NTTG Study Report
for the
2016-2017 Public Policy Consideration Scenario

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1. Background

During Quarter 1 of the NTTG 2016-2017 Regional Planning Cycle, the Renewable Northwest ("RNW") and the Northwest Energy Coalition (NWEC") jointly submitted a Public Policy Consideration ("PPC"), defined in the NTTG Funders' Attachment K) request for a scenario analysis study. This request was to assess the transmission impacts and reliability implications associated with the retirement of Colstrip Power Plant ("Colstrip") units 1 and 2, the hypothetical closure of Colstrip unit 3, the integration of replacement wind resources at the Broadview substation and the inclusion of a gas plant in the Billings area. Members of the NTTG Technical Workgroup ("TWG"), and representatives from RNW and NWEC jointly reviewed the request and agreed on modifications to the requested study. These modifications, and the associated study assumptions, are documented in the NTTG 2016-2017 Study Plan, Attachment 3. The NTTG Study Plan, including the PPC Study Proposal for a Scenario Analysis, was subsequently approved by the NTTG Steering Committee on July 20, 2016. The result of this analysis is included in this report.

This study does not constitute a total transfer capability, Path Rating, Generation Interconnection Agreement or Transmission Service Request study and the results herein should be used for informational purposes only. The results of this analysis do not suggest or imply that a one-for-one substitution of wind or a combination of wind and gas for coal is feasible without further analysis or system improvements. This study does not imply or convey transmission rights in any fashion.

2. Study Assumptions

Several assumptions were made to create the scenario to retire the three Colstrip units:

- All introduced generation, wind and gas, will be exported on Path 8
- The 1494 MW of Type 4 wind was modeled on the Broadview 500 kV bus and was dispatched at 0%, 35% and 100%
- The introduced generation on the Broadview 500 kV bus is assumed to meet the voltage requirements that would be required as a result of an actual interconnection; any voltage contributions or deviations from the collector system is assumed to be mitigated at the POI
- The 250 MW gas plant was modeled onto the Alkali Creek 230 kV bus without a Remedial Action Scheme ("RAS") for 500 kV outages that would be similar to the RAS assumed for the proposed new wind at Broadview. In an actual interconnection or transmission service request, the need for a RAS would be evaluated. The gas plant was modeled in with cases that had the wind at Broadview modeled at 1244 MW; the 1244 MW was dispatched at 0%, 35% and 100%.
- A RAS to trip the new Broadview wind was assumed to be designed to act faster than the current Colstrip Acceleration Trend Relay ("ATR"). By having the RAS act faster than the ATR, it both protects the transmission system

and does not interfere with the inputs to the ATR. These changes occur by 2026

  - This assumption was driven by the fact that the RAS for the new Broadview wind was intended to mimic the action of the ATR. For 500 kV outages, the ATR decides how many Colstrip units need to be tripped to maintain stability. The assumption is that a new generator on the 500 kV system would have a RAS that acts similarly to the ATR because generation will still need to be tripped for 500 kV outages and that tripping should occur before the ATR acts. To coordinate with the ATR, the wind tripping needs to be much faster than the ATR to avoid multiple trips. This coordination has yet to be determined.

- No new transmission lines or facilities beyond those already planned for operations in the year 2026 will be considered.
- For any contingency that results in a loss of generation, generators in the northwest were assumed to be re-dispatched to accommodate for the loss of generation.

3. Base cases

NTTG used TEPPC's 2026 version 1.3, edited to incorporate fixes to load shapes, modified resource mapping by the four Western Regions, plus other adjustments that enhanced the accuracy of the database. The production cost model simulating the 2026 load and resources forecast, was used to identify stressed system conditions (i.e., load and generation dispatch conditions) to study. A production cost model uses the costs of operating a fleet of generators to minimize costs for the 8760 hours of the year while simultaneously adhering to a wide variety of operating constraints. The production cost model data for the selected system conditions were then translated into power flow base cases. A power flow model is a numerical analysis of a single condition flow (e.g., hour) of electric power in an interconnected system. There was a significant effort undertaken to ensure that the round trip produced a case that was both steady-state and dynamics capable. Additionally, it took numerous person-hours to convert selected steady-state contingencies into dynamics-ready contingencies. Without this effort, the automation of the dynamics analysis would not have been possible.

The base case used for this PPC study was a Montana to the Northwest (MT-NW) Case that had been adjusted to have high flows on WECC Path 8 coming out of Montana. The TWG prepared the following scenario cases to study the request:

- MT-NW case (case "C" in the TWG study) was used as the basis for comparison: in addition to the closure of Colstrip units 1 and 2, Colstrip unit 3 was also turned off.

- MT-NW case with Colstrip units 1, 2 and 3 offline, modified to include a 1494 MW wind farm on the Broadview 500 kV bus. The new Broadview wind was modeled at 0%, 35% and 100% ~~the following~~ dispatch levels. The three levels of wind dispatch were chosen to reflect the inherent variability in a renewable resource. 0% and 100% were chosen to represent the extreme ends of the output spectrum. 35% was chosen as an acceptable mid-spectrum value as 35% is often used as the default output on a wind facility in WECC base cases.~~:~~
- ~~0%, 35%, 100%~~
- MT-NW case with Colstrip units 1, 2 and 3 offline modified to include a 1244 MW wind farm on the Broadview 500 kV bus along with a 250 MW gas plant in Billings. The 1244 MW wind farm replaces the 1494 MW wind farm. The gas plant was kept at full output and the new Broadview wind was modeled at the following dispatch levels:
  - 0%, 35%, 100%

The TWG started with case "C" from the initial production cost model runs from the Study Plan. Case "C" has Path 8 flows from Montana to the Northwest of approximately 2189 MW and the path is rated at 2200 MW. From that case, the TWG turned off Colstrip unit 3 and modified the case to include the proposed wind at Broadview, as well as the gas plant in the Billings area. The wind was modeled directly on the Broadview 500 kV bus and assumed to have a RAS that would immediately trip the wind project for any single or double 500 kV outage between Colstrip and Garrison. The decision to trip the full output of the wind farm was based on typical ATR action that trips Colstrip generation for these outages. The gas was modeled on the Alkali Creek 230 kV bus; this bus was chosen as being a viable location from an electrical perspective. Gas transmission impacts were not considered.

Because Path 8 exports (flows from Montana to the Northwest) were of primary interest, the breakdown of each case and its associated Path 8 west-bound MW flows are provided in Table 1.

Table 1: MW flows for Montana to the Northwest on Path 8

Case Description	Montana to the Northwest (MW)
Case for Plan (Case "C")	2189
CS units 1, 2 and 3 offline, new BV wind at 100%	2203
CS units 1, 2 and 3 offline, new BV wind at 35%	1382
CS units 1, 2 and 3 offline, new BV wind at 0%	926
CS units 1, 2 and 3 offline, new BV wind at 100%, with the gas plant	2194
CS units 1, 2 and 3 offline, new BV wind at 35%, with the gas plant	1522

CS units 1, 2 and 3 offline, new BV wind at 0%, with the gas plant	1136

The TWG focused on Path 8 Montana to the Northwest flows in the development of these cases. For the base Case (Case “C”), the TWG adjusted the case until the maximum reliable export on Path 8 of 2200 MW was achieved. Then, when creating the case with the loss of Colstrip unit 3 and the inclusion of 1494 MW of wind at full dispatch at the Broadview 500 kV bus, the TWG again adjusted the case to achieve the maximum reliable export of 2200 MW. This adjustment naturally occurred when 250 MW of the wind at Broadview was replaced with a 250 MW gas turbine in Billings. From those “seed” cases, a reduction of the wind resulted in a similar MW reduction of west-bound Path 8 flows.

By focusing on the path flows for the cases with the most generation, the TWG has ensured that the outages would be comparable. The 500-kV system to which the Colstrip units are attached is a unique and critical component of the transmission system. Historically, it is the MW flow on Path 8 (i.e., Montana to the NW path) that will govern the type of transmission (and generation) response to outages on the 500-kV system from Colstrip to the west.

4. Power Flow Analysis Results; Steady State and Transient Stability

All analyses involved both steady state ~~powerflow~~power flow and transient stability runs. The TWG started by analyzing the case with Colstrip units 1and 2 offline and performing steady state and stability analyses. The results of the analyses conclude that there are no voltage violations, thermal overloads or transient stability concerns present in the case.

The TWG then modeled an additional 1494 MW of Type 4 wind on the Broadview 500 kV bus dispatched at 100%. The case was then modified so that there was approximately 2200 MW flowing on Path 8 from Montana to the Northwest. The two subsequent base cases had the new Broadview wind dispatched at 35% and 0%; both cases had fewer MW flowing westbound on Path 8 as the TWG was attempting to represent the variable nature of the wind and how that variability impacts the transmission system. The TWG then performed both steady state and transient stability studies on these three cases and for the contingencies analyzed the TWG found no thermal overloads, voltage excursions or transient stability concerns that would indicate that new equipment would be needed to supplement the wind for coal substitution.

The TWG then took the 1494 MW Broadview wind case and reduced the wind at Broadview from 1494 MW to 1244 MW while concurrently modeling 250 MW gas plant on the 230 kV Alkali Creek bus in Billings. This analysis did not include a gas transmission component; the Alkali Creek bus was selected because it is ideally situated to accommodate new generation from an electric perspective. The case with 1244 MW of new wind at Broadview dispatched at 100% and the 250 MW gas plant in Billings was also modified to have approximately 2200 MW westbound on Path 8 from Montana to the Northwest. The subsequent cases had the 1244 MW of wind at Broadview dispatched at 35% and 0% and had fewer MW flowing on Path 8 to the west. The TWG performed steady state and transient stability analyses on the three cases and found that there were no thermal overloads, voltage violations or transient stability concerns.

The TWG ensured that the results of the steady state analysis corresponded with the results from the transient stability analysis by comparing post-contingency steady state voltages with post-contingency transient voltages after they had settled. The TWG found that the two types of analyses resulted in similar voltages and therefore concluded that the modeling and analyses were performed correctly.

~~Appendix A lists all contingencies that were analyzed. Each contingency listed was analyzed as both steady state and transient stability.~~The TWG analyzed over 400 contingencies in this analysis, of which, over 30 were also analyzed dynamically.

5. Production Cost Model

As specified in the Study Plan, Production Cost Modeling (PCM) was performed on the case that was selected as being the “best” from an electrical perspective. Since none of the cases resulted in the inability for Path 8 to experience the full 2200 MW export, a case that has both wind and gas to replace the coal was selected as it will provide the largest range of options to economically operate the system. The PCM was run with and without the 250 MW gas plant in Billings to more fully ascertain the impact of the cost of running a gas plant in conjunction with a wind farm, and the result showed minor shifts in wind and thermal generation, but no change to hydro. Both scenarios with and without gas turbine (GT) showed increased dispatch in Montana wind (e.g., different level of wind penetration) and IPC, PAC and PGE thermal dispatch.

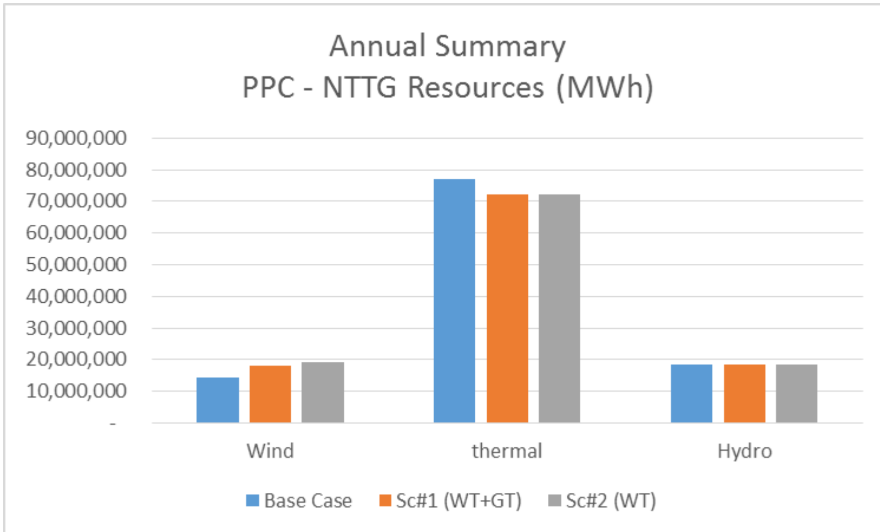

Figure 1: NTTG Generation - Annual Summary (MWh)

The results of the PCM runs are consistent with the results that would be expected when low cost wind dispatch replaces higher cost resources, see figure 2. That is, the times when there is a majority of wind and hydro available for dispatch results in a cheaper dispatch cost than when the system has more coal and gas dispatched(e.g., hourly resources have zero fuel costs). Operating costs when running a system with both wind and gas replacing coal is more expensive than running a system with just wind; but both of those scenarios are cheaper than running the system with coal (250 MW GT vs. 778 MW (net) Colstrip 3 coal). However, beyond this limited dispatch analysis, other costs and benefits are not estimated within this study (e.g. capital costs, flexibility reserves, single world dispatch, etc.). At no time did the change in generation introduce congestion on Path 8 west bound flows.

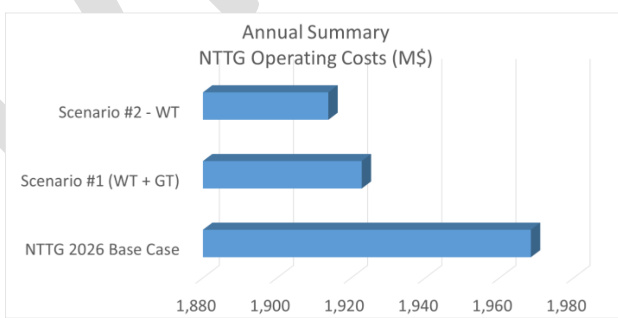

Figure 2: NTTG Annual Operating Costs (M$); based on the TEPPC 2026 CC cost assumptions

6. Conclusions

The Renewable Northwest Project (RNW) submitted a Public Policy Consideration request for a scenario analysis study for the NTTG 2016-2017 ten-year transmission planning cycle. This study report assessed an accelerated phase-out of coal plants while developing utility-scale renewable resources, replacing Colstrip units 1, 2 and 3 with either wind only or a combination of wind and gas.

The study results suggest that a replacement of wind or a combination of wind and gas for coal may be feasible, though nothing in this study constitutes a path study nor does it convey or imply transmission rights. Additional analysis such as sub-synchronous control interaction studies and fault duty analysis due to loss of significant amount of inertia would be required in order to understand the full impacts of phasing out of coal plants.

This limited technical study was comprised of both steady state and transient stability analyses; all of these demonstrated that there are no thermal overloads, voltage excursions or transient stability violations that would pre-empt the replacement of coal with wind or a combination of wind and gas. For the analysis performed, the TWG saw no need for a synchronous condenser as all the studies resulted in a stable system. No operational studies were performed to study the impacts on voltage performance due to two lightly loaded 500 kV lines out of Colstrip with only one unit online. Also impacts on the sub-synchronous resonance (SSR) due to Unit 3 offline were not part of this analysis.

This study did not model the collector system for the wind farm on the Broadview bus and, therefore, didn’t address any capacitance or reactance that could result from the collector system itself; that analysis would take place in a generation interconnection request. This study assumed that the output from the new wind farm met all the voltage requirements that would be required of a real interconnection.

The RAS for the new Broadview wind was assumed to act similarly to the ATR that protects the transmission system by tripping Colstrip generation for 500 kV outages. The timing of the RAS and the equipment necessary to produce the desired result would take place in the study work for an actual generation interconnection request. This study merely confirmed that RAS is required to maintain the stability of the transmission system.

The results of the PCM analysis showed no transmission congestion on the major path connecting Montana to the NTTG footprint (paths 8, 18 and 80). The PCM model dispatched hourly resources with zero fuel costs over gas and coal (e.g., Montana wind dispatched at high capacity factor-- annual average of 35%).