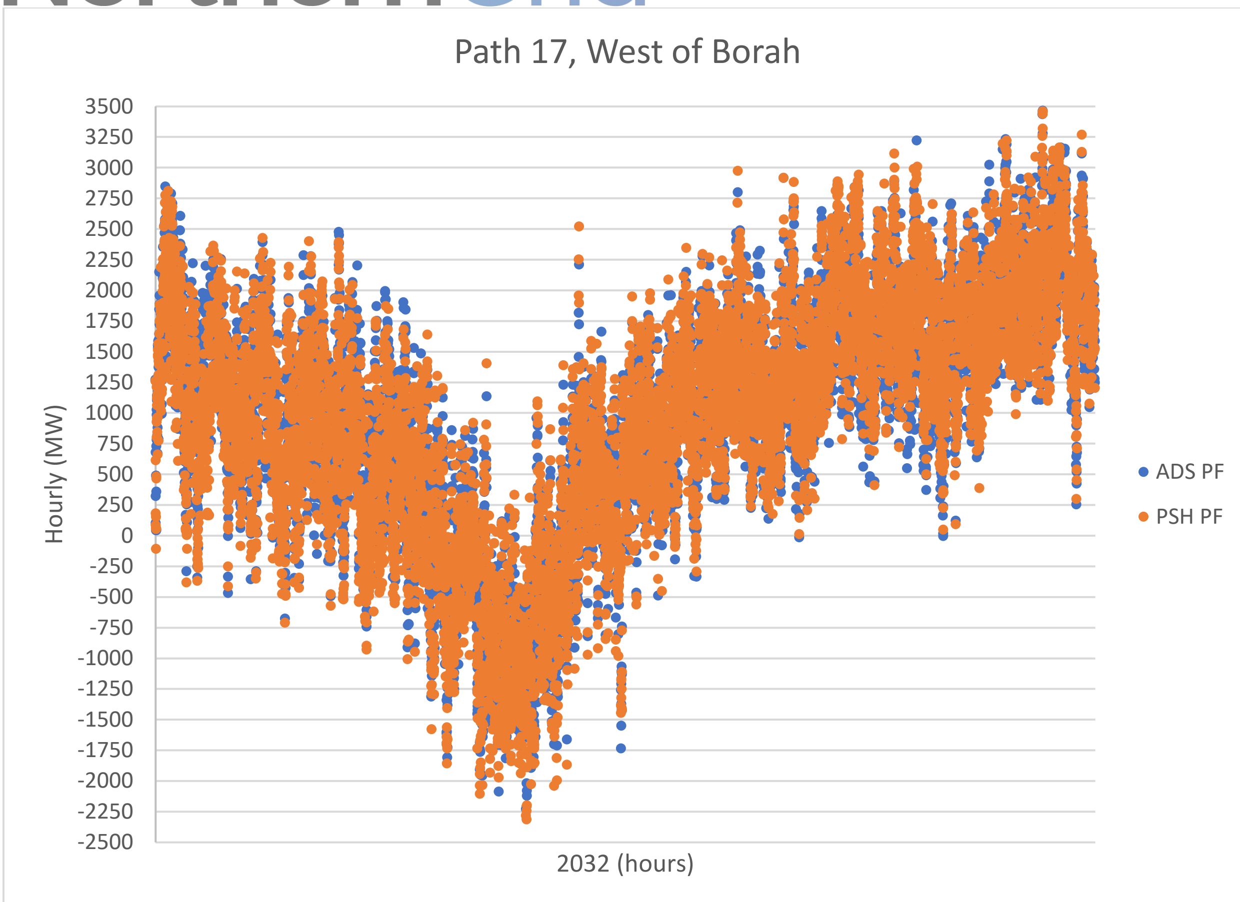

Figure 7: Path 17 (positive indicates westbound)

Figure 17 shows the time series for the West of Borah path. West of Borah is predominately an east to west path; negative values indicate west to east functioning of the path.

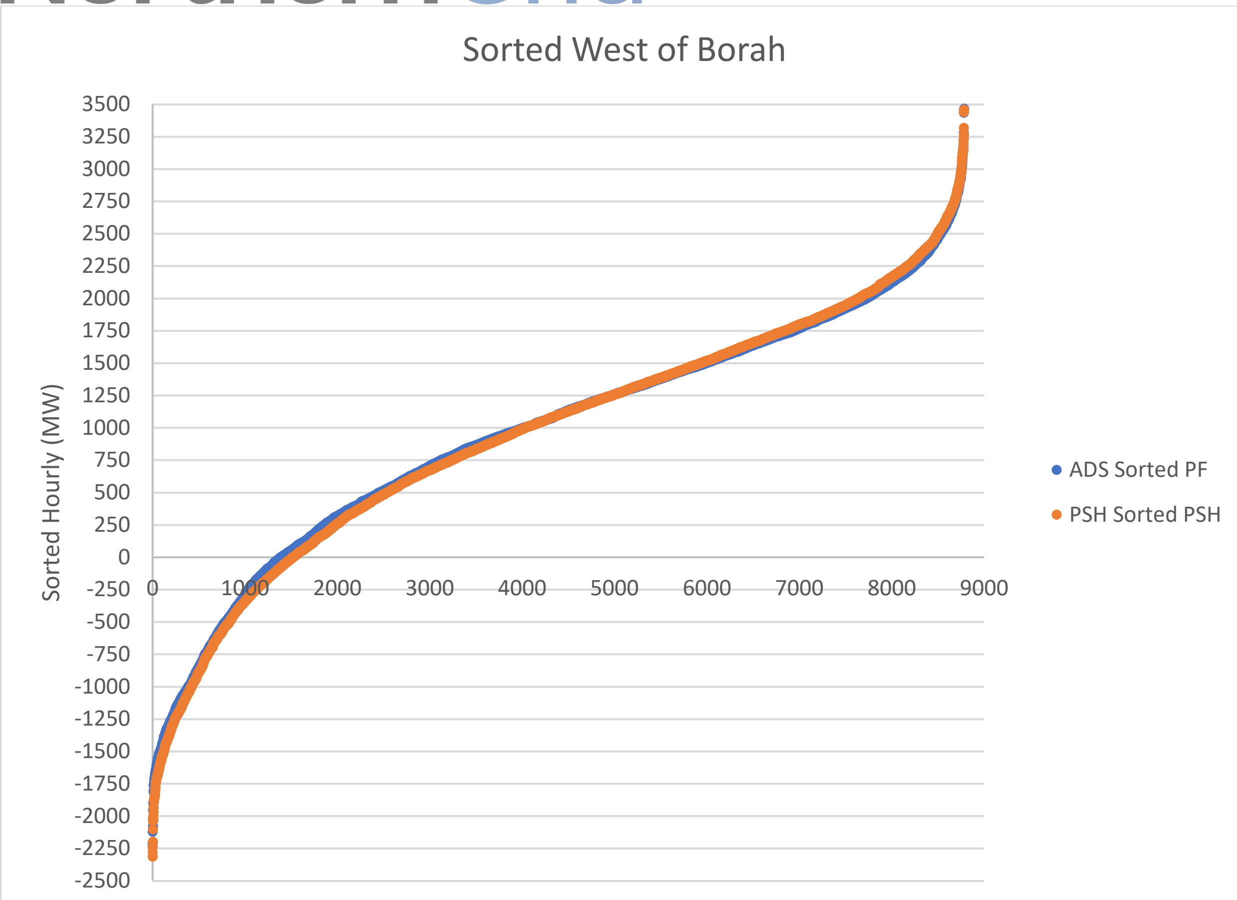

Figure 8: Sorted West of Borah

The sorted output for West of Borah presents as inconclusive results as the time series. Normally, a congestion plot would accompany the discussion, but in this instance, neither case resulted in any congestion on the West of Borah Path.

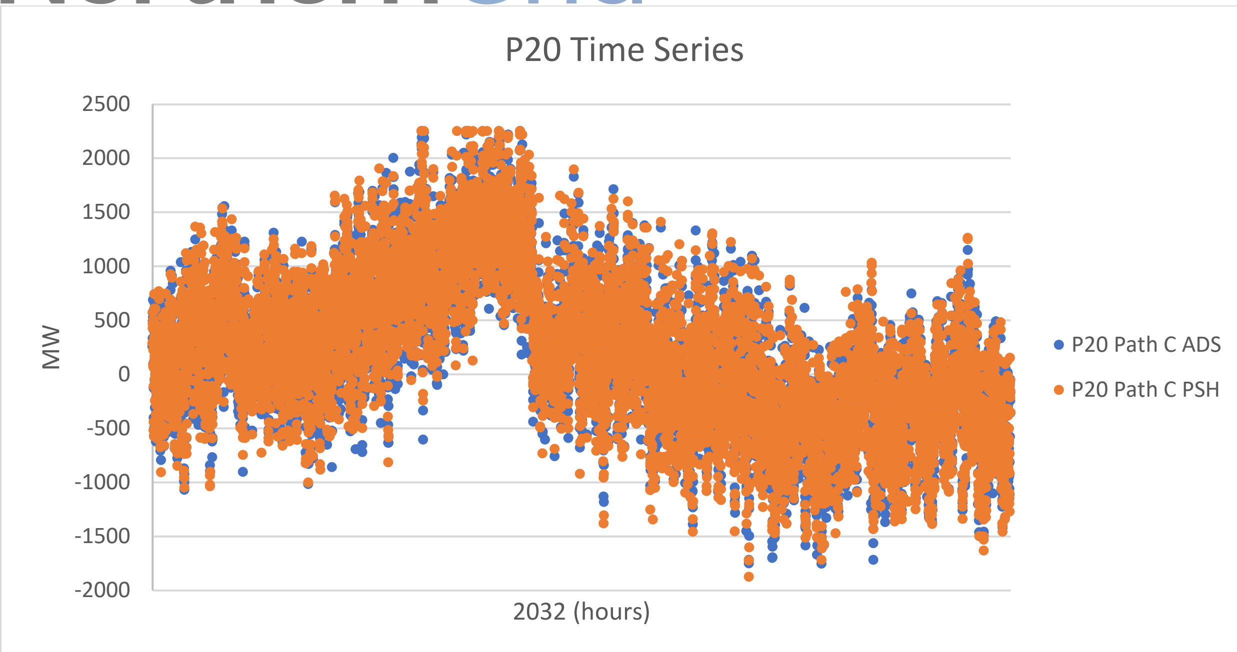

Figure 9: Path 20/Path C

Figure 9: Path 20/Path C shows the times series for the maximum hourly flows through Idaho to Utah, with positive southbound values. Congestion occurs for a handful of hours.

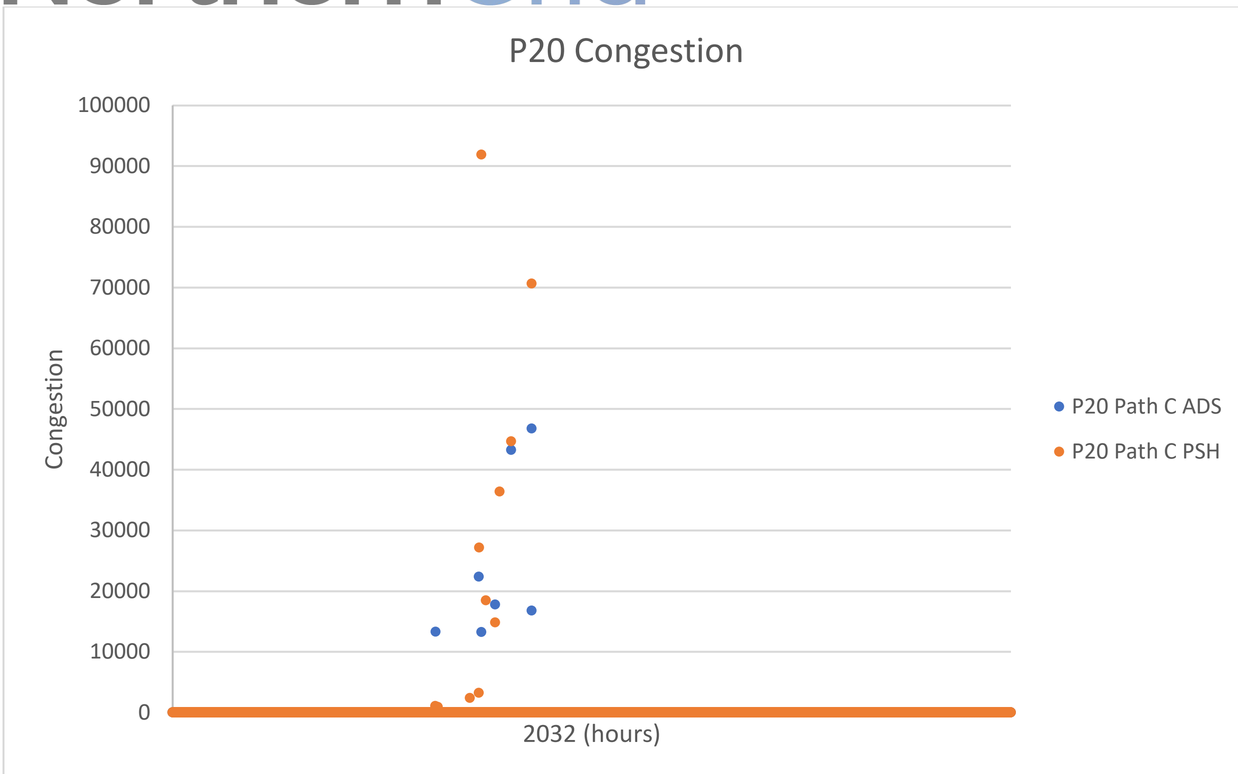

Figure 10: Path 20 Congestion

The non-zero congestion costs correspond with the times when Path 20 hit an operating maximum. There were no significant impacts to the expected operation of Path 20 due to the pumped storage project.

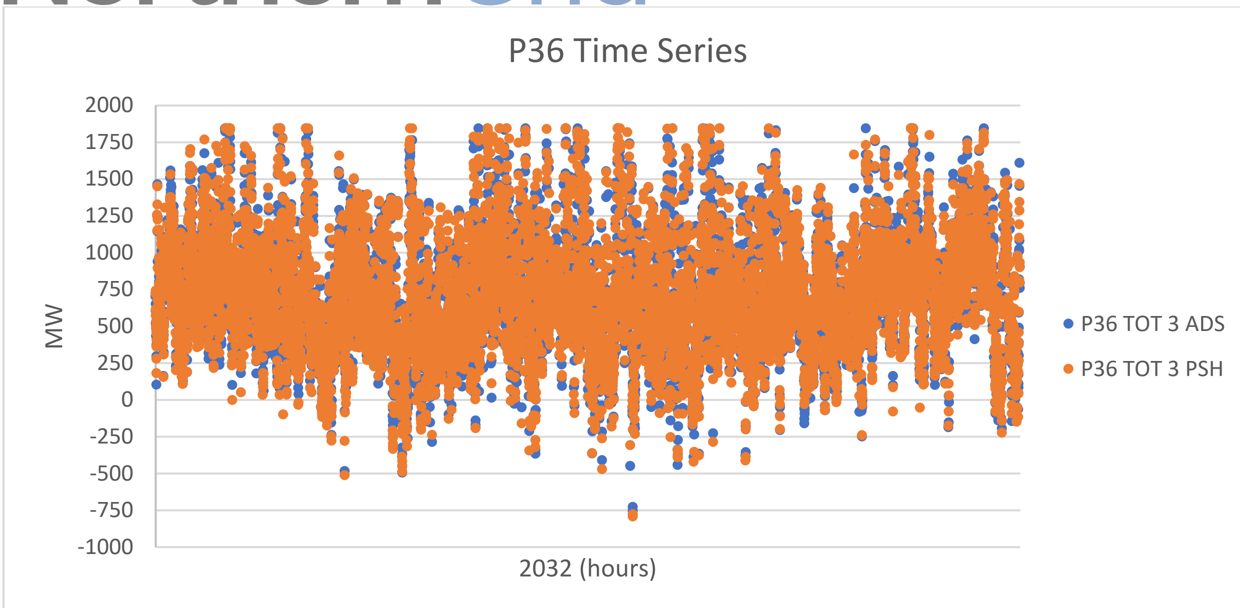

Figure 11: Path 36, Tot 3

Figure 11: Path 36, Tot 3 shows that the path behaves similarly for each of the cases and that each case results in congestion and that the pumped storage project did not significantly impact either the power flow or the congestion.

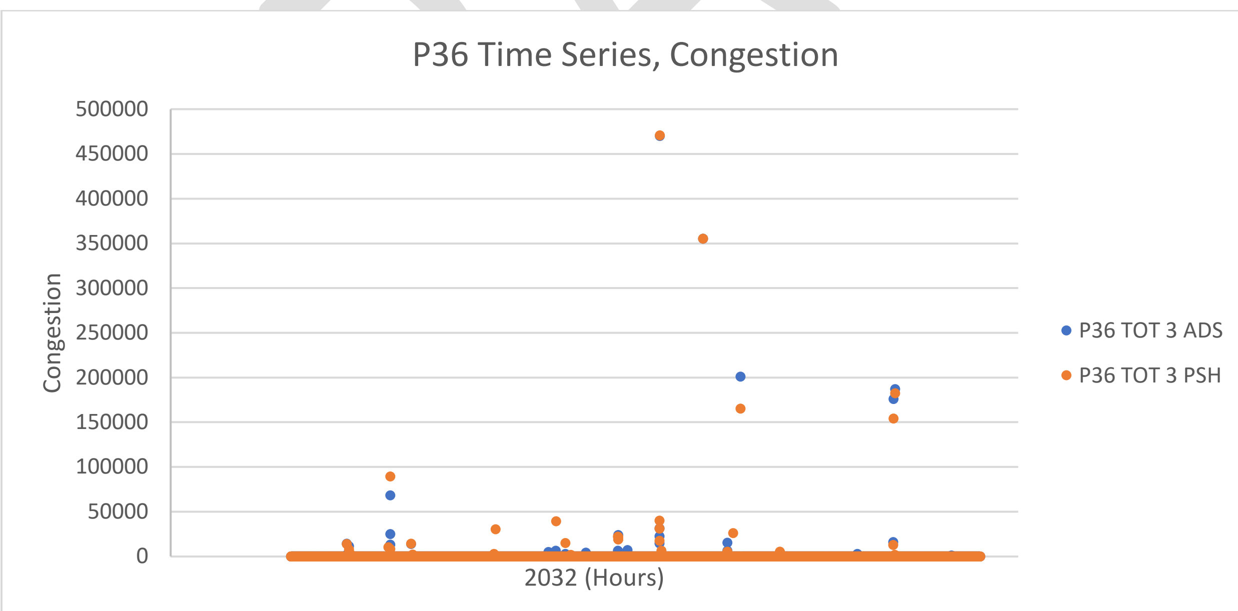

Figure 12: Path Idaho to the Northwest Congestion

Emissions

The following plots represent the overall regional change in emissions for either nitrogen oxides (NOx) or sulfur oxides (SOx) on a Regional level.

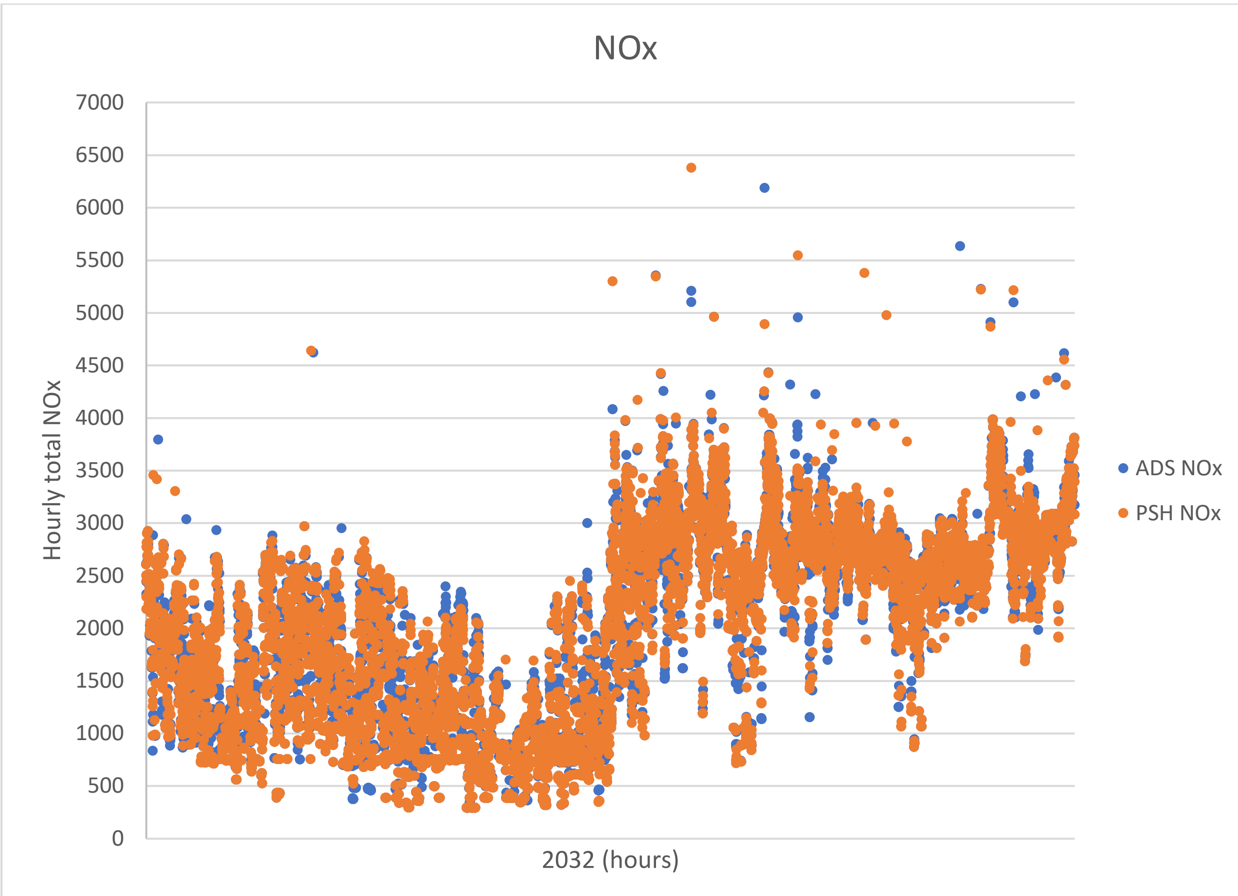

Figure 13: NOx

The time series for the regional NOx outputs does not clearly indicate the impact of the SPS project on a regional level.

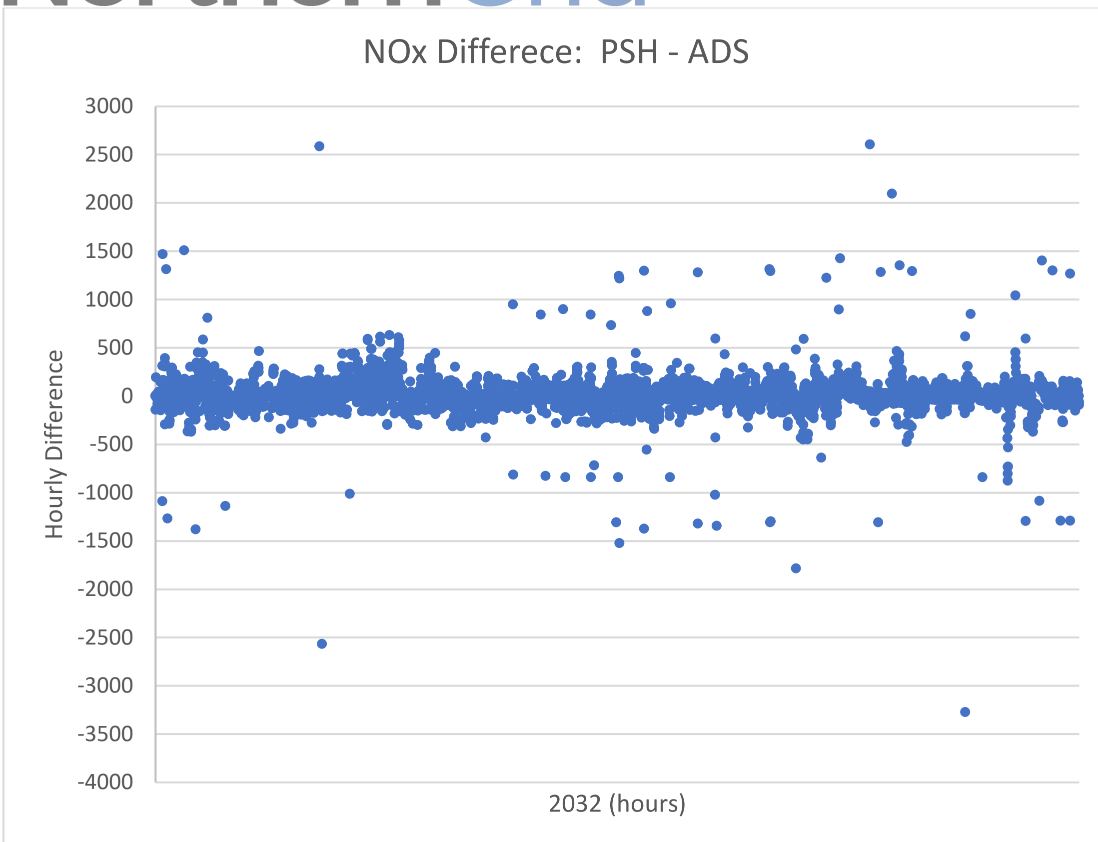

Figure 14; NOx Difference

Similarly, Figure 15 does not indicate if the overall NOx emissions were significantly different given the SPS project.

Table 2: NOx

	ADS	PSH	Diff: PSH - ADS
Mean	1,992	2,000	9
Standard Deviation	911	912	154
Range	5,895	6,085	5,878
Minimum	295	295	(3,274)
Maximum	6,191	6,380	2,604
Sum	17,494,985	17,570,939	75,953

On average, there were more NOx emissions in the case with the pumped storage project than without, however, the changes represent a negligible percentage of the overall NOx emissions.

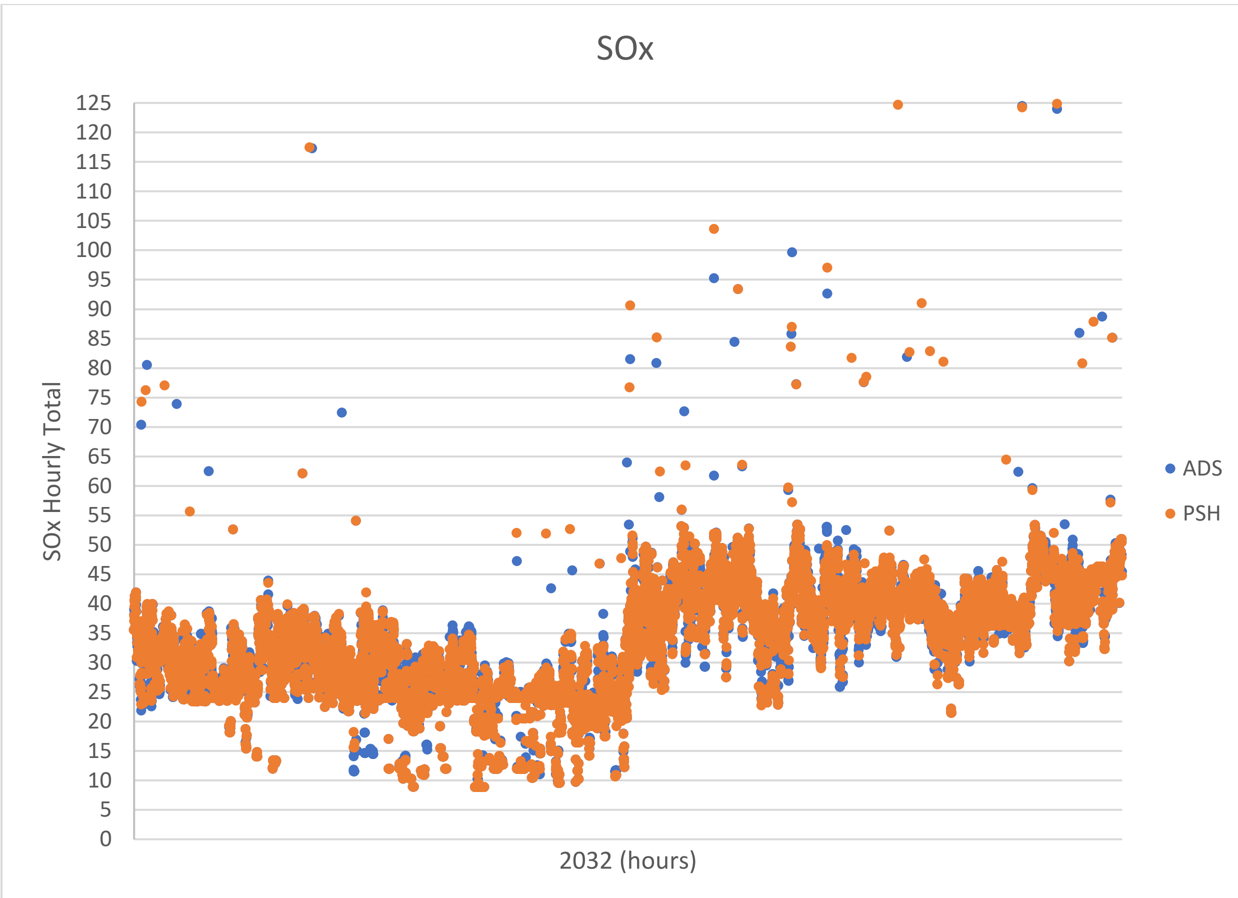

Figure 15: Sox

Similar to the NOx output, the impact of the pumped storage project on a regional level is not apparent.

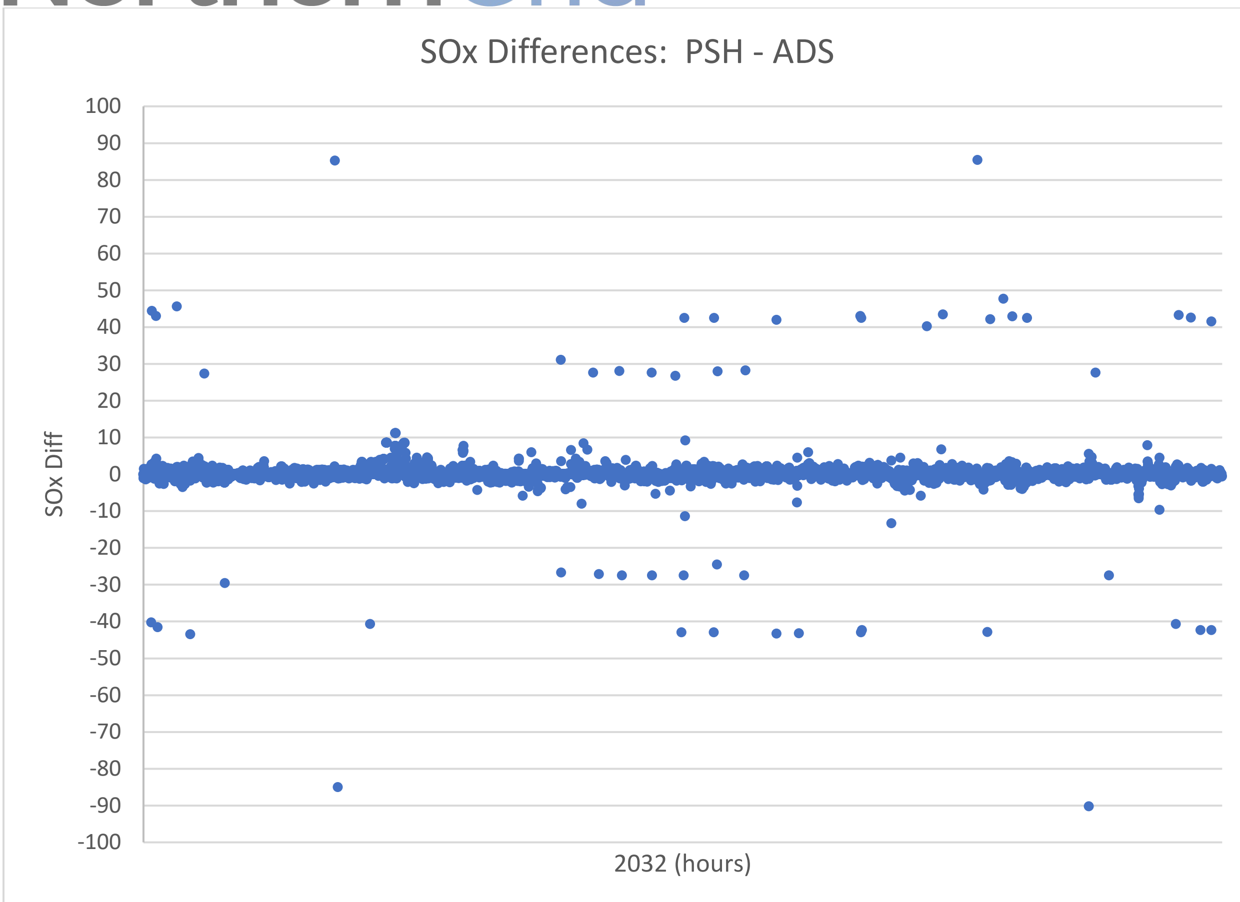

Figure 16: SOx Differences

The SOx differences are centered around 0, suggesting little to no change to SOx due to the pumped storage project.

Table 3: SOx Summary

	ADS	PSH	Diff: PSH - ADS
Mean	33	33	0
Standard Deviation	10	10	4
Range	119	117	176
Minimum	9	9	(90)
Maximum	128	126	85
Sum	**291,705**	**292,659**	**953**

On average, there was negligible difference between the SOx values in the two cases.

Regional Fuel Usage

Table 4: Regional Yearly output by Fuel Type (MWh)

Case	2032ADS	2032PSH	Diff: PSH-ADS
Coal	31,116,283	31,252,232	135,949
Combined Cycle	14,388,465	14,556,167	167,702
MWH	(509,700)	(494,499)	15,202
Electricity	(301,122)	(243,381)	57,742
NG	35,437,798	35,322,708	(115,090)
Solar	41,478,565	41,581,610	103,045
Water	127,682,075	127,781,042	98,966
Petroleum Coke	424,943	424,908	(36)

Table 9: Regional Yearly output by Fuel Type (MWh) shows the megawatt-hours for the entirety of the NorthernGrid region broken down by fuel type.

The following eight graphics show the summation of the daily output for the different fuel types, separated by fuel type. The fuel type for each comparison is indicated on the right-hand side of the graphic. The dark blue, “2032PSH” represents the output with SPS modeled for the NorthernGrid region.

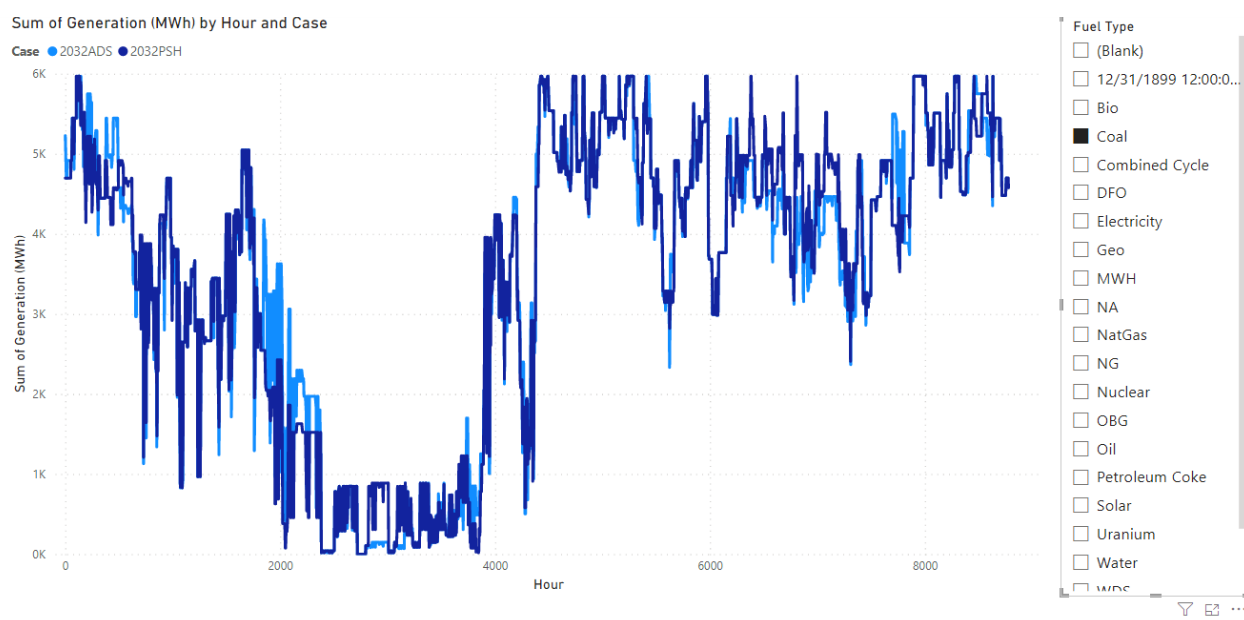

Figure 17: Coal, with and without SPS

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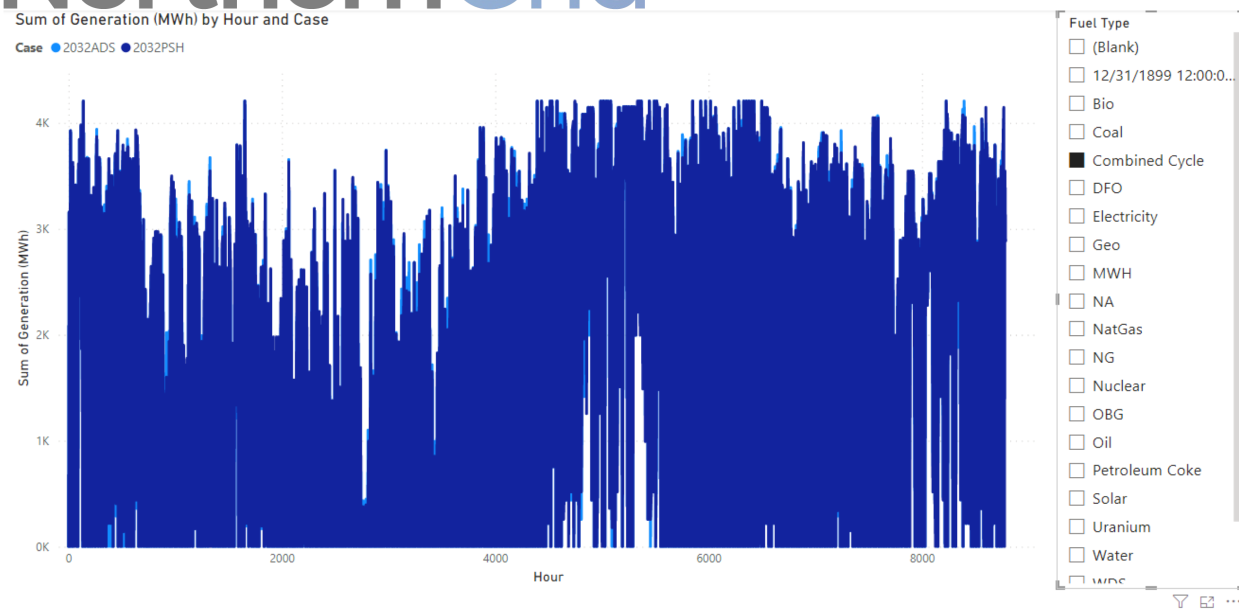

Figure 18: Combined Cycle, with and without SPS

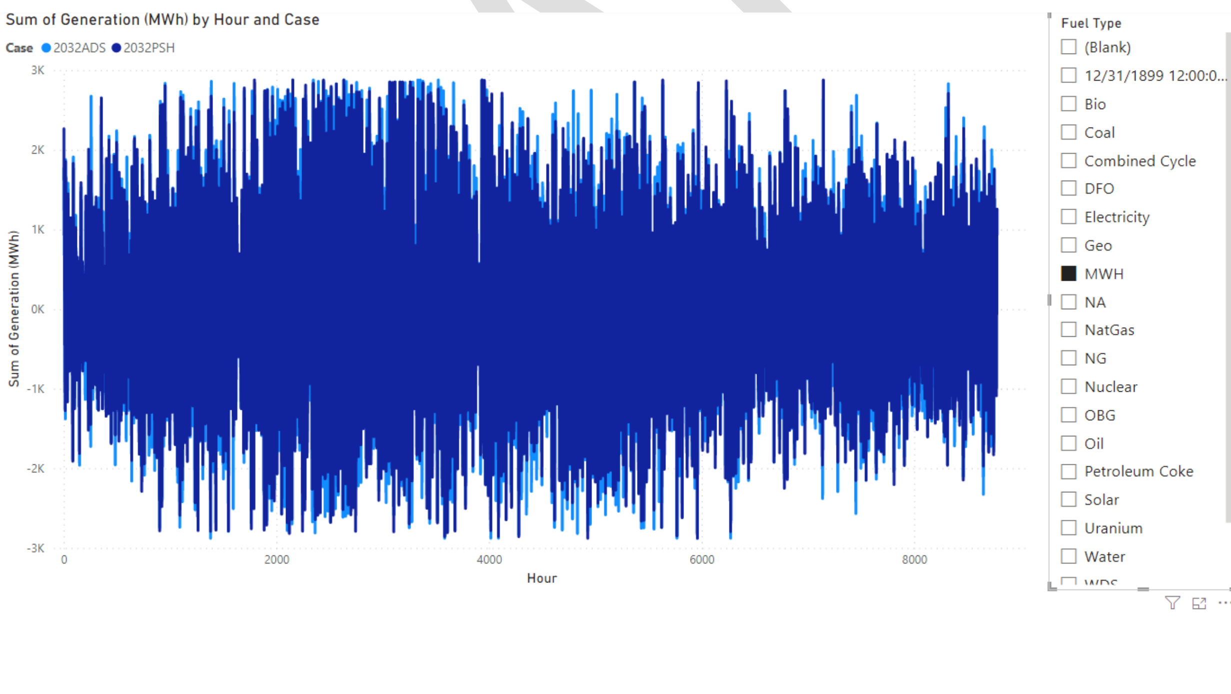

Figure 19: MWH with and without SPS

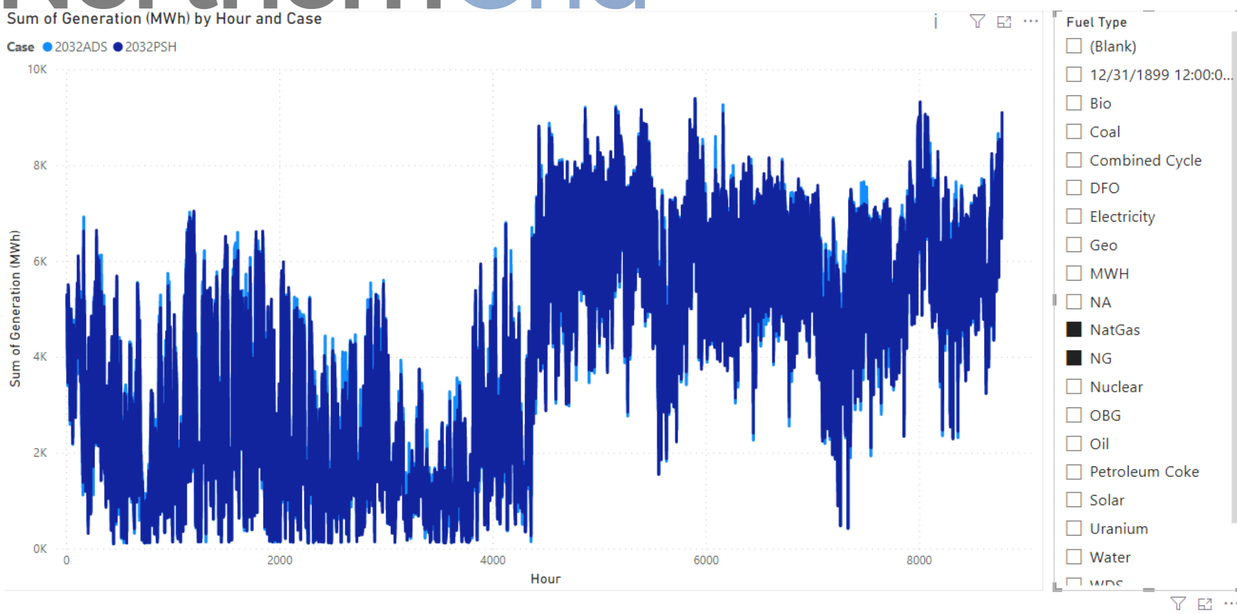

Figure 20: Natural Gas with and without SPS

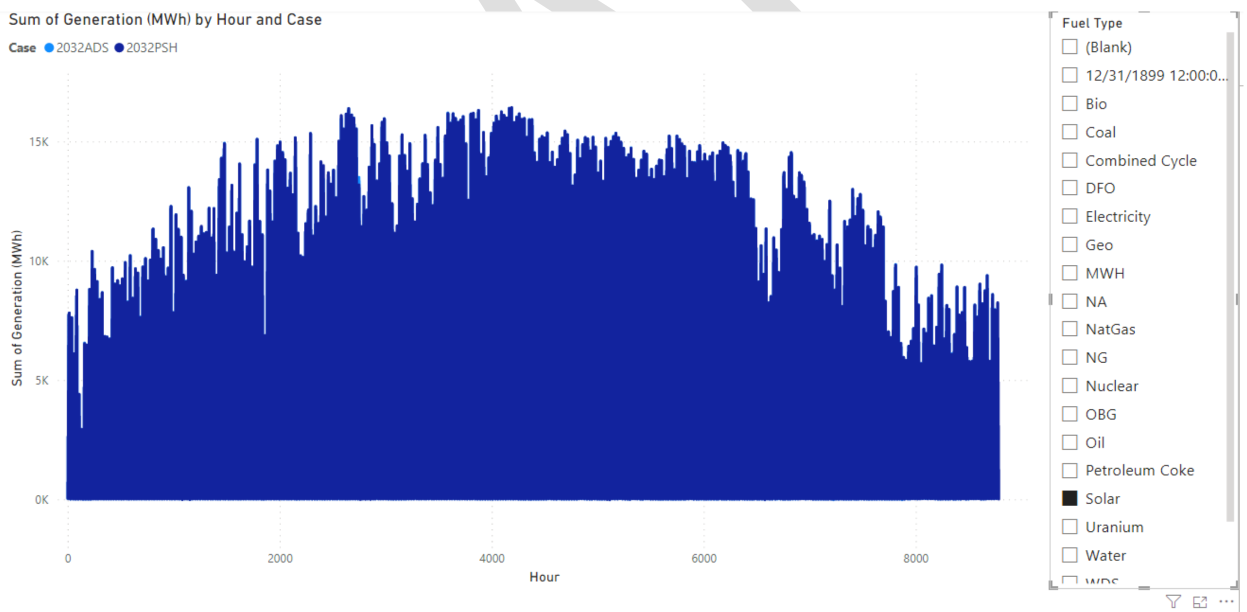

Figure 21: Solar with and without SPS

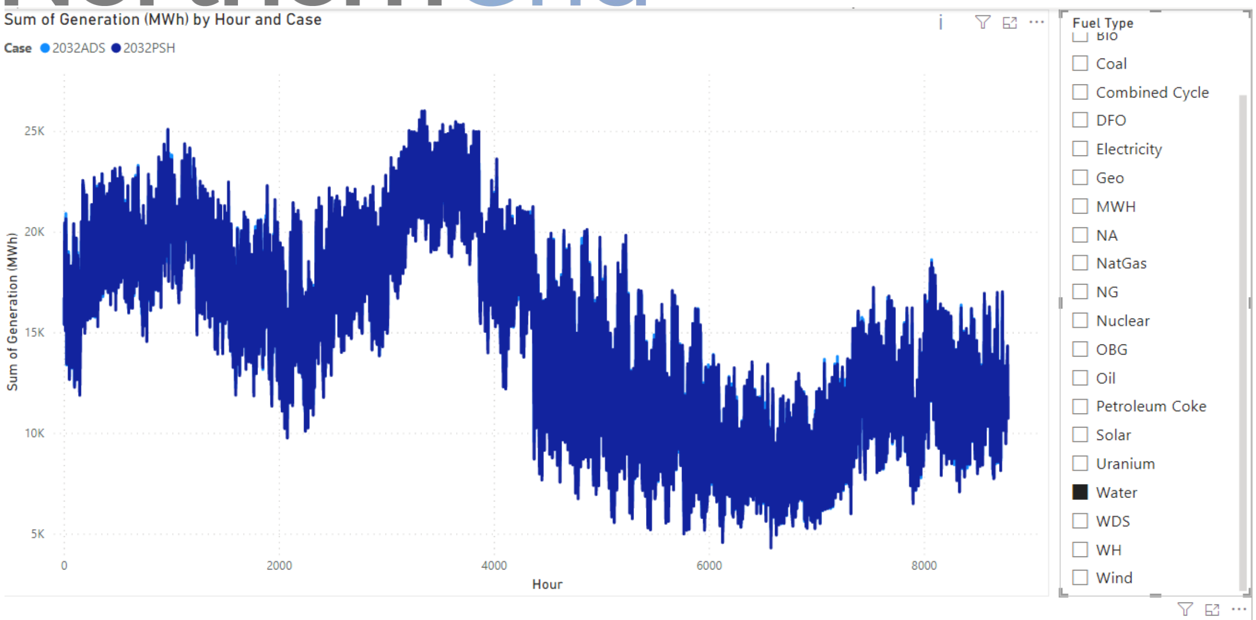

Figure 22: Water with and without SPS

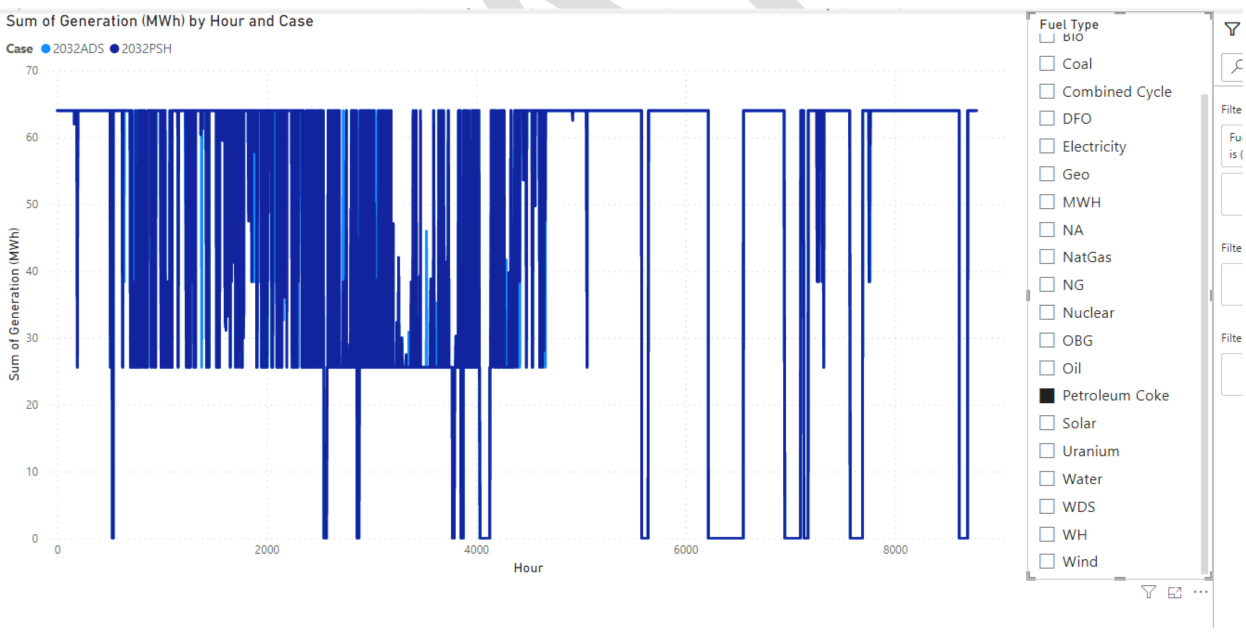

Figure 23: Petroleum Coke with and without SPS

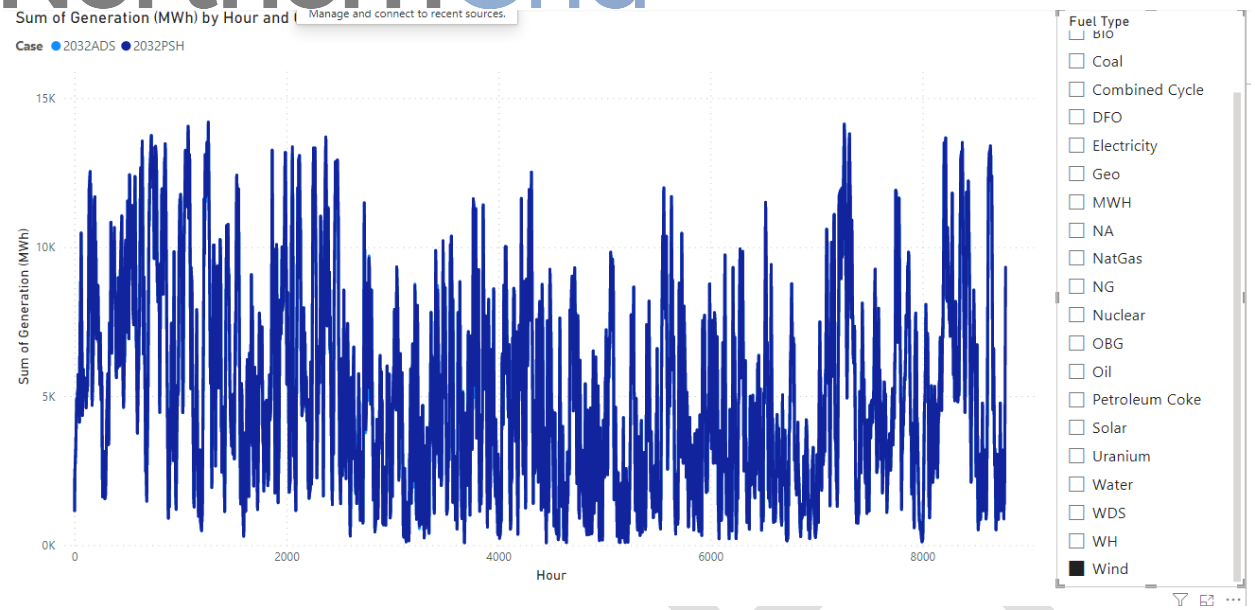

Figure 24: Wind with and without SPS

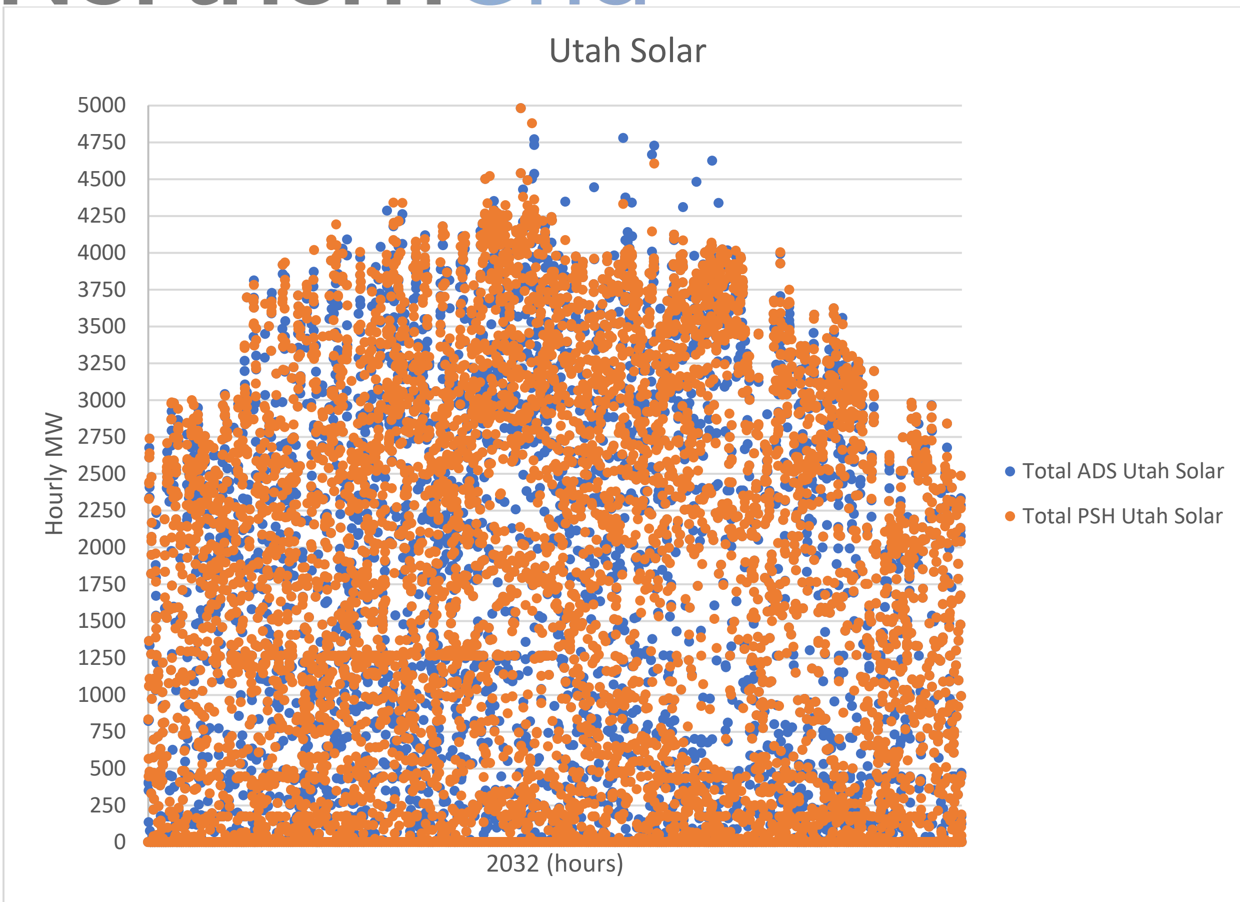

Figure 25: Utah Solar

While the time series output of the solar plants in Utah suggests that there is more solar output in the warmer months, it is largely silent on the impact of the pumped storage project.

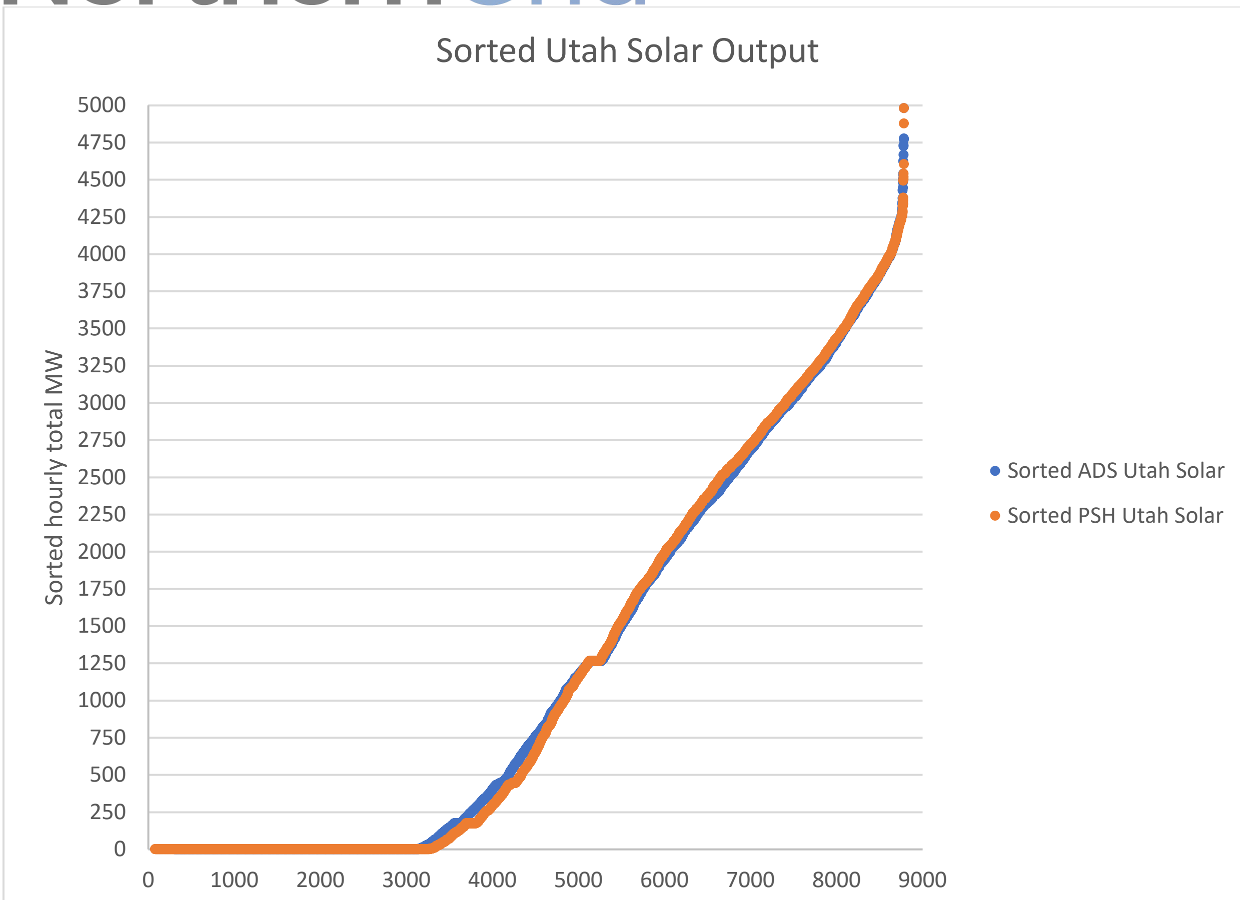

Figure 26: Sorted Utah Solar

The sorted hourly output from the Utah solar facilities does not provide any further clarity on the impact of the pumped storage projects. On average, the pumped storage project does allow for more output from the solar facilities, but at a negligible amount.

Table 5: Utah Solar Monthly total output and revenue

	Total Output (MWh)		Total Revenue (k$)	
	With	Without	With	Without
January	525,915	525,915	$ 11,846,770	$ 11,595,031
February	652,167	652,167	$ 10,044,873	$ 9,466,161
March	889,491	889,491	$ 14,408,752	$ 12,192,216
April	1,043,686	1,041,783	$ 7,322,355	$ 5,408,155
May	1,179,480	1,175,437	$ 10,506,315	$ 8,698,448
June	1,388,759	1,388,904	$ 24,241,686	$ 23,398,989
July	1,092,820	1,092,820	$ 34,612,736	$ 34,602,141
August	1,119,121	1,119,121	$ 32,668,519	$ 32,385,020
September	1,022,816	1,022,816	$ 27,002,722	$ 26,756,175
October	744,137	744,137	$ 17,482,289	$ 17,615,303
November	616,628	616,628	$ 14,247,470	$ 14,086,886
December	461,186	461,186	$ 13,303,137	$ 13,281,148
Grand Total	10,736,205	10,730,405	$ 217,687,624	$ 209,485,675

Table 5 depicts the changes to the monthly total generation and revenue for the Utah solar units. Overall, there is an increase in the revenue from the solar generators in Utah. The

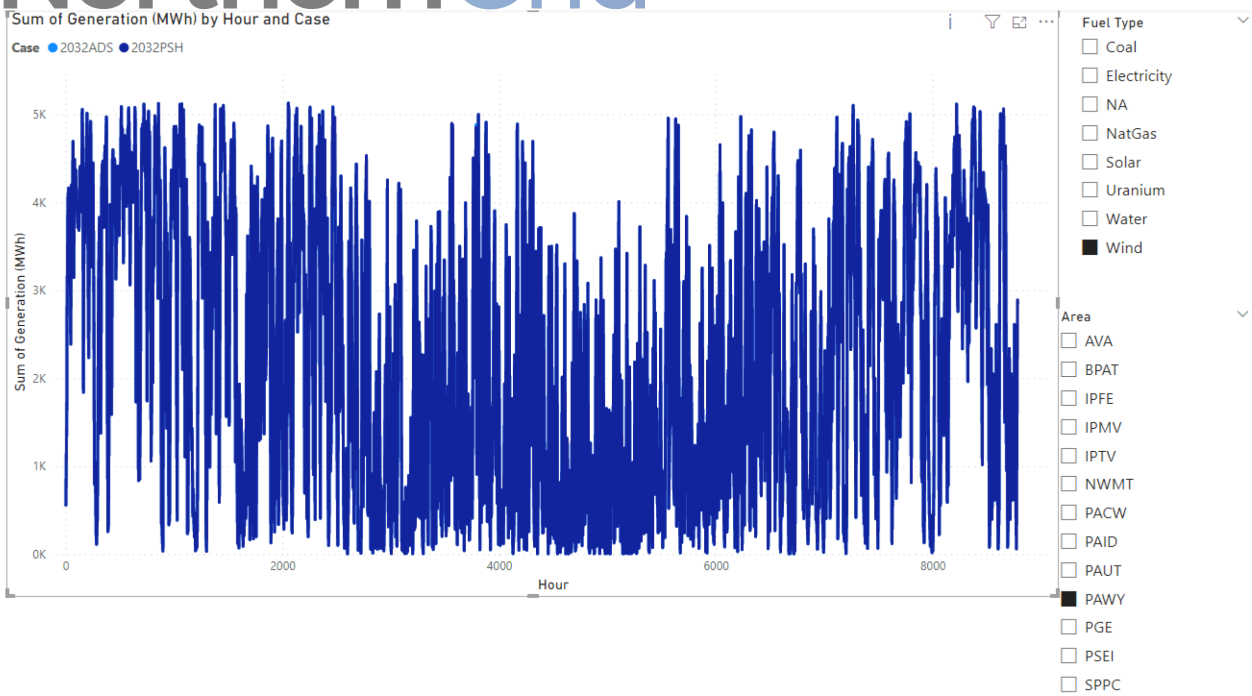

Figure 27: Daily total wind output for the Wyoming area, with and without SPS

Similar to the Utah Solar, the wind output in Wyoming is largely silent on the impact from the SPS.

Table 6 shows the total monthly generation and revenue for the Wyoming wind units; overall there is an increase in Wyoming wind revenue and output.

Table 6: Wyoming Wind Monthly output and Revenue

	Total Monthly Output (MWh)		Total Monthly Revenue (k$)	
	With	Without	With	Without
January	2,701,756	2,701,756	$ 58,068,533	$ 57,272,248
February	2,122,593	2,122,593	$ 34,629,017	$ 34,068,342
March	1,918,044	1,917,853	$ 35,194,369	$ 32,754,978
April	1,553,165	1,542,054	$ 16,948,328	$ 16,600,790
May	946,006	944,366	$ 11,233,491	$ 11,049,882
June	1,173,238	1,169,192	$ 20,170,796	$ 19,857,772
July	686,447	686,447	$ 21,066,887	$ 21,041,986
August	881,075	881,075	$ 24,547,962	$ 24,360,697
September	1,259,824	1,259,824	$ 32,559,937	$ 32,450,377
October	1,476,563	1,476,563	$ 33,421,907	$ 33,844,860
November	1,811,421	1,811,421	$ 41,322,428	$ 40,974,913
December	2,083,199	2,083,199	$ 55,208,287	$ 55,320,235
Total	18,613,332	18,596,345	$ 384,371,941	$ 379,597,080

Table 7: Total Yearly Generation, Cost of Generation, and Revenue

	Total Gen (MWh)		Total Cost (k$)		Total Revenue (k$)	
	Without	With	Without	With	Without	With
Avista	12,258,721	12,259,012	$ 184,205	$ 182,910	$ 322,072	$ 323,509
Bonneville	117,002,091	117,088,491	$ 330,526	$ 332,702	$ 3,129,140	$ 3,150,729
Chelan	5,338,174	5,338,174	$ -	$ -	$ 125,004	$ 125,905
Idaho	19,080,200	19,099,404	172,465	170,234	520,750	522,671
NV Energy	30,041,363	29,908,283	$ 583,975	$ 579,406	$ 822,715	$ 824,636
NorthWestern	12,333,362	12,391,711	$ 94,858	$ 95,503	$ 300,581	$ 303,450
PacifiCorp-West	22,776,941	22,885,361	$ 388,805	$ 392,530	$ 678,035	$ 684,201
PacifiCorp-Idaho	9,133,359	9,161,957	$ 83,781	$ 84,634	$ 229,422	$ 233,738
PacifiCorp-Utah	36,281,010	35,855,018	$ 578,352	$ 569,741	$ 971,190	$ 976,467
PacifiCorp-Wyoming	25,333,136	25,370,124	$ 133,041	$ 133,861	$ 559,298	$ 567,094
Portland General	15,957,687	15,979,971	$ 278,085	$ 277,851	$ 443,929	$ 446,055
Puget Sound	18,323,565	18,348,161	$ 310,989	$ 311,050	$ 528,046	$ 530,090
Seattle	6,448,427	6,448,427	$ -	$ -	$ 130,150	$ 131,224
Tacoma	2,924,496	2,924,496	$ -	$ -	$ 76,968	$ 77,403
Total	333,232,533	333,058,589	$ 3,139,081	$ 3,130,423	$ 8,837,299	$ 8,897,174

Table 7 depicts the total generation, cost, or revenue for each area described for the total year. Altogether, for the region that is being addressed, the total generation decreased, the total cost decreased, and the total revenue increased.

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Conclusion

The results of this analysis suggest that the regional impact of the addition of 900 MW of pumped storage at the 500 kV Aeolus bus on the NorthernGrid system with more than 50,000 MW of load may be minimal, given the assumptions of the study and the modeled operation of the SPS project. The SPS project did not significantly increase or reduce congestion on the future Gateway system. The SPS project did not significantly impact the Wyoming wind output or Utah solar. System inertia is not addressed in a production cost modeling output.