Appendix N. Renewable curtailment

As more variable energy resources are added to the system the amount of generation curtailed due to oversupply increases. This appendix discusses why oversupply happens and includes projections of future oversupply events.

N.1 Impact of resource curtailment

The addition of non-dispatchable intermittent resources in PGE's resource stack makes the balancing of demand and supply of energy increasingly complicated. These resources are primarily wind and solar, with hydropower uncertainty potentially adding to the complexity of committing the right resources at the right time leading. We define resource curtailment the result of regional surplus of wind and solar that cannot be balanced in other way than by shutting them down.

From PGE perspective, when wind is strong, hydropower is constrained to run at a given level, and solar generation is peaking, the combined output of such resources will be higher than PGE load. In this case, PGE will first attempt to:

- Sell surplus energy to the market
- Turn off thermal plants, if operationally possible, and/or fill storage, and/or minimize hydropower output if doable.

When both solutions are exhausted, the only option left is renewable curtailment, which is the partial or total shut down of the wind generation from one or more PGE wind and plants.

This section describes the impact of wind and solar curtailment on the value of such resources in the long-term. To estimate this effect, we used our WECC model, the same Aurora model used to forecast electricity prices in the PWN, as curtailment is triggered by regional imbalances. PGE estimated the monthly average generation curtailed for all wind and solar resources in Oregon and Washington under normal conditions and Reference Case prices. We did not identify which wind plant will be curtailed. We instead estimated how much is the expected overall curtailment for the whole wind and solar fleet in the entire PNW.

Using the WECC simulated resource output, we estimated curtailment as the difference between simulated generation and resource theoretical availability. We did this for all wind resources in Oregon and Washington, both existing and added by Wood Mackenzie to meet future load to 2043, both on-shore resources and off-shore. The result is that curtailment does and increasingly is projected to occur, especially in the Spring, when PNW wind, PNW hydropower, and WECC solar all maximize generation. **Table 178** shows the detail of simulated curtailment as percentage of maximum available monthly capacity for the future

RRRR, which represents normal condition, with reference gas prices and a California-like carbon cost. For each year and each month, the expected regional curtailment is color coded as follows: green, if there is no expected regional curtailment; yellow, when regional curtailment is expected; orange, when curtailment is significant; red, when regional curtailment is severe.

Table 178. Simulated wind curtailment in Oregon and Washington: RRRR future

Report Year/Month	1	2	3	4	5	6	7	8	9	10	11	12
2023	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2024	0%	0%	0%	0%	-1%	0%	0%	0%	0%	0%	0%	0%
2025	0%	0%	0%	-1%	0%	0%	0%	0%	0%	0%	0%	0%
2026	0%	0%	0%	0%	-1%	0%	0%	0%	0%	0%	0%	0%
2027	0%	0%	0%	0%	0%	-1%	0%	0%	0%	0%	0%	0%
2028	0%	0%	0%	-1%	-2%	-1%	0%	0%	0%	0%	0%	0%
2029	0%	0%	0%	-1%	-1%	-1%	0%	0%	0%	0%	0%	0%
2030	0%	0%	0%	-4%	-4%	-4%	-1%	0%	0%	0%	0%	0%
2031	0%	0%	0%	-5%	-7%	-6%	0%	0%	0%	0%	0%	0%
2032	0%	0%	0%	-7%	-18%	-9%	0%	0%	0%	0%	0%	0%
2033	0%	0%	0%	-8%	-9%	-10%	0%	0%	0%	0%	0%	0%
2034	0%	0%	0%	-10%	-15%	-18%	-2%	0%	0%	0%	0%	0%
2035	0%	0%	0%	-13%	-18%	-19%	0%	0%	0%	0%	0%	0%
2036	0%	0%	-1%	-29%	-52%	-62%	-4%	0%	0%	0%	0%	0%
2037	0%	0%	-1%	-29%	-57%	-67%	-3%	-1%	-3%	0%	0%	0%
2038	0%	0%	-5%	-37%	-76%	-79%	-9%	-1%	0%	-1%	0%	0%
2039	0%	0%	-4%	-38%	-69%	-78%	-11%	-1%	-1%	-1%	0%	0%
2040	0%	-1%	-4%	-42%	-79%	-88%	-14%	-1%	-1%	-2%	0%	0%
2041	0%	0%	-2%	-44%	-74%	-84%	-17%	-5%	-4%	-3%	0%	0%
2042	0%	0%	-7%	-50%	-83%	-92%	-26%	-8%	-3%	-2%	-1%	0%
2043	0%	0%	-6%	-52%	-79%	-83%	-30%	-5%	-6%	-3%	0%	0%

Short-term simulated wind curtailment is not significant under normal conditions, while starting in the mid-2030s it becomes much more so as more and more wind is added to the system. We used the same methodology to estimate solar curtailment in Oregon and

Washington and reported results in **Table 179**. In our model, solar curtailment is not significantly impacting generation until the 2040s. This is the result of less capacity installed in the PNW and the Wood Mackenzie modeling choice of having wind curtail before solar. This means that solar plants are curtailed only after all wind is offline (a modeling simplification). Any actual curtailment will depend on operational constraints and financial considerations.

Table 179. Simulated solar curtailment in Oregon and Washington: RRRR future

Report Year/Month	1	2	3	4	5	6	7	8	9	10	11	12
2023	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2024	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2025	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2026	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2027	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2028	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2029	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2030	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2031	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2032	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2033	0%	0%	0%	0%	-1%	0%	0%	0%	0%	0%	0%	0%
2034	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2035	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2036	0%	0%	0%	0%	0%	-2%	-2%	0%	0%	0%	0%	0%
2037	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2038	0%	0%	0%	0%	0%	-4%	-6%	0%	0%	0%	0%	0%
2039	0%	0%	0%	0%	0%	-1%	-4%	0%	0%	0%	0%	0%
2040	0%	0%	0%	0%	0%	-5%	-5%	0%	0%	0%	0%	0%
2041	0%	0%	0%	0%	-1%	-4%	-4%	0%	0%	0%	0%	0%
2042	0%	0%	0%	0%	0%	-8%	-9%	0%	0%	0%	0%	0%
2043	0%	0%	0%	0%	-1%	-3%	-11%	0%	0%	0%	0%	0%