



NorthernGrid

1 Economic Study Request

2 Pumped Storage Hydro in Wyoming

3 Request

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

6 “Seminoe Pumped Storage Transmission and Economic Benefits Study 900MW x 10 hours pumped
7 hydro energy storage facility, interconnecting at 500kV at Aeolus Substation, Carbon Co. Wyoming.
8 Projected placed in service date of June 2029. The project would significantly enhance capacity of
9 Gateway transmission to deliver additional highquality wind energy from WY to UT the PNW. The
10 project can also reduce future congestion on the Gateway System, including at Aeolus, Clover/Mona
11 while accommodating wind expansion in WY; provide shaping and firming of WY wind to meet capacity
12 needs; provide shaping and firming of UT solar via the Clover/Mona area to meet capacity needs;
13 provide system inertia that replaces lost inertia from coal retirements in WY and UT. The project has a
14 wide range in generation and pumping, up to 900MW, dispatchable. The project will have 3 units of
15 300MW ea., variable speed generators that can provide maximum value and flexibility to the operations
16 of the transmission system and integration of intermittent renewable energy generation. The ramp rate
17 is up to 30MW /sec, 0 to full output in 30-60 seconds. The project can generate at full capacity, 900MW
18 for 10 hours, and in pumping mode at 900MW for 13 hours. Additional technical information will be
19 made available as needed.”

20 .

21 [Study Plan for Economic Study Request: Pumped Storage at Aeolus Request](#)

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

- 24 1. 900 MW dispatchable pumping capability, 13-hour duration
- 25 2. 900 MW dispatchable generating capability, 10-hour duration
- 26 3. Proposed interconnection at the 500 kV Aeolus substation
- 27 4. Planned in-service date of June, 2029

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



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1 Study Scope

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

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7 Analysis

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

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

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

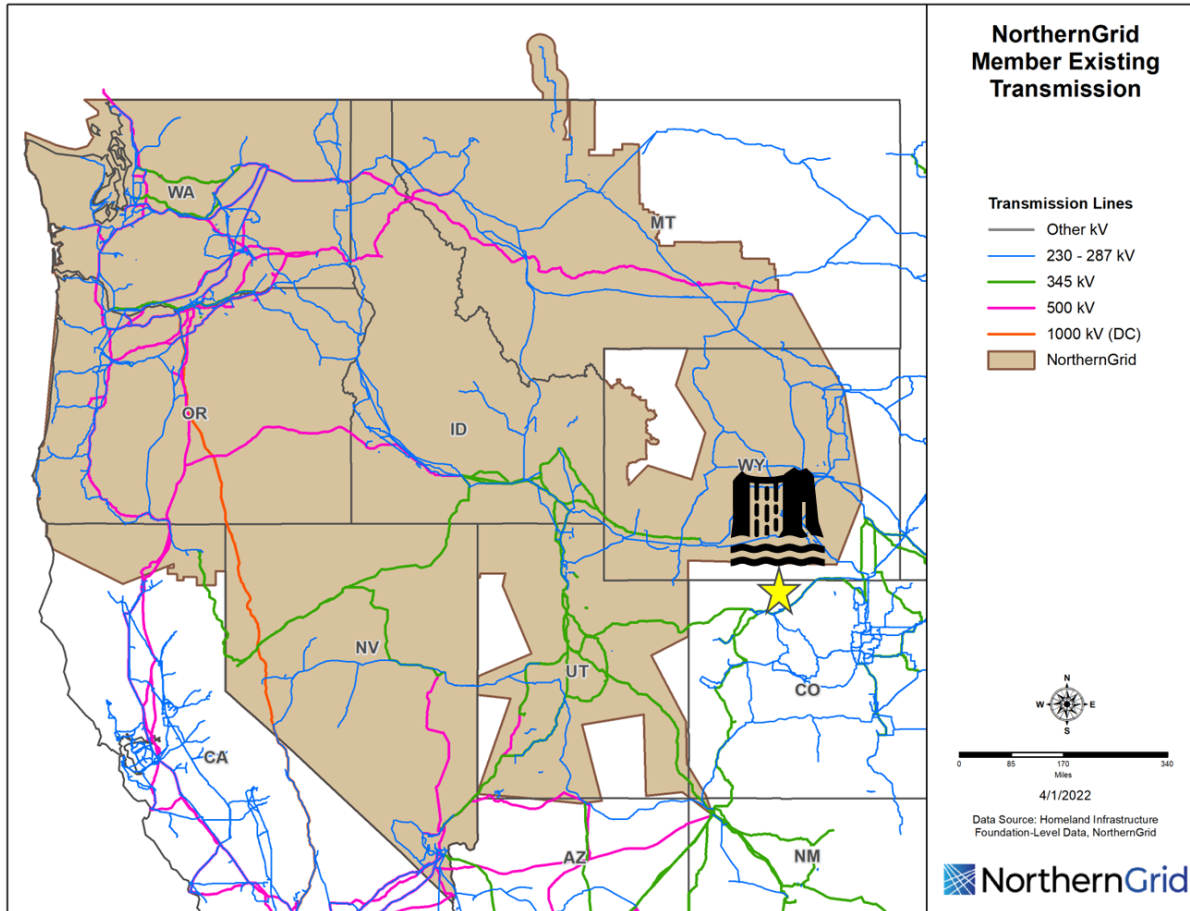
23 Report

24 A report of the Economic Study Request, methodology, and findings will be complete by March 31,
25 2023, or other date agreed upon between the Parties. This economic study report will be a stand-
26 alone report that will be included as an appendix to the Regional Transmission Plan. This report in
27 no way constitutes an analysis for generation interconnection, load service, or transmission service;
28 its findings may inform the regional transmission planning process.



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1 Analysis



2
3 *Figure 1: Representation of the SPS project*

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

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1 Results

2 The following set of plots represent the observed impact to the transmission system given the assumed
3 installation of 900 MW of pumped storage generation at the 500 kV Aeolus substation and with no
4 additional transmission system upgrades. Hitachi GridView Version 10.3.44 was used to analyze the
5 2032 ADS, with and without the SPS and for the case with the SPS, the pumped storage simulation
6 option used was that of, "Daily Scheduling on Price". While GridView dispatches the system on an
7 hourly basis given the fuel costs and transmission constraints of the transmission system, the results of
8 GridView analyses should in no way be construed as operational instruction.

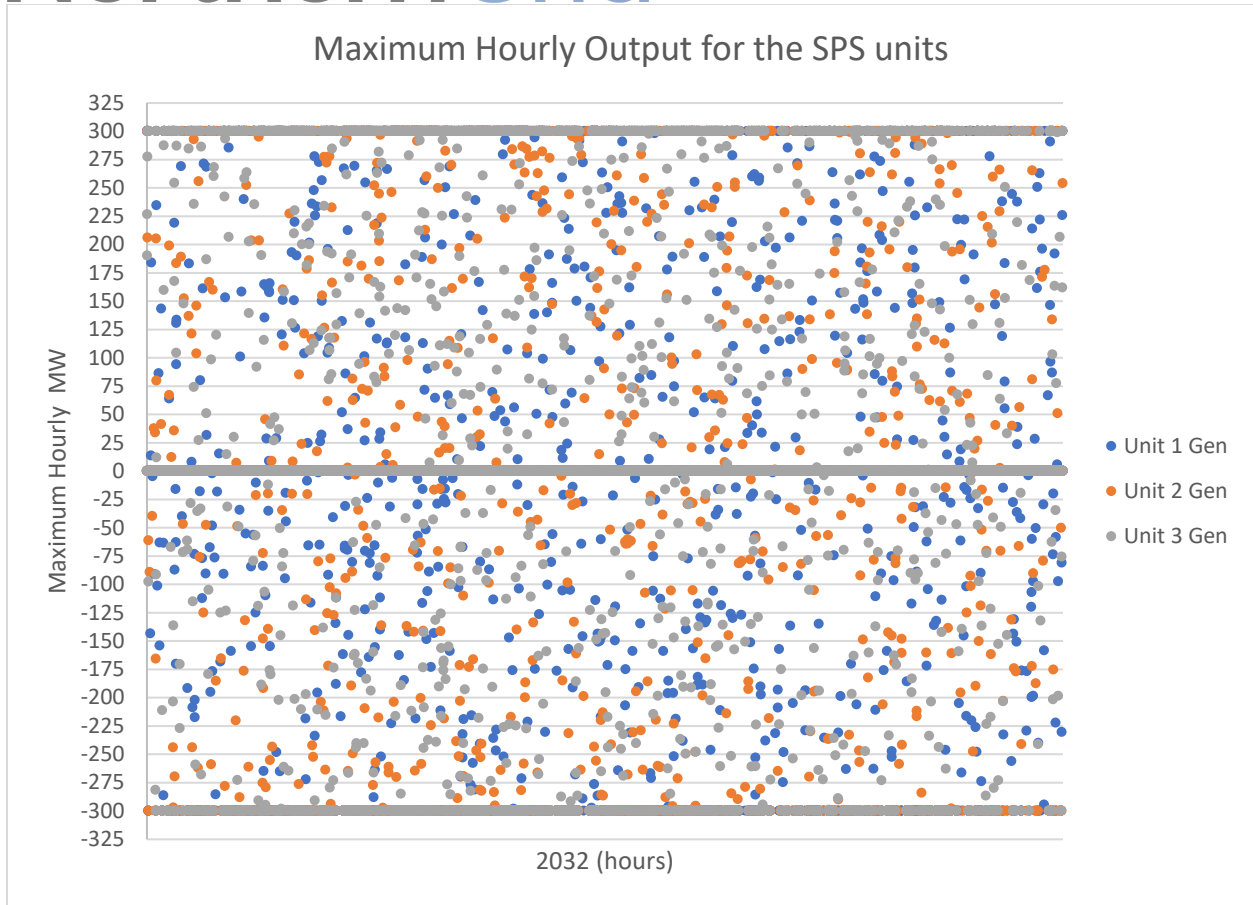
9 Using the "Daily Scheduling on Price" option, GridView models pumped storage in the following fashion:
10 first, GridView dispatches the system without the pumped storage project. GridView then determines
11 how the pumped storage projects should operate based on the system conditions/state of the pumped
12 storage devices/availability of the pumped storage to pump or charge and then re-dispatches the
13 system, including the pumped storage projects. GridView staff were consulted throughout the modeling
14 process to ensure the SPS was modeled correctly given the "Daily Scheduling on Price" option.

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

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

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

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1 *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

2

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

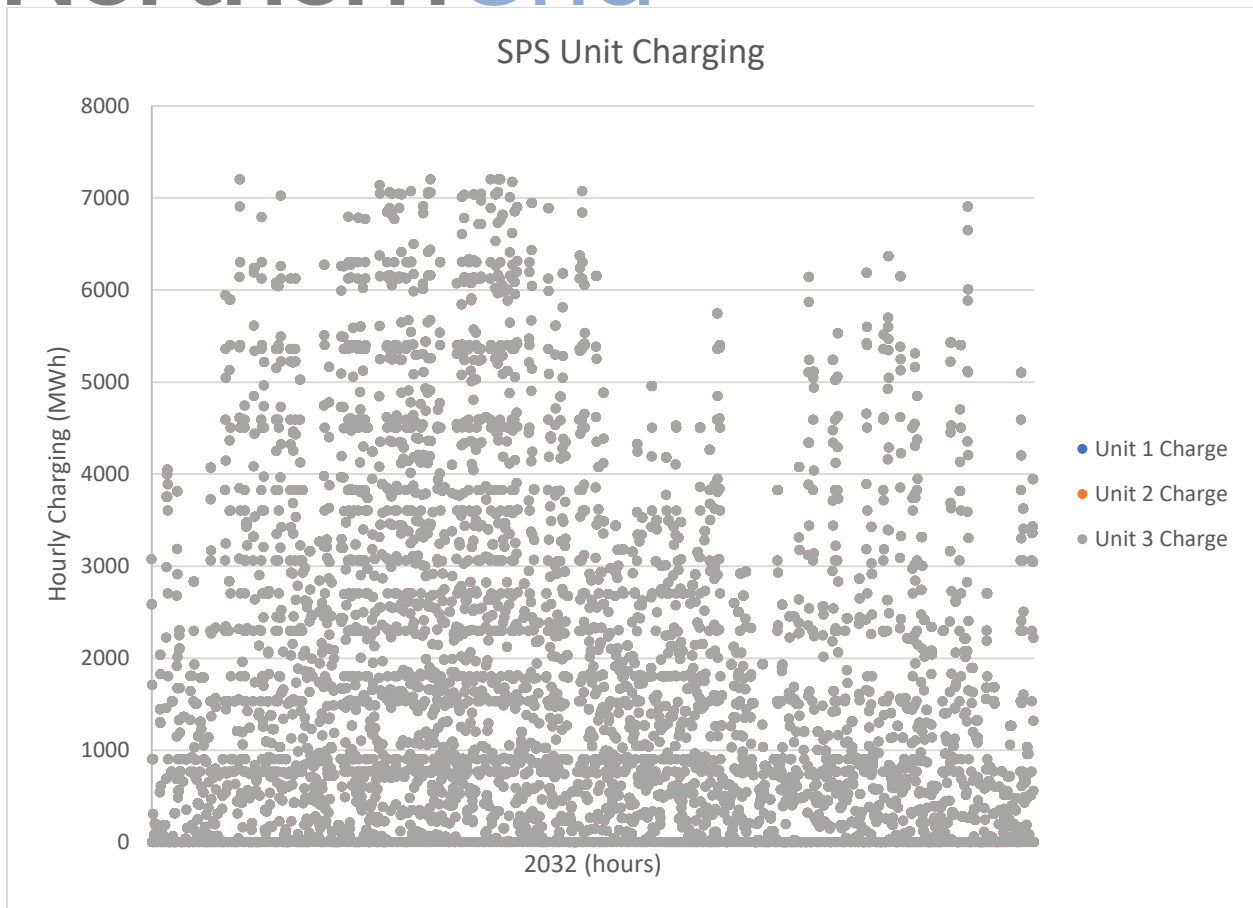
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2 *Figure 3: Hourly Charging for SPS Units*

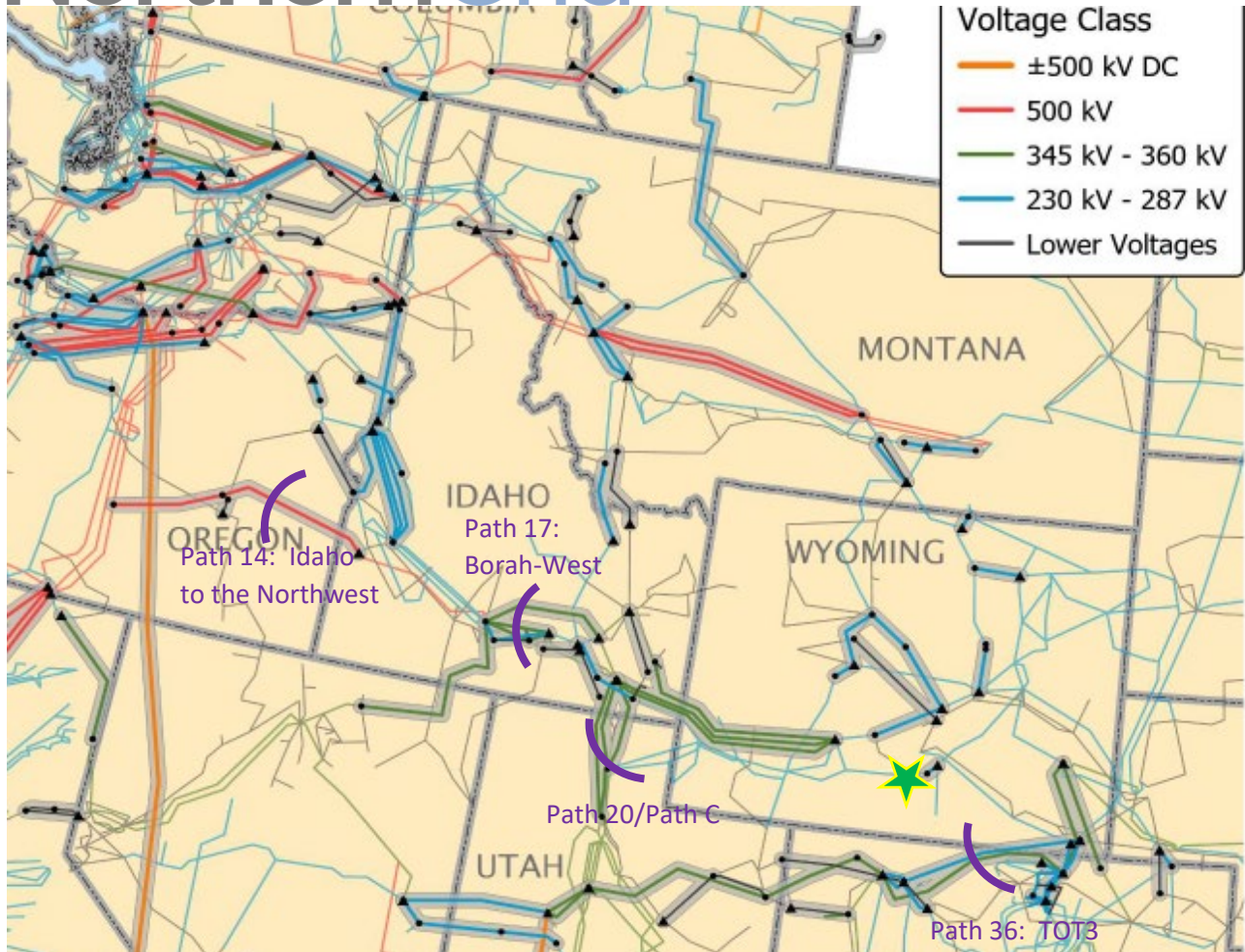
3 Figure 3 shows the hourly charging for the SPS units. The values are identical due to how GridView
4 treats the collective pumped storage plant. For the SPS project, the three 300 MW pumped storage
5 units were modeled with equal participation factors in the overall plant function. The storage
6 component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

8 The regional impact of the installation of 900 MW at the 500 kV Aeolus substation can be observed
9 through measuring the impact to select Western Electric Coordinating Council (WECC) Paths.

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2 *Figure 4: Select WECC Paths*

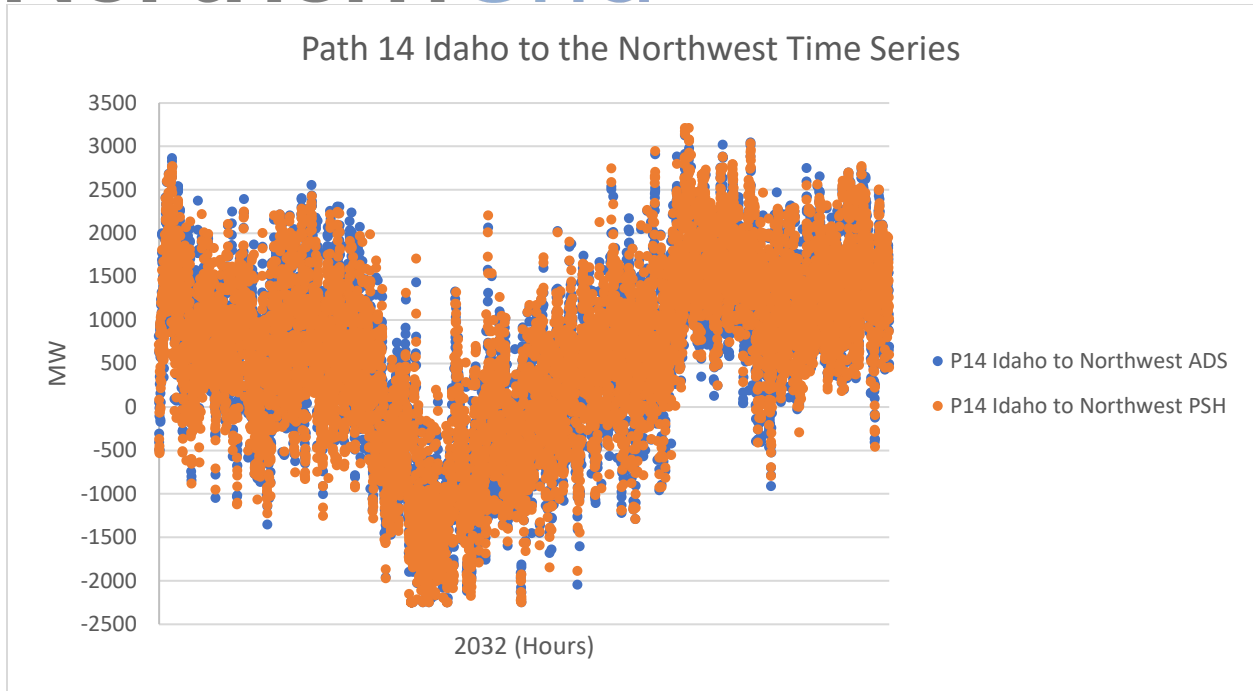
3 Figure 4 shows the select WECC paths chosen for this report. In all Figures and Tables, the following
4 acronyms are defined as:

5 ADS Anchor Data Set, the “pre” case

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



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

3 Figure 5: Path 14, Idaho to the Northwest, westbound prevailing demonstrates that the path behaves

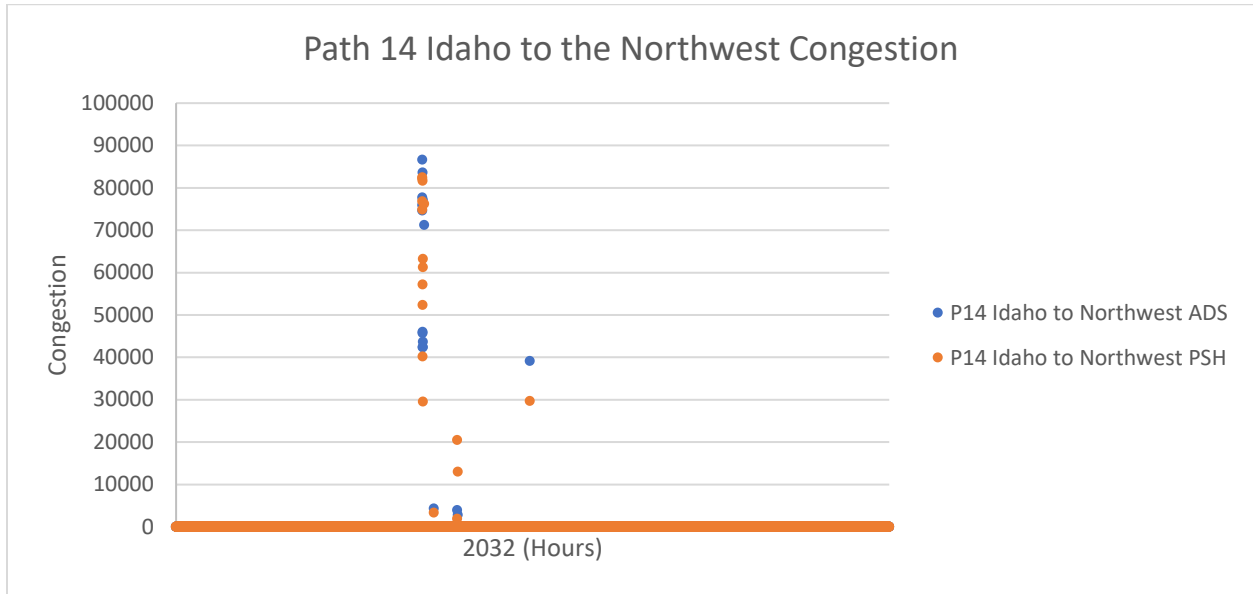
4 similarly with and without the pumped storage project, and further statical scrutiny revealed that the

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- 1 average difference on the megawatts on Path 14 between the two different cases is 16 MW, which is
- 2 negligible for the path.
- 3 There are times when the flows on the Path 14 reach either an upper or lower limit, resulting in
- 4 congestion.

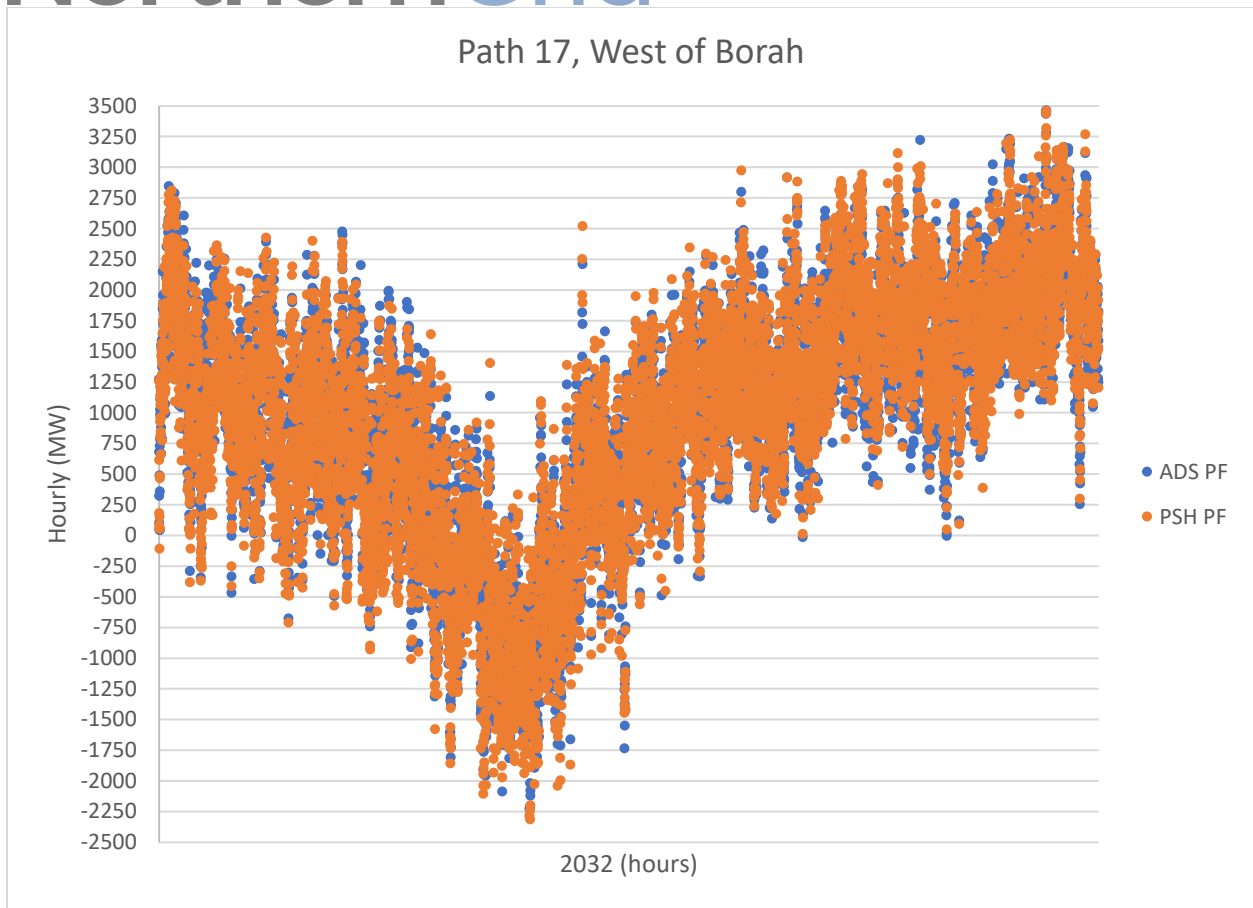


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6 *Figure 6: Path 14 Congestion*

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



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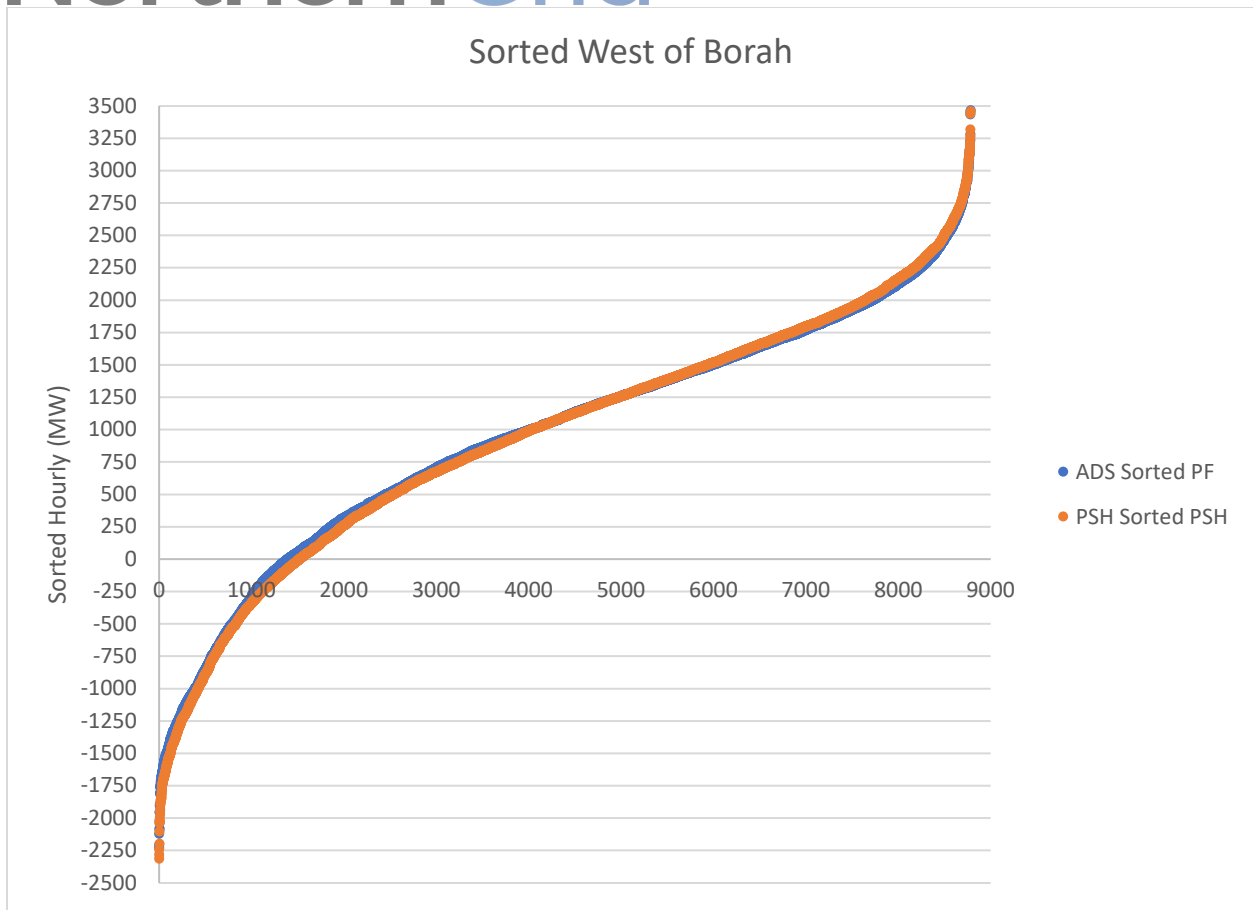
2 *Figure 7: Path 17 (positive indicates westbound)*

3 Figure 17 shows the time series for the West of Borah path. West of Borah is predominately an east to

4 west path; negative values indicate west to east functioning of the path.



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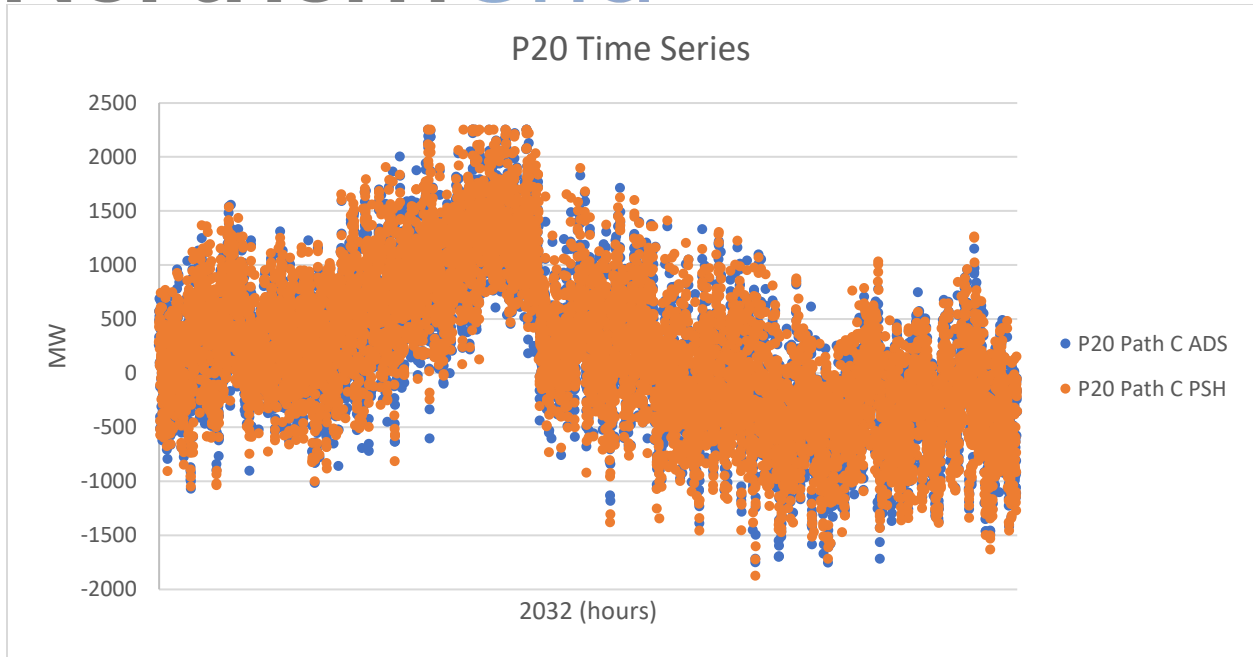
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2 *Figure 8: Sorted West of Borah*

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



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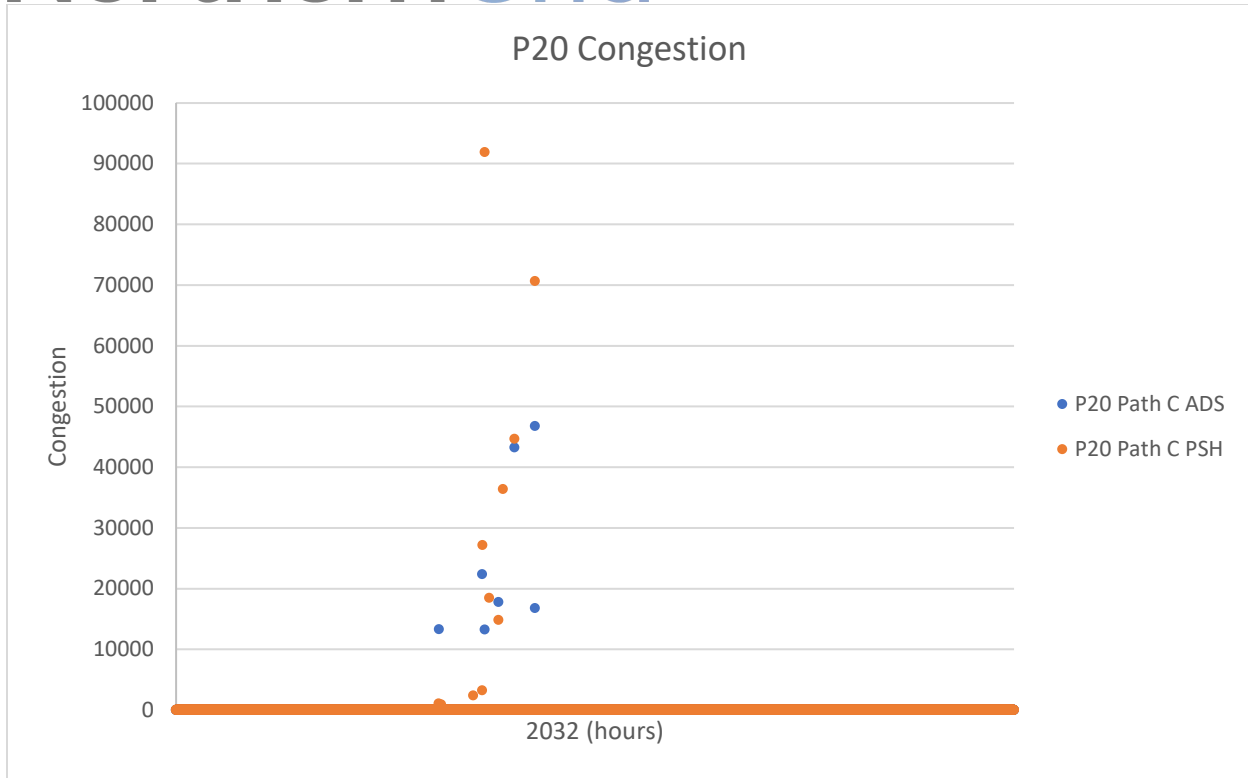
Figure 9: Path 20/Path C

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.

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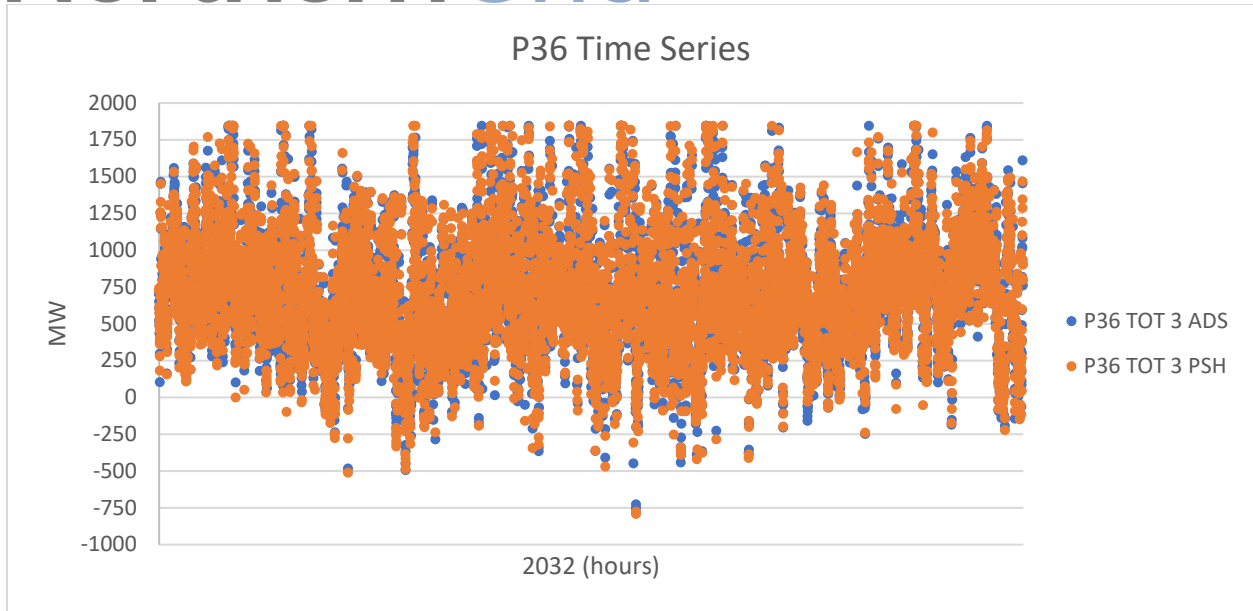
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2 *Figure 10: Path 20 Congestion*

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



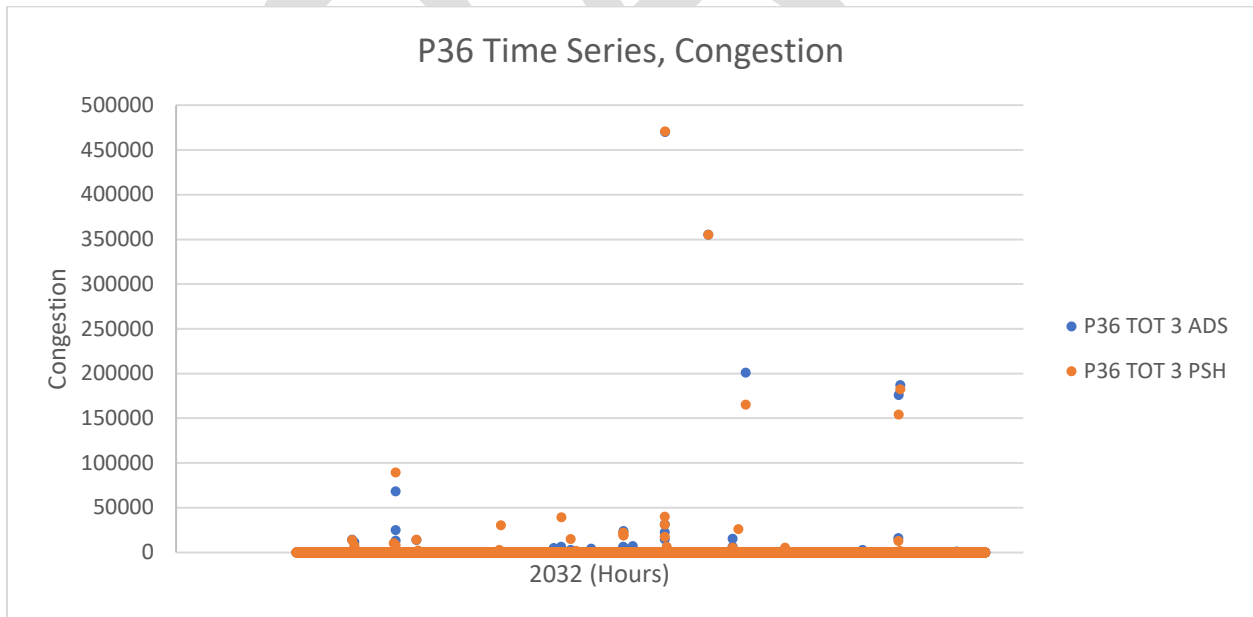
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2 *Figure 11: Path 36, Tot 3*

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



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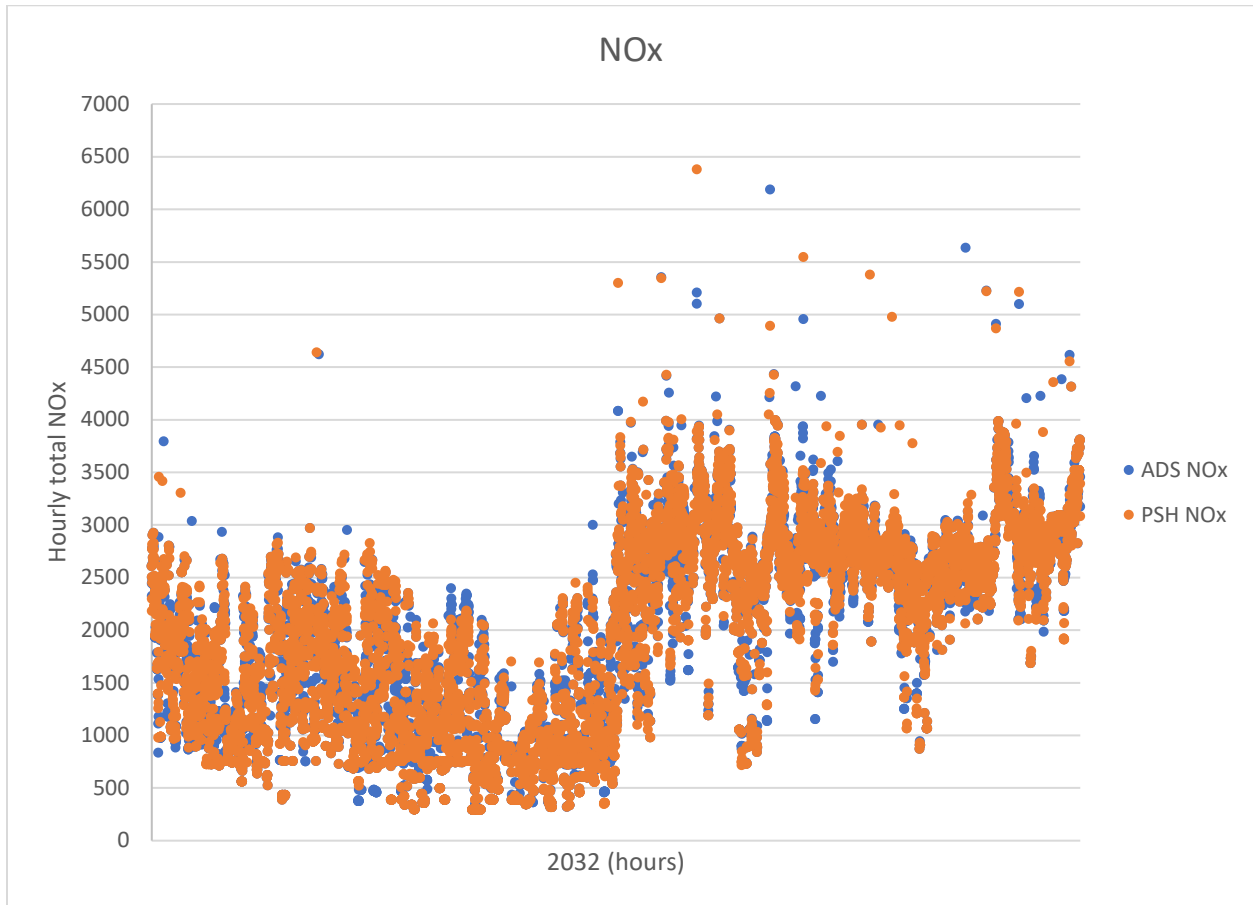
7 *Figure 12: Path Idaho to the Northwest Congestion*



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1 Emissions

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



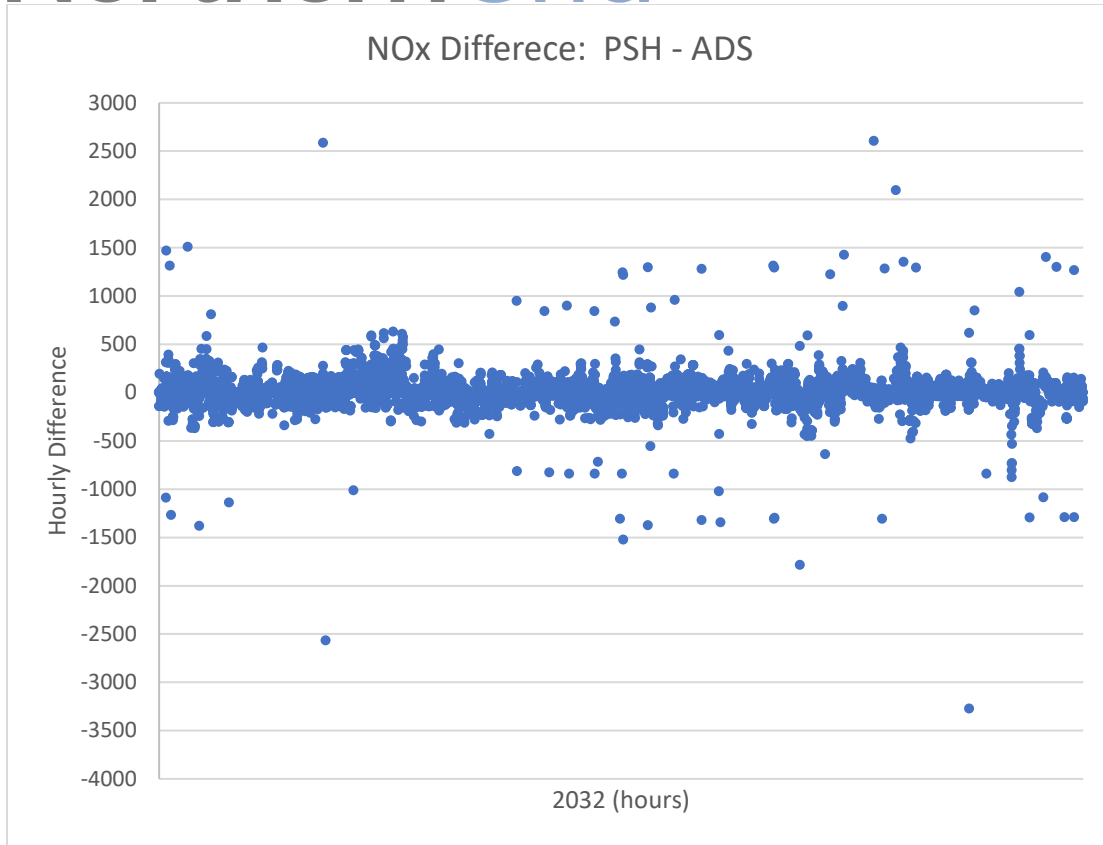
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5 *Figure 13: NOx*

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



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2 *Figure 14; NOx Difference*

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

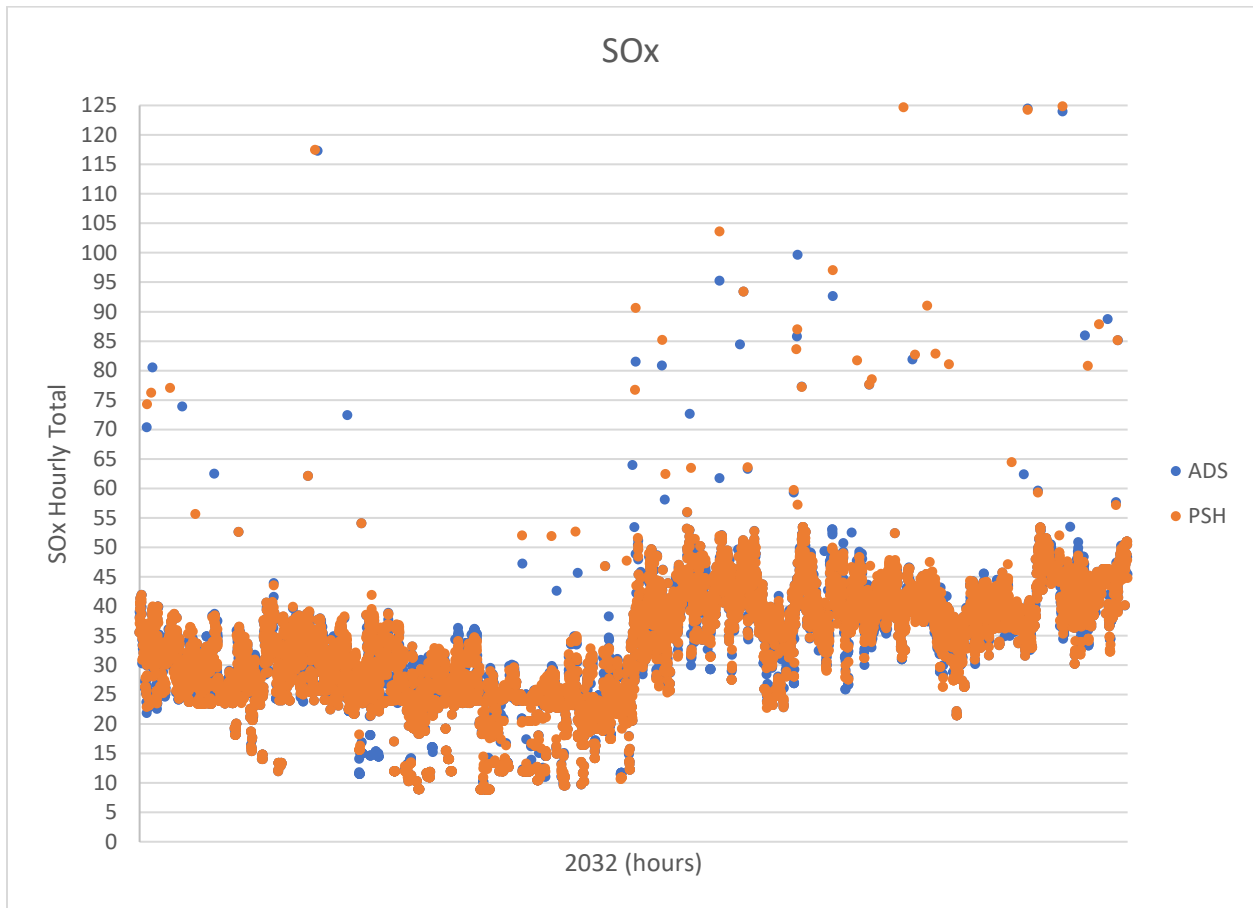
5 *Table 2: NOx*

	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



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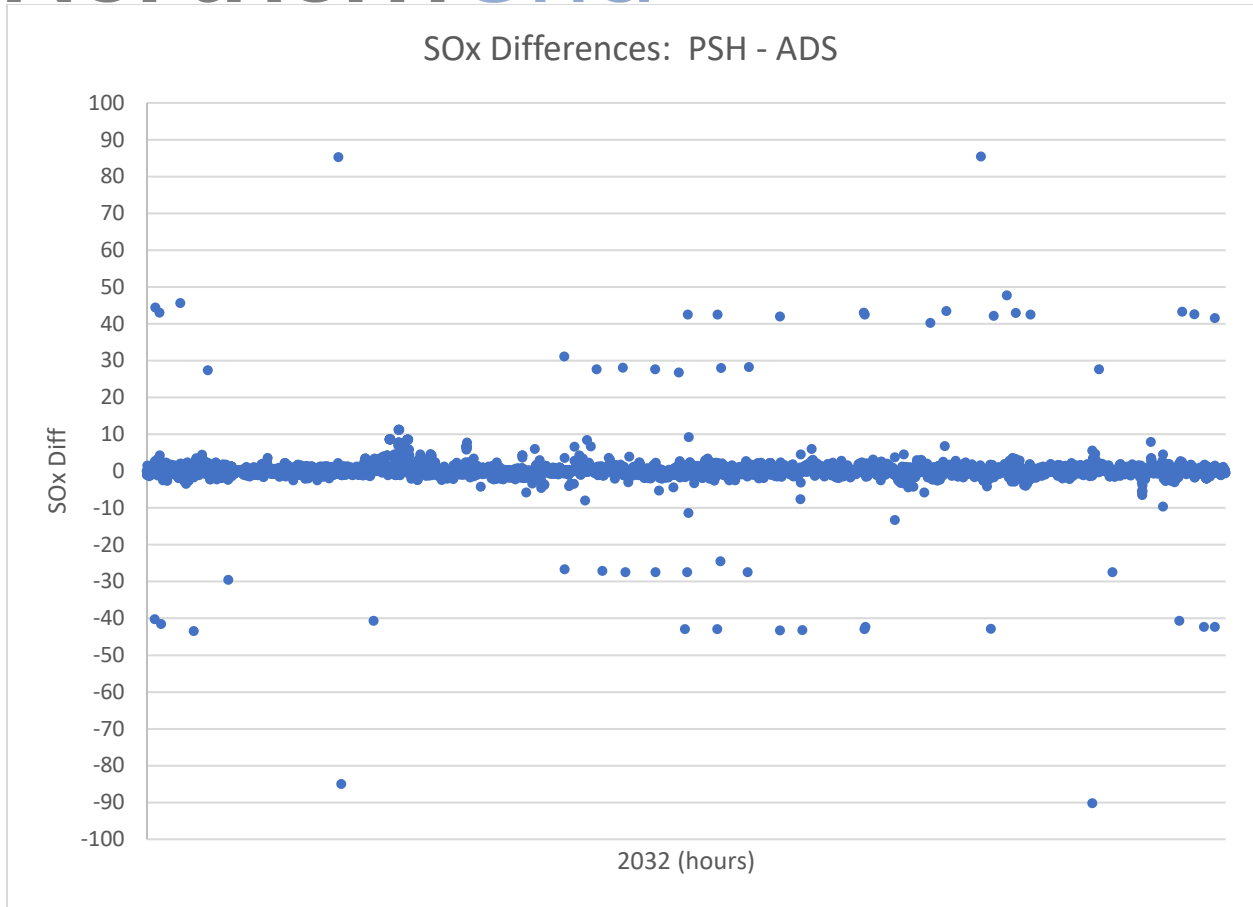
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- 2 On average, there were more NOx emissions in the case with the pumped storage project than without,
- 3 however, the changes represent a negligible percentage of the overall NOx emissions.



- 4
- 5 *Figure 15: Sox*
- 6 Similar to the NOx output, the impact of the pumped storage project on a regional level is not apparent.



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Figure 16: SOx Differences

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



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1 *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

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

3

4 Regional Fuel Usage

5 *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)

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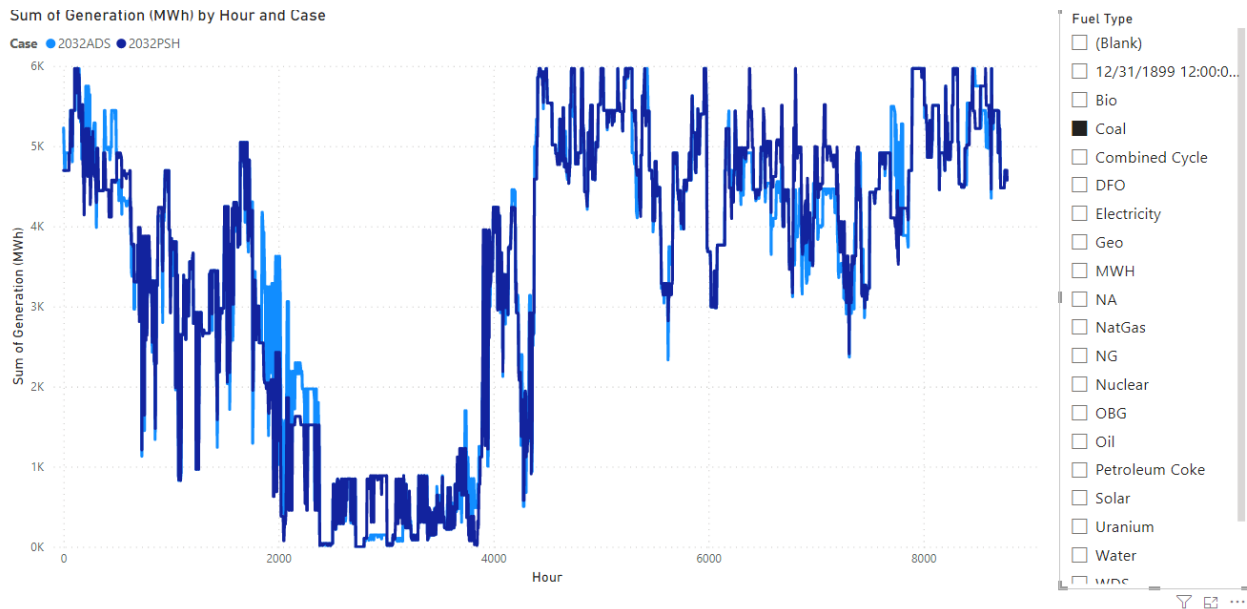
7 Table 9: Regional Yearly output by Fuel Type (MWh) shows the megawatt-hours for the entirety of the
8 NorthernGrid region broken down by fuel type.



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

5



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7 *Figure 17: Coal, with and without SPS*

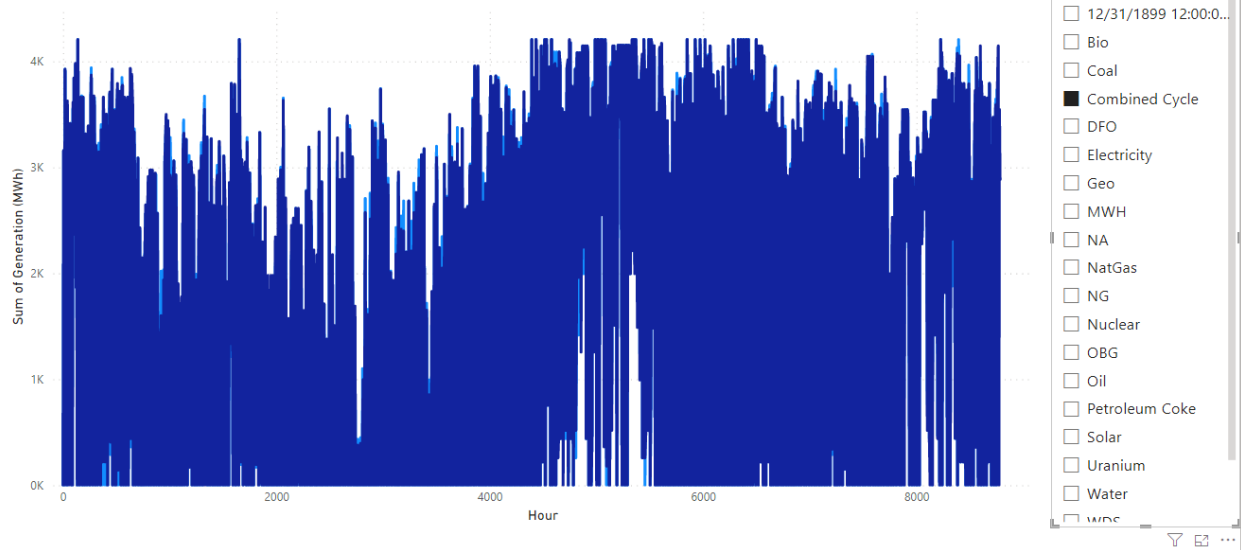
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Sum of Generation (MWh) by Hour and Case

Case ● 2032ADS ● 2032PSH

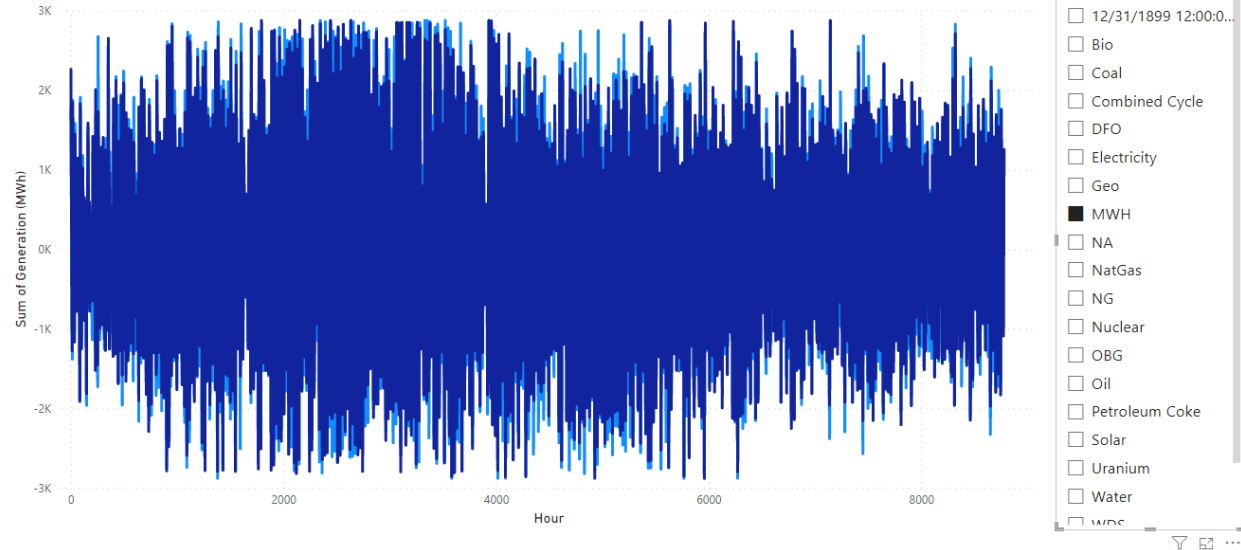


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2 *Figure 18: Combined Cycle, with and without SPS*

Sum of Generation (MWh) by Hour and Case

Case ● 2032ADS ● 2032PSH



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4 *Figure 19: MWH with and without SPS*

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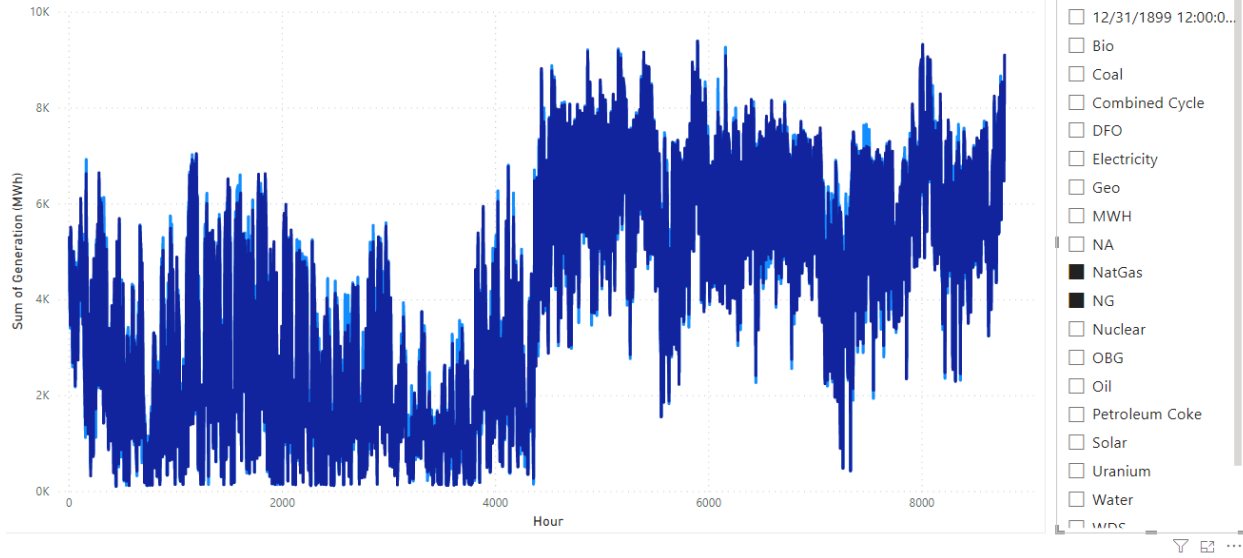
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Sum of Generation (MWh) by Hour and Case

Case: 2032ADS 2032PSH

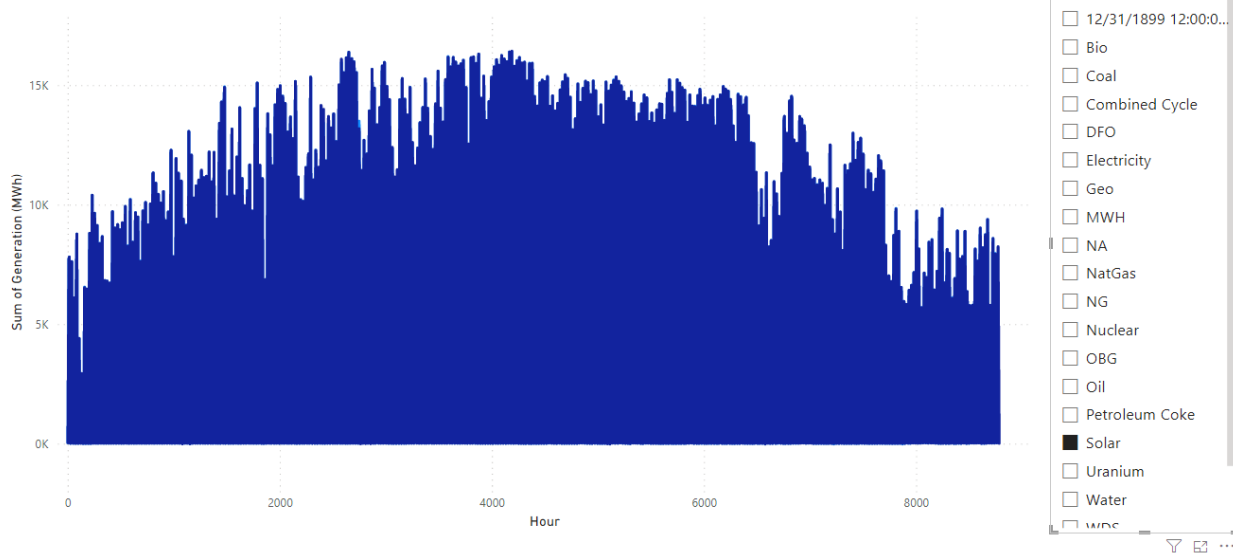


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2 Figure 20: Natural Gas with and without SPS

Sum of Generation (MWh) by Hour and Case

Case: 2032ADS 2032PSH

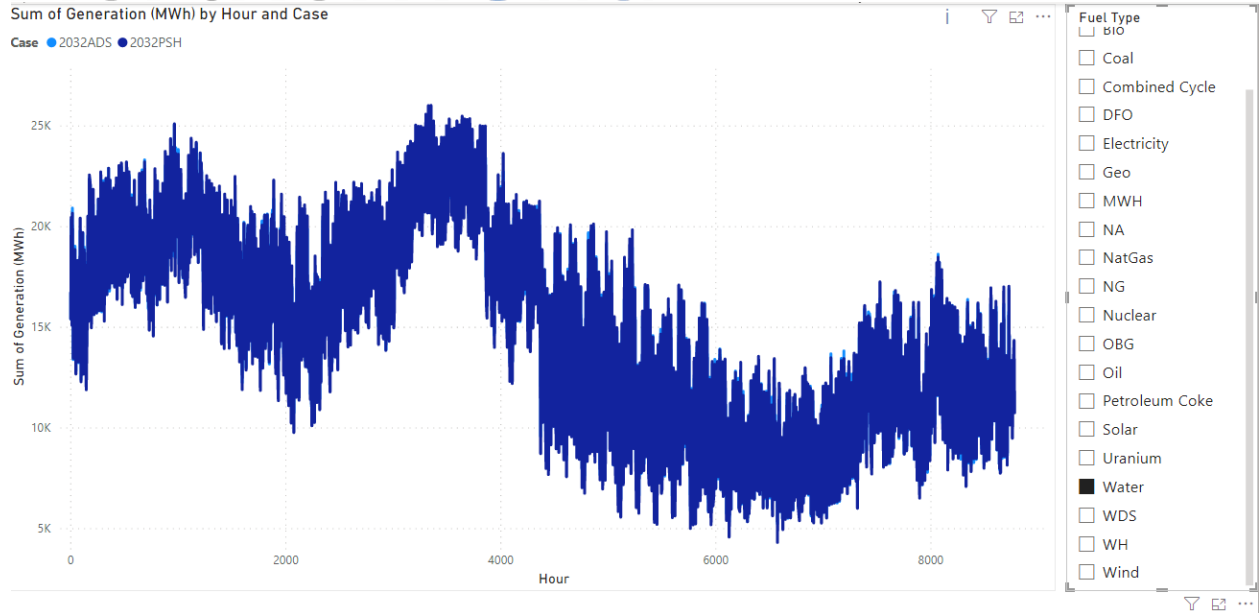


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4 Figure 21: Solar with and without SPS

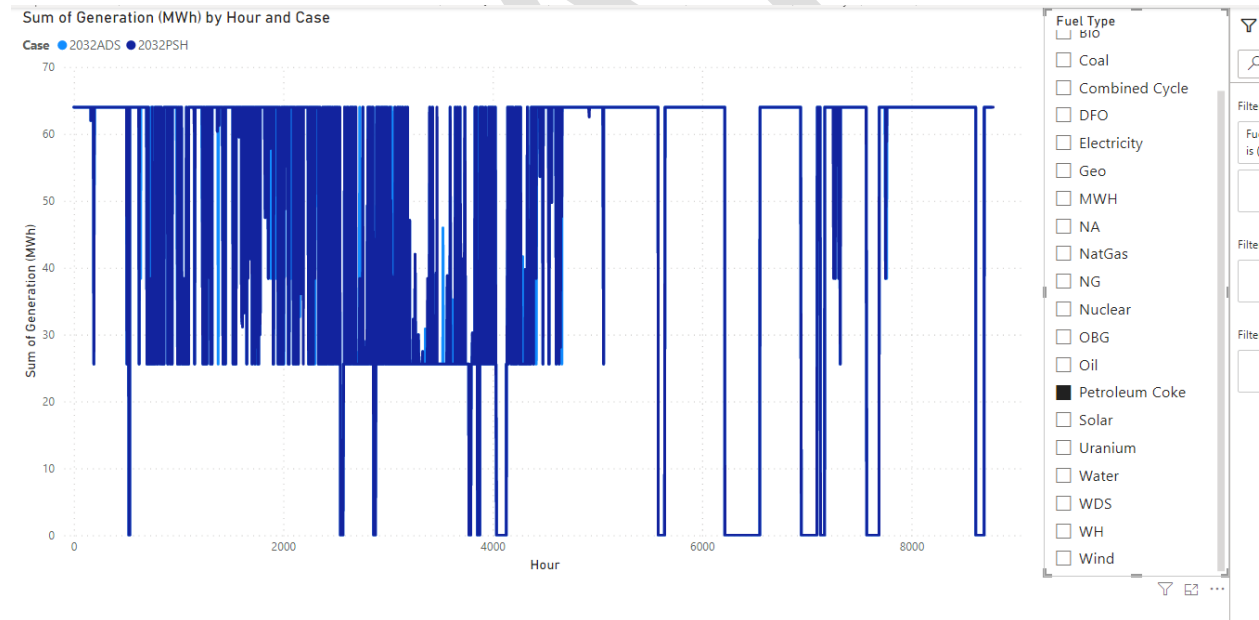


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2 *Figure 22: Water with and without SPS*



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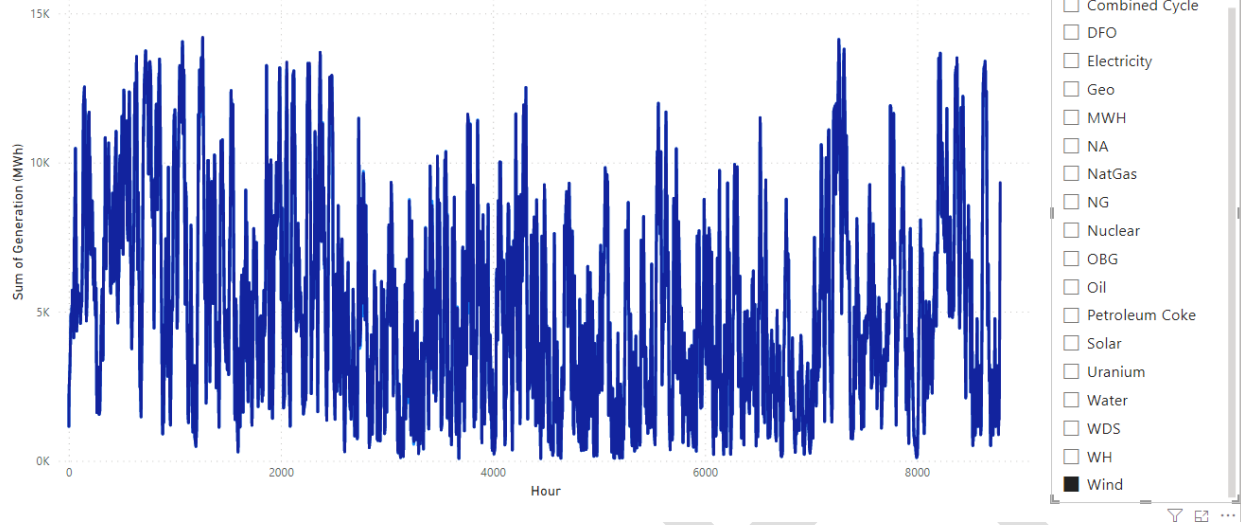
4 *Figure 23: Petroleum Coke with and without SPS*



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Sum of Generation (MWh) by Hour and (Manage and connect to recent sources.)

Case ● 2032ADS ● 2032PSH



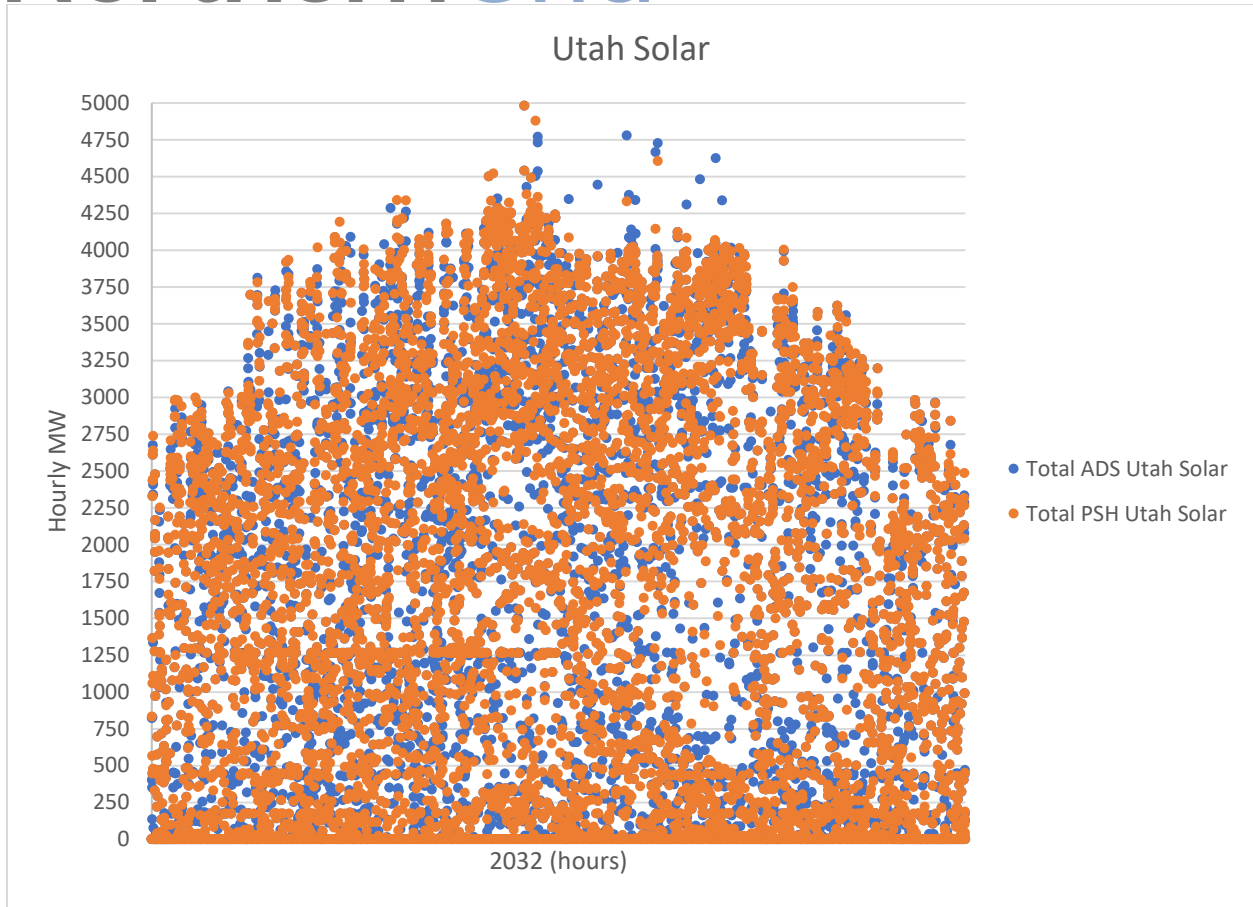
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Figure 24: Wind with and without SPS

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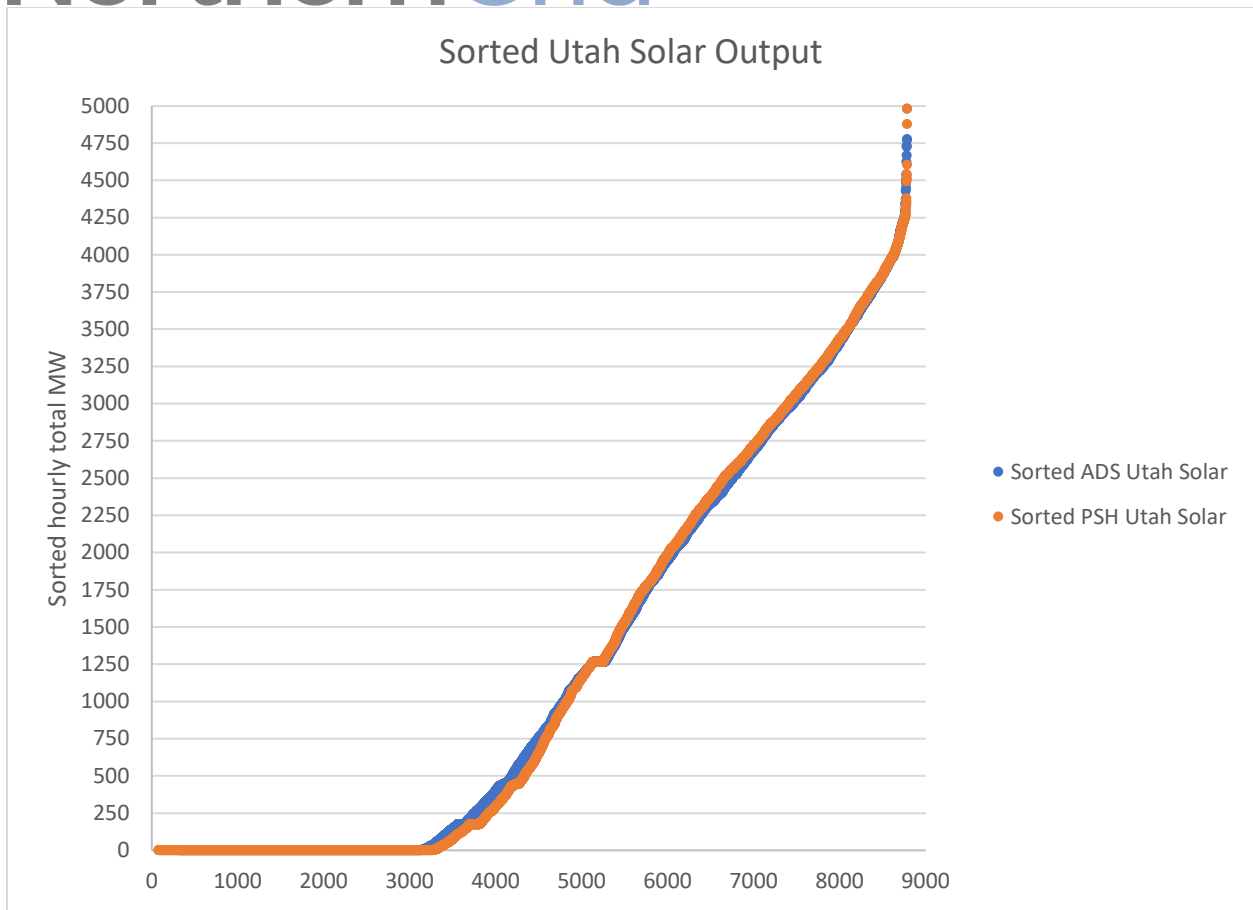
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2 *Figure 25: Utah Solar*

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



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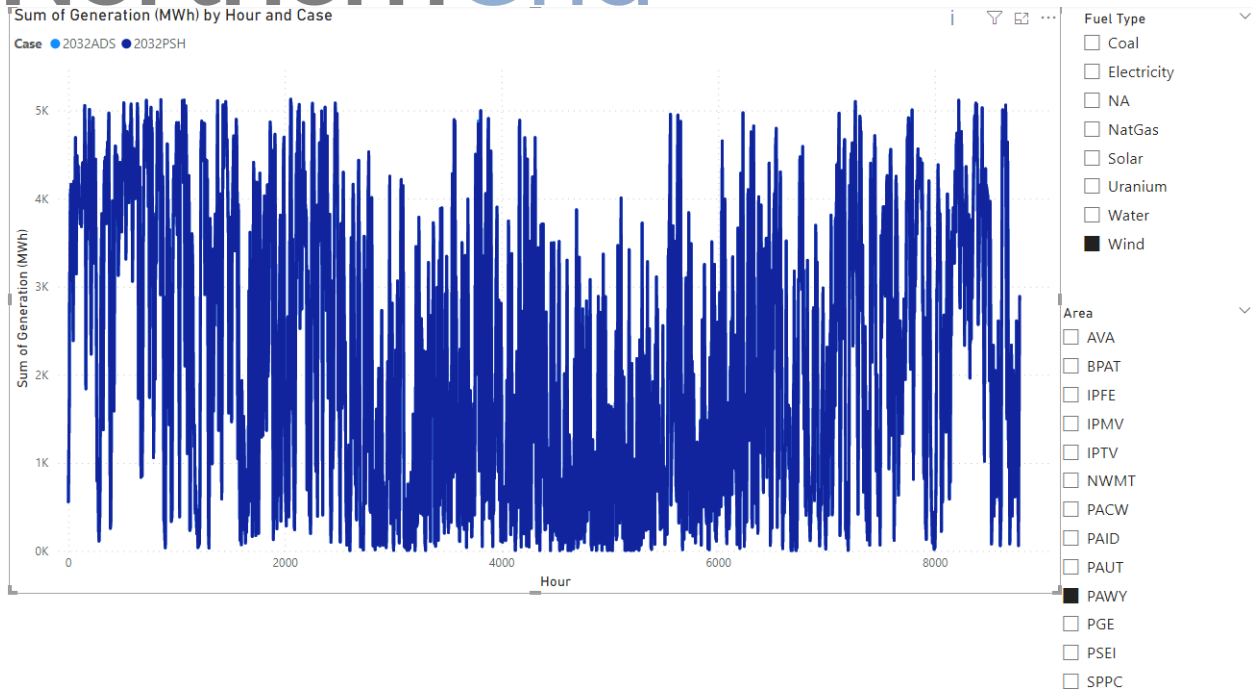
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Figure 26: Sorted Utah Solar

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.



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

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

4 Conclusion

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

11