Appendix J. ELCC sensitivities

This appendix discusses effective load carrying capability (ELCC) values, portfolio interactions, and sensitivities. For general information on resource ELCCs in this IRP, see **Chapter 10, Resource economics**, and for information on the Sequoia model, see **Appendix H, 2023 IRP modeling details**.

The base assumptions in the Sequoia model changed over the course of 2023 IRP modeling due to resource changes, load changes, and stakeholder feedback. Some of these sensitivities ran earlier in the process with previous model versions. As a result, readers should focus on the directionality of the change in the sensitivities rather than the absolute values.

J.1 ELCC and resource portfolios

PGE uses the Sequoia model to calculate resource ELCC values, using the following steps:

- The model runs once to establish a base system capacity need.
- The model runs again with a new resource added and produces a new capacity need.
- The difference in capacity need between the base system and the system with the new resource added determines how much effective capacity the resource contributes.
- The effective capacity value is divided into the resource nameplate value to calculate the ELCC.

The 2023 IRP tests resource ELCCs in the year 2026. The base 2026 power system for ELCC testing has a resource deficit of 429 MW in the winter and 506 MW in the summer.[481] ELCCs can be calculated untuned, with a system deficit, or tuned, where the base power system has had resources added until it is resource adequate or nearly adequate. For portfolio creation PGE runs ELCC studies in an untuned system. Portfolio creation ELCC values for each resource are located at the end of this appendix. PGE also runs a tuned ELCC study that includes the IRP Preferred Portfolio. Tunned ELCC values are in **Appendix K, Tuned system ELCCs**.

Some resources, like batteries or pumped hydropower storage, may have lower ELCC values when tested in untuned systems. This is due to not having sufficient energy to charge. For

[481] Due to input changes the ELCC base system in the winter has a need 1 MW lower than the final 2026 need (which is 430 MW in the winter). PGE staff tested changes in ELCC values at 100 MW of resource added with the updated model and found an average change of less than 1 percentage point and a max change of 2 percentage points. Due to the small size of these changes untuned ELCC values were not rerun.

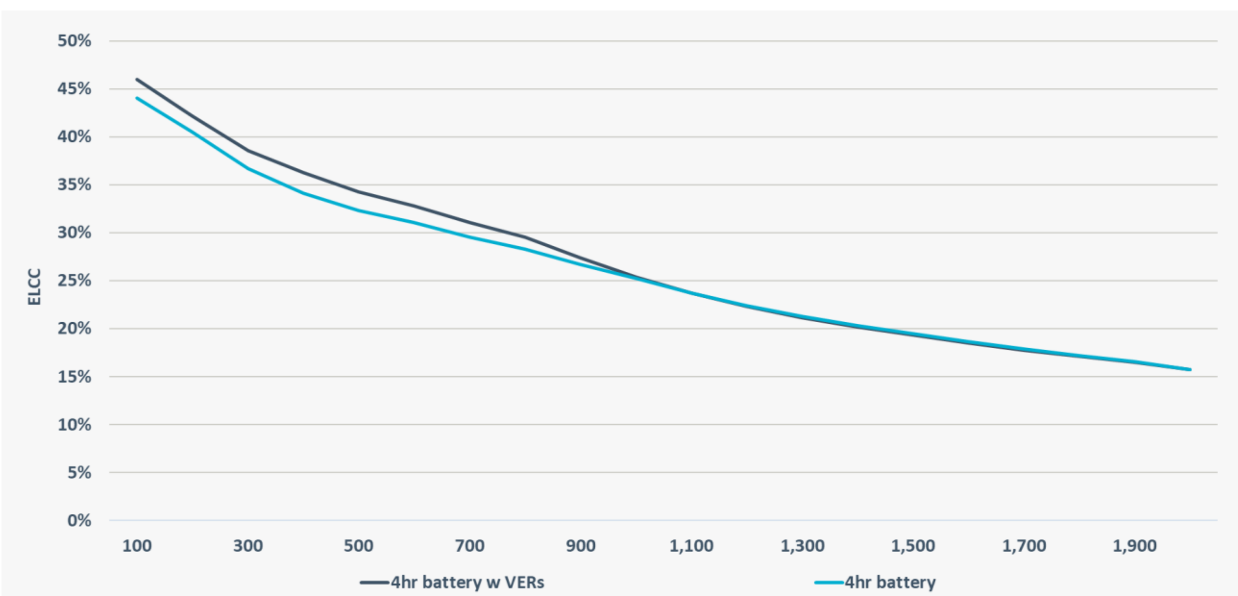
example, a battery might typically charge at night when tested in a relatively adequate, tuned system. But in an untuned deficit system, there may not be power available to charge at night, reducing the battery's ability to provide power the next day during key hours.

The 2023 IRP took two steps to provide more energy to batteries for charging when running untuned ELCC studies:

- Sequoia runs hourly in one-week increments. For the 2023 IRP, the starting charge state of storage at the beginning of the week is 100 percent rather than 50 percent used in the 2019 IRP Update. This adds additional energy into storage resources to help offset reduced charging ability in the untuned system.
- Increased the light-load hour market floor from 200 MW to 400 MW (initial modeling in the 2023 IRP used 200 MW as the light-load-hour floor). This gives storage more energy to charge from at night, to reflect a system/West with surplus energy during low-demand hours.

Beyond the two steps outlined previously, PGE also tested but did not include running untuned storage ELCCs with additional wind & solar added to the resource mix. In the test around 100 MWa of energy was added from a mix of wind and solar proxy resources. The model was then run to test winter 4-hr battery ELCCs. **Figure 138** shows an increase in 4-hr battery ELCC values with VERs as compared to 4hr battery in the Reference Case. The largest increase in the test is 2 percent, the average increase is 1 percent. PGE will continue investigating how to best model storage ELCC values in future planning work.

Figure 138. Winter 4hr battery with and without VERs



J.2 ELCC & transmission products

Transmission assumptions play a role in determining resource ELCC values. Many IRP resources require transmission over the BPA system. The IRP models two Bonneville Power Administration (BPA) transmission products, firm, and conditional firm with up to 200 hours of curtailment (CF200). Less than firm transmission products, like CF200, tend to produce lower ELCC values relative to firm transmission.

The Reference Case IRP approach to modeling CF200 transmission is to curtail the resource during the highest 100 hours of load per year. Since high-load hours are correlated with outages, the loss of resources in those hours reduces ELCC values. Other modeling approaches to CF200 transmission may yield different results.[482]

The IRP tests three CF200 transmission sensitivities. The sensitivities vary the hours curtailed by CF200 transmission from 100hr (Reference Case) to 200hrs, 50hrs, and 25hrs. The impact of these curtailment levels is tested on 300 MW of Gorge Wind and McMinnville Hybrid proxy resources. In all cases, increasing the number of hours curtailed reduces the resource ELCC value. The results, including the IRP reference values for firm transmission and 100hr of curtailment, are shown in **Figure 139** and **Figure 140**.[483]

[482]There is uncertainty on how to model CF200 transmission, for constancy the IRP takes the same approach as the 2021 PGE RFP, Docket No. UM 2166, Order No. 21-320, Appendix A page 24, available at: https://apps.puc.state.or.us/orders/2021ords/21-320.pdf

[483] These tests ran with an earlier version of the Sequoia model. The ELCC values may not align with the final values in the IRP. The directionality of the values should be the focus for the reader.

Figure 139. Conditional firm sensitivities, Gorge Wind, 300 MW

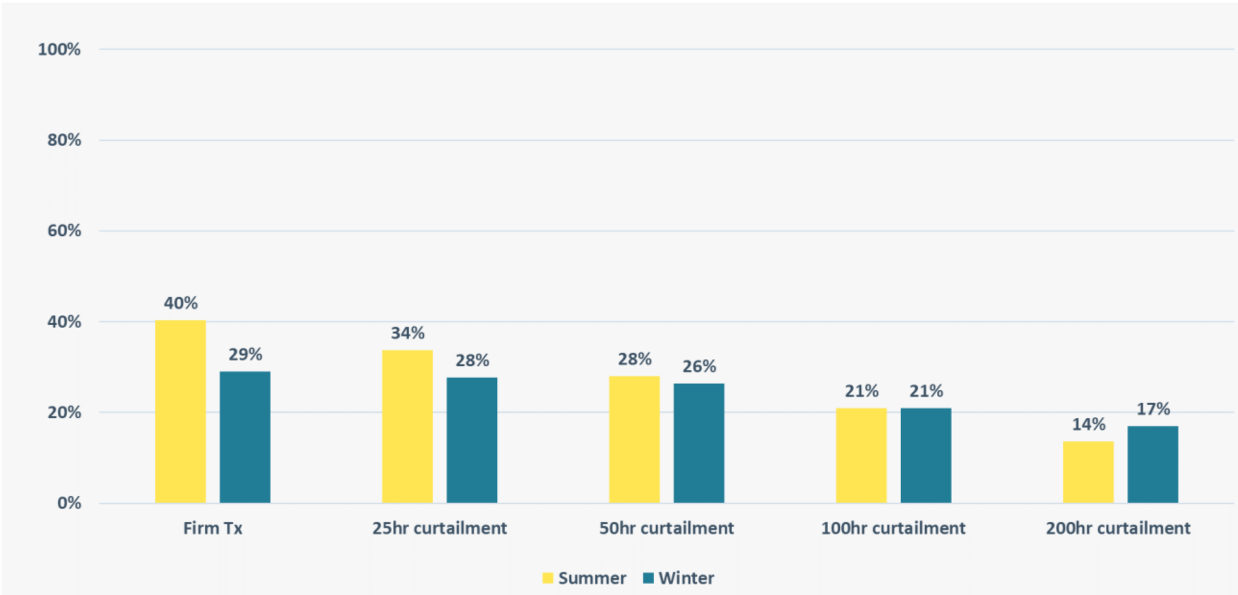
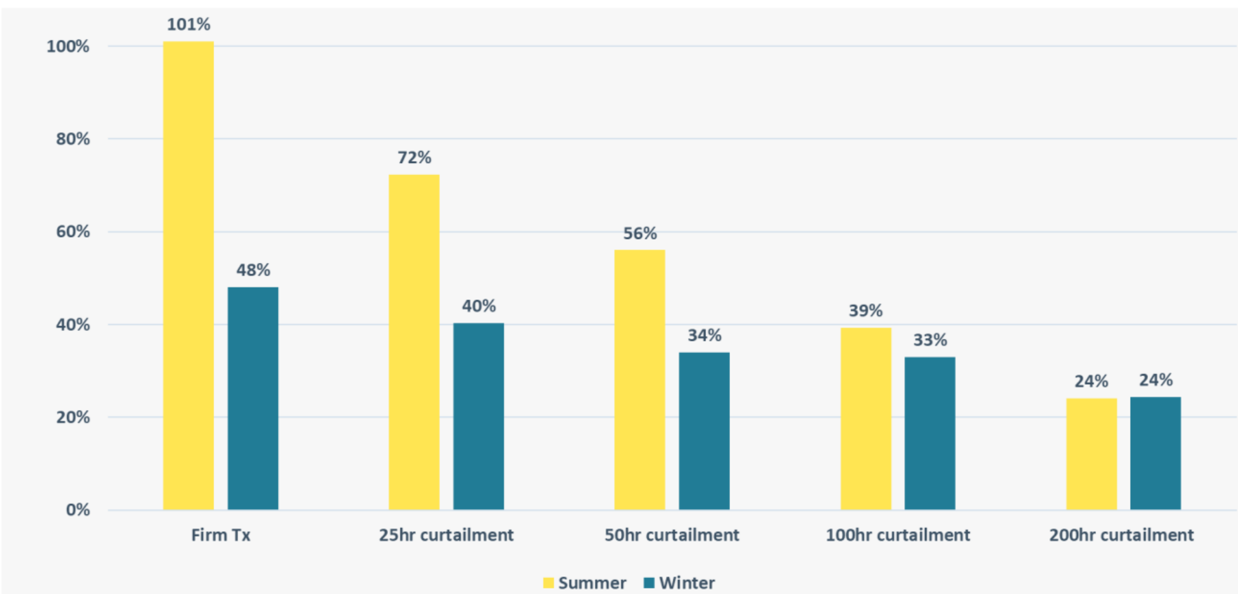


Figure 140. Conditional firm sensitivities, McMinnville Hybrid, 300 MW[484]



[484] ELCCs of over 100 percent can be achieved, typically due to the resource meeting need and providing energy for charging storage / saving hydropower.

PGE will continue to explore conditional firm transmission modeling options going forward. The CF200 modeling approach in the Reference Case, curtailing the top 100 load hours per year, is used due to uncertainty on modeling the product and a desire to maintain consistency with the 2021 RFP. Uncertainty on the CF200 transmission product arises since:

- Past curtailments are not a good indicator of future curtailments since sales of the CF200 product continue, leading to higher levels of transmission use
- BPA no longer posts conditional firm transmission available transmission capacity (ATC) inventories, making it challenging to assess future levels of system use
- BPA has not provided guidance on how to model the CF200 product

J.3 ELCC and resource characteristics

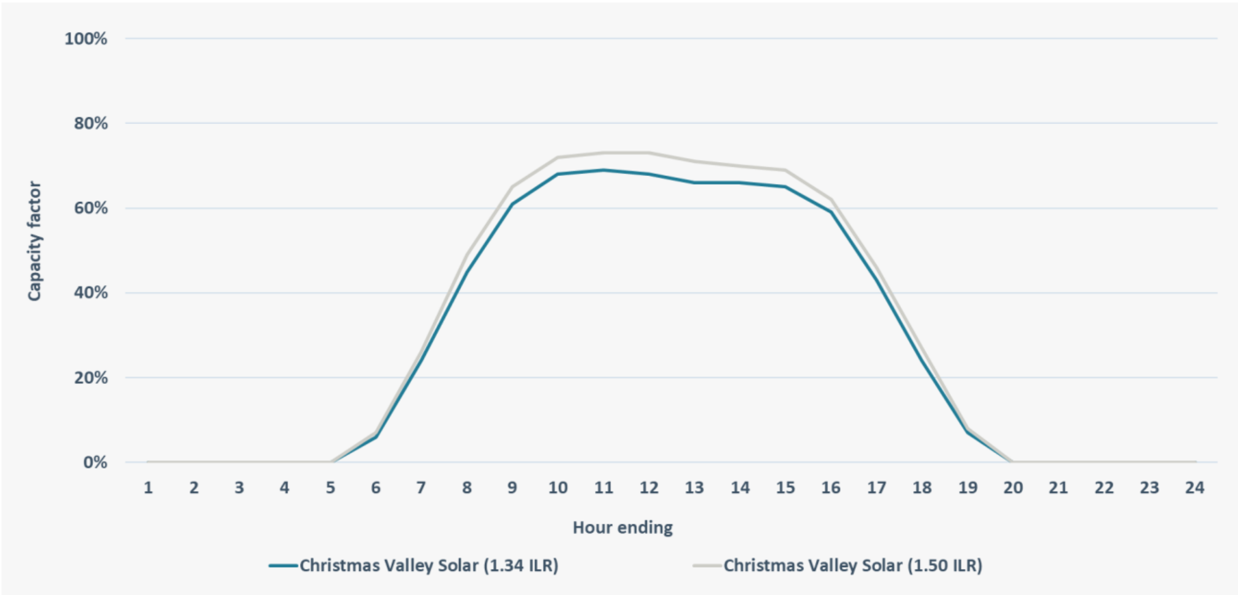
The 2023 IRP uses proxies to evaluate new resource options. These proxies are representative of new resources but do not represent the full range of options. To help study different solar facility specifications, the IRP tests the impact of solar inverter loading ratios (ILR) on ELCC values. A solar ILR describes the amount of DC solar panels in relation to the projects AC inverter. For example, a project with 134 MW of DC panel and a 100 MW AC inverter has an ILR of 1.34.[485]

Higher ILRs are beneficial for maximizing solar facility output. By collecting more solar irradiance, higher ILR facilities provide steadier/higher power output in cloudy conditions, during early morning and late evening hours, and higher output in the winter. During some hours, this higher output leads to clipping. Clipping occurs when the panels are capturing more solar power than the inverter size. Clipping generally increases when the ILR increases. The primary disadvantage to higher ILR for solar projects is higher costs due to the extra panels.

Figure 141 shows the annual hourly capacity factors of two solar facilities – one with the IRP default ILR of 1.34 and the other with a 1.50 ILR. Both sites use the Christmas Valley solar location. On an annual average basis, the 1.34 ILR project has a capacity factor of 28.0 percent, whereas the 1.50 ILR project is at 29.9 percent.

[485] 1.34 is the 2023 IRP default for utility scale stand-alone solar, utility scale hybrid projects in the IRP used a 1.50 ILR.

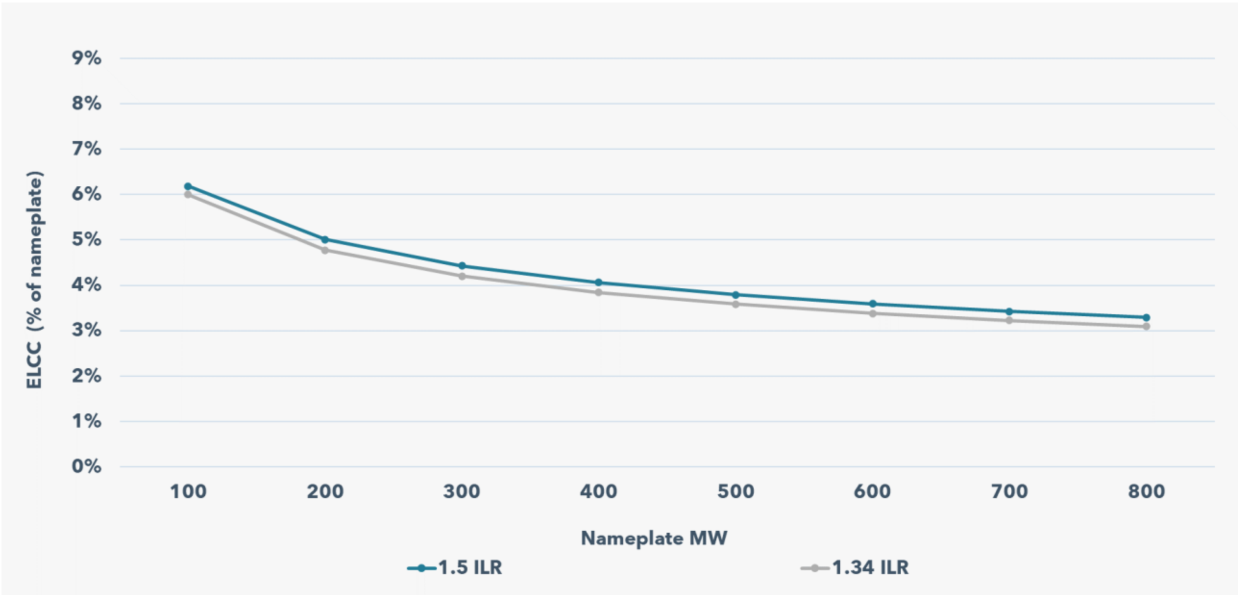
Figure 141. Annual hourly solar capacity factors by ILR



To test the impact of ILR on ELCC values, Sequoia analyzed both projects. The results are shown in **Figure 142** for 100 to 800 MW nameplate of resource added to the model. Over all eight resource tranches, the 1.50 ILR resource has higher ELCC values than the 1.34 ILR resource.[486]

[486] These tests ran with an earlier version of the Sequoia model. The ELCC values may not align with the final values in the IRP. The directionality of the values should be the focus for the reader. These results were shared in the April 2022 PGE Roundtable meeting.

Figure 142. Solar ILR ELCC test, Christmas Valley



For the 2023 IRP, PGE uses a stand-alone solar facility proxy with an ILR of 1.34 to comport with the NREL ATB data.[487] Additionally, the value of 1.34 is similar to values used by other Northwest utilities, as shown in **Table 132**. The table also includes the ILR value out of a more recent National Renewable Energy Laboratory (NREL) report, which moves the ILR down to 1.28. In part due to stakeholder requests, and in part due to DC coupling reducing the clipping issue, the utility scale solar-hybrid resource proxy has an ILR of 1.50.

Table 132. Inverter loading ratio in NREL and Northwest power planning documents

Source	Value	Notes
NREL 2020 ATB	1.34	Report released in 2021
NREL 2021 ATB	1.28	Report released in late 2021
PacifiCorp 2021 IRP[488]	1.30	Reduced from 1.46 in prior IRP based on industry trends - page 191

[487] The PGE IRP solar assumptions point to 2020 NREL data (released in early 2021). The 2021 NREL data (released in late 2021) use a solar ILR of 1.28. Available at: https://www.nrel.gov/docs/fy22osti/80694.pdf
[488] See page 191, available at: https://www.pacificorp.com/content/dam/pcorp/documents/en/pacificorp/energy/integrated-resource-plan/2021-irp/Volume%20I%20-%209.15.2021%20Final.pdf

Source	Value	Notes
Puget Sound Energy 2021 IRP[489]	1.20	"All solar resources were modeled with a DC to AC ratio of 1.2" - page 55 appendix D
Idaho Power 2021 IRP	1.30	Discussed in February 2022 UM 2022 PUC Staff meeting
PGE 2023 IRP value	1.34	Proxy resource based on 2020 Q1 NREL study
NWPCC 2021 Power Plan[490]	1.40	Samples a range of IRPs/studies – only source higher than 1.3 is PAC from 2019 IRP (PAC has reduced value since)

J.4 IRP portfolio creation ELCC ladders

The following figures show the ELCC values of IRP proxy resources out to 2,000 MW nameplate run in an untuned 2026 system for IRP portfolio creation purposes. ELCC values calculated in a tuned system are available in **Appendix K, Tuned system ELCCs**. **Figure 143** and **Figure 144** shows the ELCC values of wind resources in the IRP.

[489] Available at: https://www.pse.com/-/media/PDFs/IRP/2021/appendix/Appendix_B-M_Complete.pdf?sc_lang=en&modified=20220307202833&hash=EFC80E908F117D14A97A30322D88AFAC
[490] Available at: https://nwcouncil.app.box.com/s/kp0c6w5ivhqvge20bg3j40rsm13hyy1h

Figure 143. Summer wind ELCCs

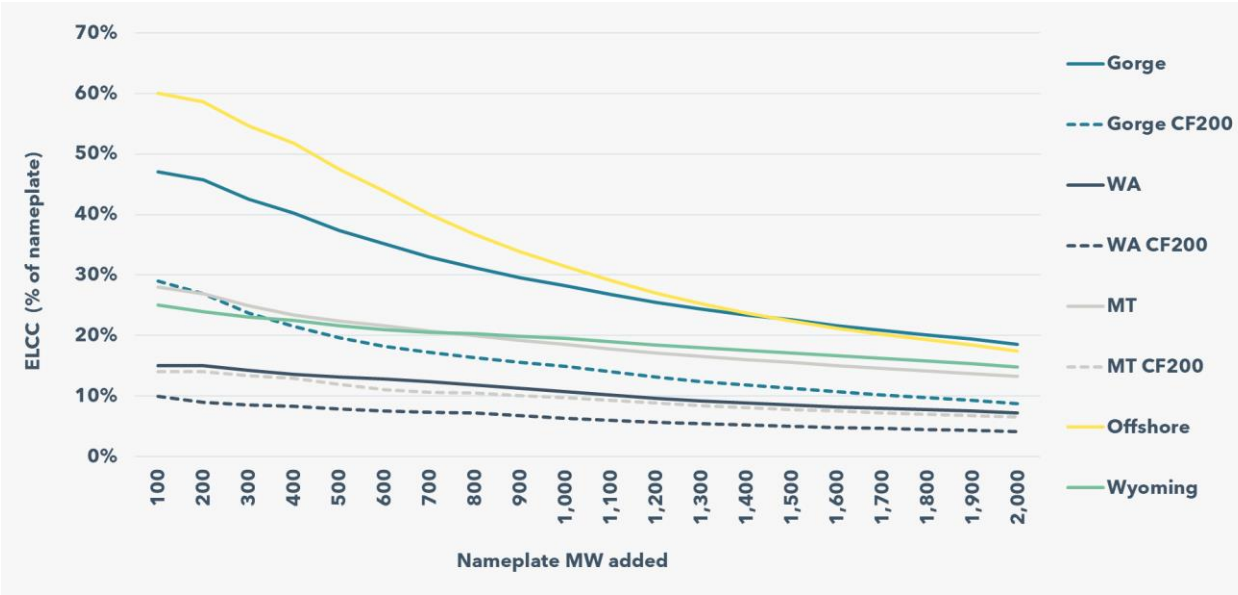


Figure 144. Winter wind ELCCs

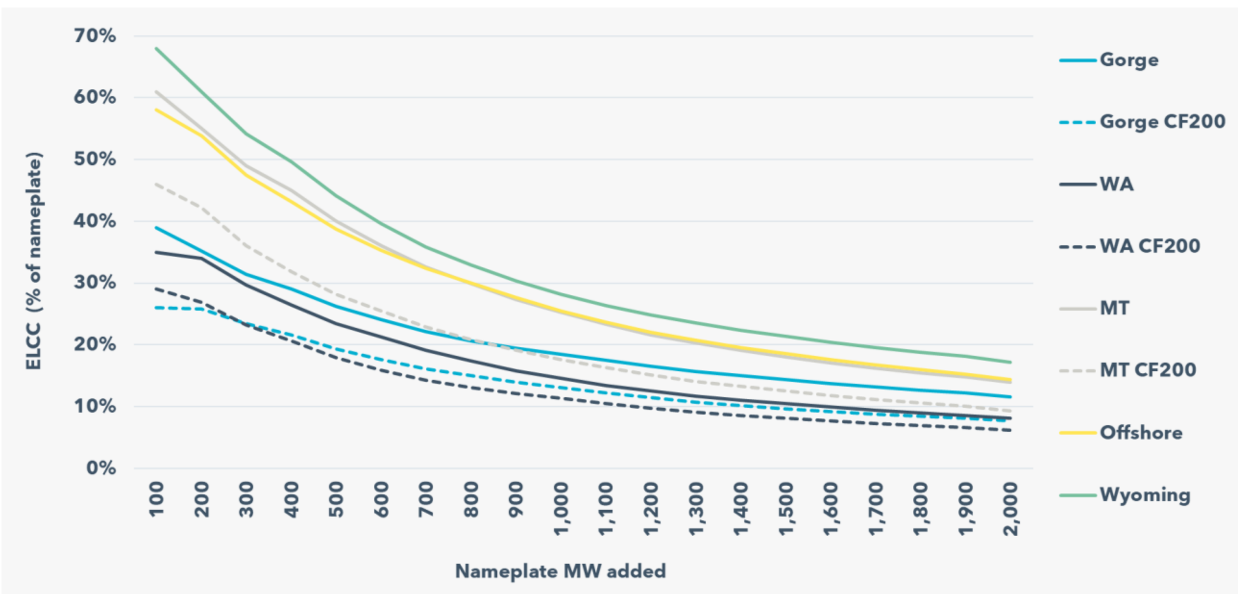


Figure 145 and **Figure 146** shows solar ELCC values in the 2023 IRP.

Figure 145. Summer solar ELCC

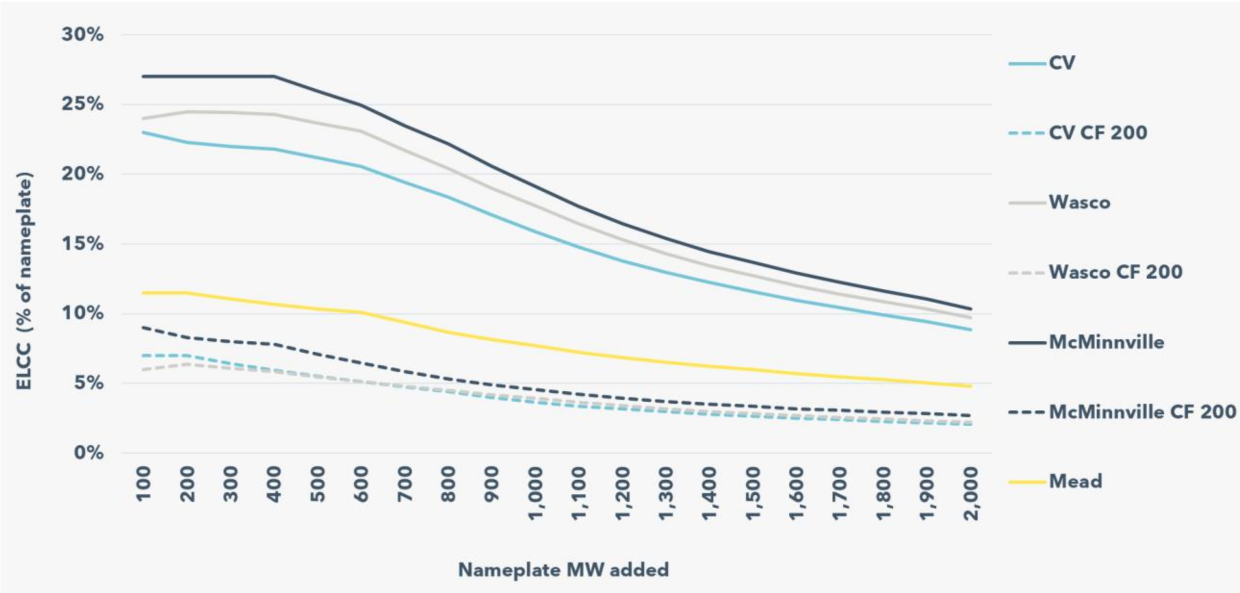


Figure 146. Winter solar ELCC

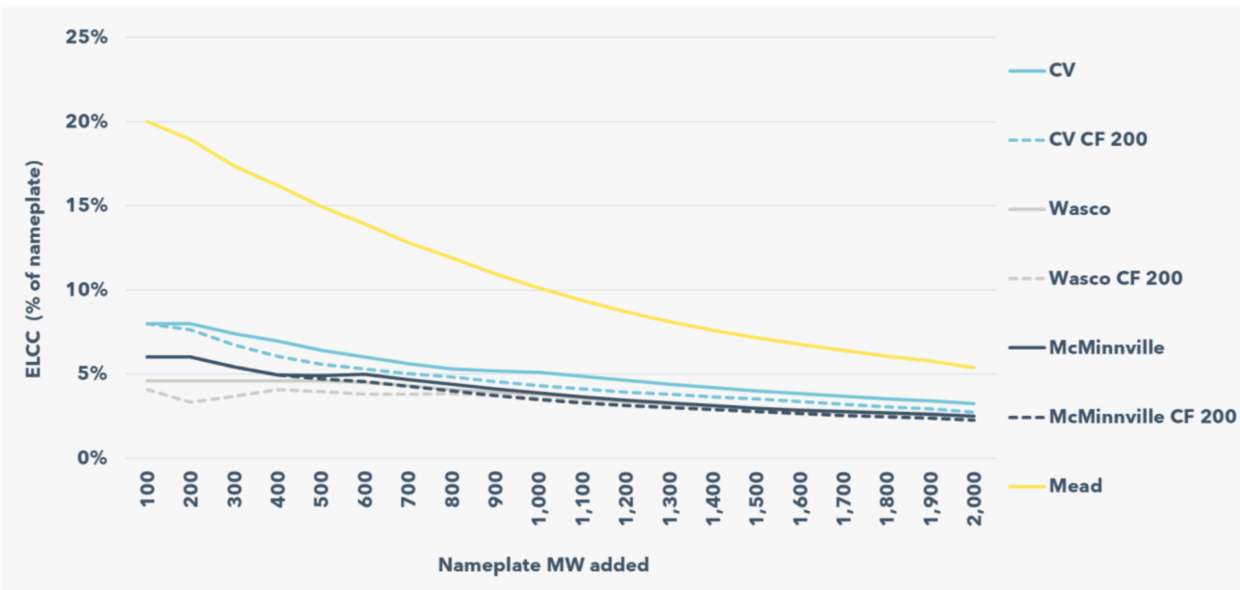


Figure 147 and **Figure 148** shows storage ELCC values.[491] Note that with pumped storage hydropower, the model entirely solves all adequacy issues before reaching the 2,000 MW

[491] Some resources, like pumped storage hydro, have ELCC values greater than 100 percent in the summer. This is generally due to the resource starting fully charged, bringing additional energy to the system.

nameplate of the resource. Once the model solves out, ELCC values are reduced by 1 percent for each subsequent 100 MW of resource.

Figure 147. Summer storage ELCC

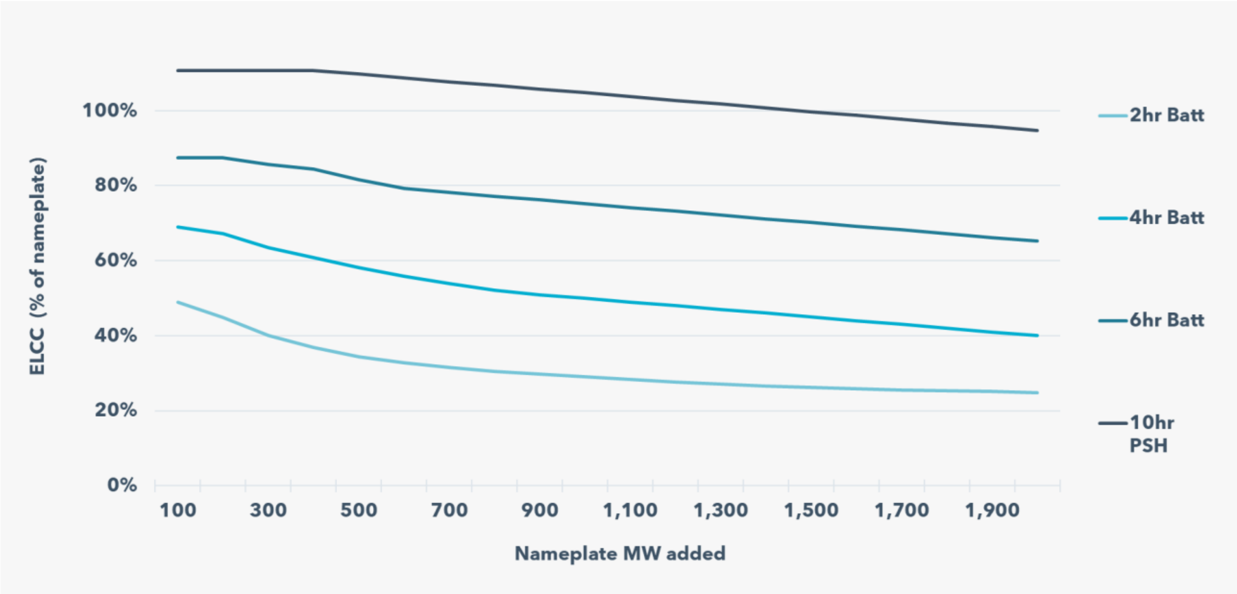


Figure 148. Winter storage ELCC

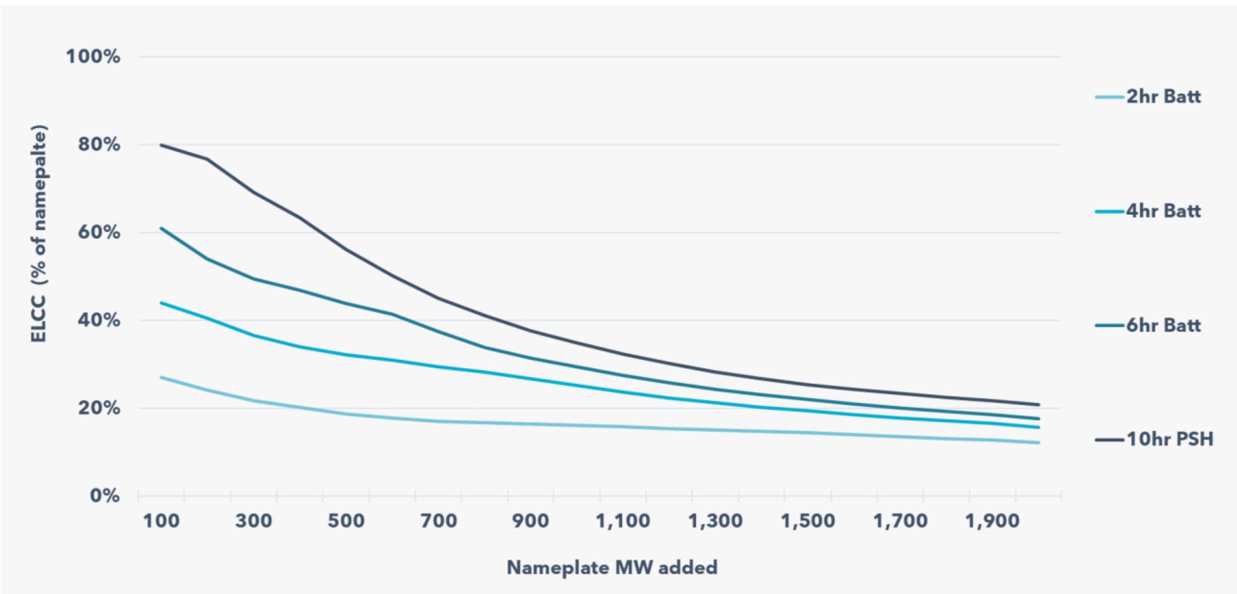


Figure 149 and **Figure 150** shows hybrid resource ELCC values. Some hybrid resources solve all adequacy issues before reaching the 2,000 MW nameplate of the resource. Once the model solves out, ELCC values are reduced by 1 percent for each subsequent 100 MW of resource.

Figure 149. Summer hybrid ELCC

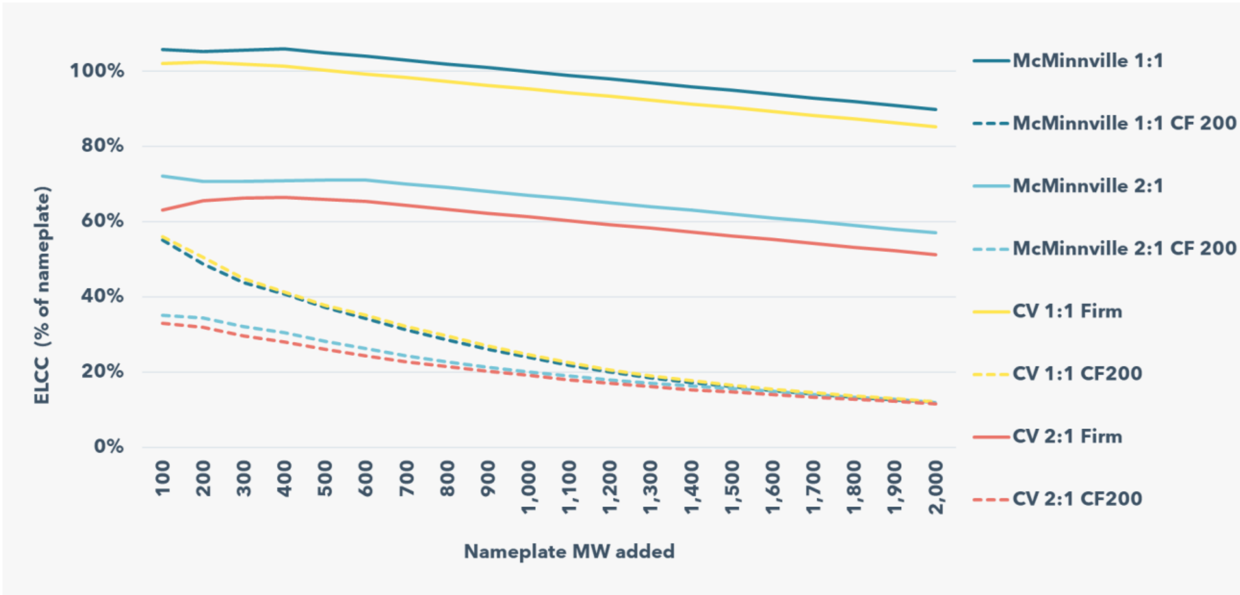


Figure 150. Winter hybrid ELCC