January 12-16, 2024, Cold Weather Event WRAP Retrospective

Western Power Pool (WPP) and its Participants partner in managing critically important reliability programs and together have a vested interest in ensuring safe and reliable grid operations. One of these programs is the Western Resource Adequacy Program (WRAP), the first regional resource adequacy program in the Western Interconnect.

The WRAP utilizes probabilistic methods to model variability in load, resource performance, and outages with the goal of establishing a sufficient Planning Reserve Margin (PRM) to meet a seasonal 1-in-10 Loss of Load Expectation (LOLE) reliability metric. Although the WRAP is currently non-binding (i.e., Participants are not charged for failing to cure resource adequacy deficiencies), the Participants and WPP are still continually looking for ways to refine design decisions with real-world experience.

The Northwest cold weather event of January 12-16, 2024 ("event") provided the WPP and WRAP Participants an opportunity to understand how actual load, resource, and forced outage performance in the WRAP Operations Program for Winter 2023-2024 compared to the reliability and resource accreditation modeling that began in the Advance Assessment for that season in January 2021. WPP has subsequently performed a detailed analysis to determine whether there would have been sufficient WRAP-obligated capacity in a binding season during the eight highest load hours on each day of the five-day event, assuming all Participants had successfully met their Forward Showing Capacity Requirements by the end of May 2023. It is important to understand that this analysis is only as accurate as the data provided to WPP. WPP and WRAP Participants are working together to continually improve data quality so both the non-binding WRAP Forward Showing and Operations Programs and after-the-fact analysis use the best data available.

To support this analysis WPP worked with WRAP Participants over the last several months to gather detailed after-the-fact data on load, resource-specific performance, resource-specific forced outages, and operational drivers of the storage hydro system. This additional data request was necessary because, at present, WRAP only requires Participants to provide aggregated data to the WRAP Operations Program. The event highlighted the need for additional data granularity and transparency to support detailed analysis and conclusions. Going forward, WRAP Participants have committed to continuing to provide similar, more granular data as part of the Revised Transition Proposal (2024-EP-1) that was recently approved by the WPP Board. As the Program anticipates its first binding season in 2027, WPP is committed to making this type of event analysis available sooner, particularly for significant regional events.

This retrospective focuses mainly on the resource and load data for those Participants in the WRAP MIDC Subregion. Data was collected from Participants in the WRAP Desert Southwest

Subregion but was not included in this analysis in the first four sections as those Participants are generally summer peaking. Participants provided after-the-fact actual data used for this analysis. The Sharing Calculation in the WRAP Operations Program uses forecast data for these values from the Preschedule Day. To focus the analysis on the most critical periods of each day, data from the top eight load hours of each day during the event were utilized. These eight hours were derived by summing the load from the twelve Balancing Authorities (BAs) in the MIDC Subregion, grouping them by day, sorting them from highest to lowest and taking the top eight. This analysis assumed all Participants met their Forward Showing Capacity Requirement (P50 Peak Load Forecast and PRM), as is the expectation of Participants in a binding WRAP.

The event report has four main sections relating to the Sharing Calculation and includes an appendix with a discussion on Storage Hydro performance:

1. Resource Performance: this section focuses on actual resource performance versus the calculated Qualifying Capacity Contribution (QCC) by resource class as accredited in the WRAP Advance Assessment and Forward Showing.
2. Unit Forced Outages: this section compares actual forced outages versus forced outages assumed in the Advance Assessment and Forward Showing.
3. Load: the third section compares actual load with the 1-in-2 load (P50 Peak Load Forecast) used to set the Forward Showing Capacity Requirement.
4. Utilization of Available Capacity: this concluding section brings together the previous three to provide an indication of whether there was sufficient capacity in the MIDC Subregion to absorb differences resulting from planned versus actual resource performance, forced outages, and load variability as well as Contingency Reserve requirements and Uncertainty.

Appendix. Storage Hydro Performance: this appendix focuses on the performance of Storage Hydro resources. While Storage Hydro forced outages are an input into the Sharing Calculation any changes in anticipated performance are not, which is why this is discussed after all the Sharing Calculation inputs.

1. Resource Performance

Wind

Figure 1 shows the Wind generation output for the top eight load hours of each of the five days from January 12-16, 2024. The black line depicts the Wind QCC value calculated in the WRAP Advance Assessment using Effective Load Carrying Capability (ELCC) while the blue columns show the actual Wind output during each hour. Any MWs above the black line are considered overperformance and is capacity available to the WRAP Operations Program (assuming it is not needed to meet an individual Participant's own load, Contingency Reserve or Uncertainty requirements). Any MWs below the black line are considered underperformance (i.e., less capacity was available to the Operations Program than assumed during the Forward Showing) and has the effect of decreasing a Participant's Sharing Calculation result, potentially making them eligible for assistance in the Operations Program. Wind resources make up 12.11% of the total nameplate resources used in the WRAP modeling of the MIDC Subregion for Winter 2023-2024 as performed in the summer of 2022.

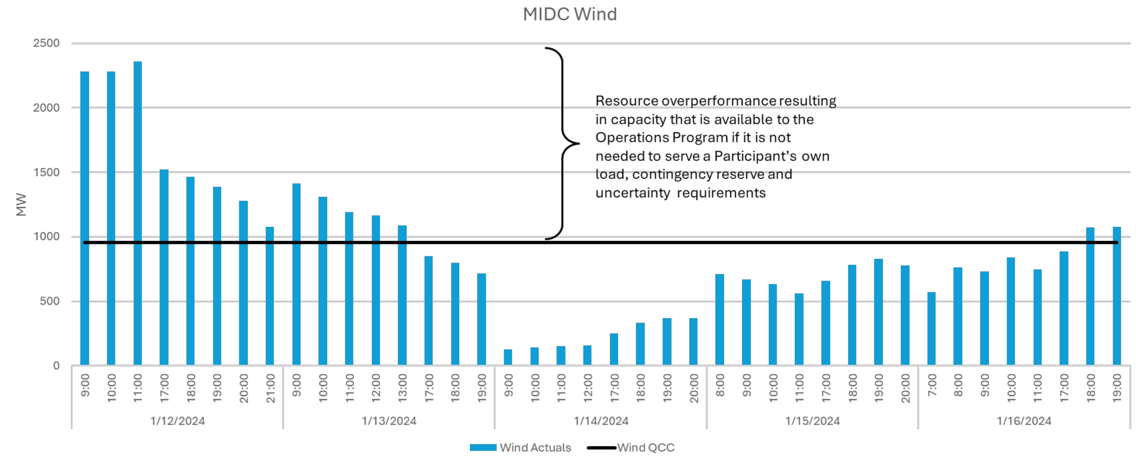

Figure 1. MIDC Wind generation output relative to the capacity value accredited in the Advance Assessment and Forward Showing (QCC value)

Solar

Figure 2 displays the MIDC Solar performance, showing the generation output over the selected hours (as described above) compared to the Solar ELCC calculated in the Advance Assessment. Solar resources make up 2.16% of the total nameplate resources used in the WRAP modeling of the MIDC Subregion for Winter 2023-2024 as performed in the summer of 2022.

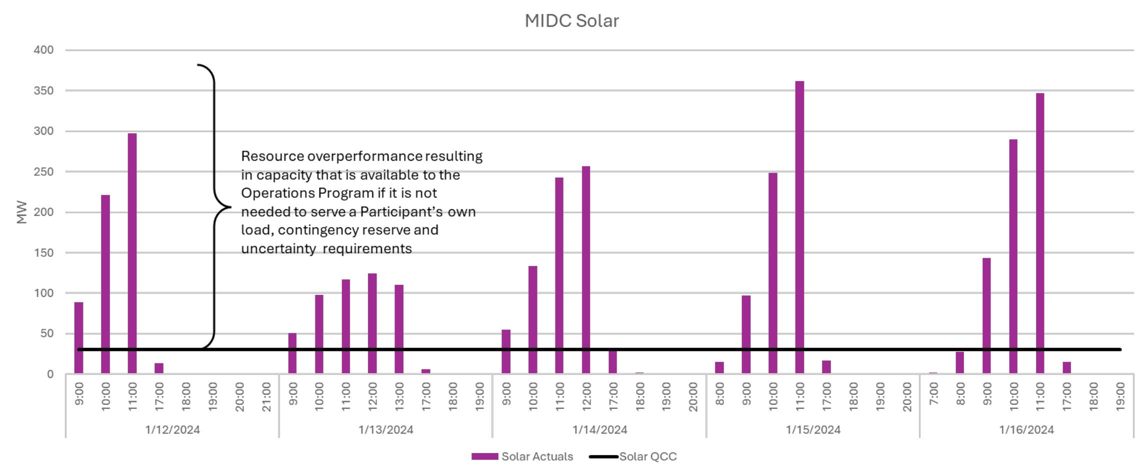

Figure 2. MIDC Solar generation output relative to the capacity value accredited in the Advance Assessment and Forward Showing (QCC value)

Run-of-River

Figure 3 displays the run-of-river (ROR) generation output compared to the ROR QCC as calculated in the Advance Assessment. Unlike other variable energy resources, ROR resources are accredited based on average monthly output over the Capacity Critical Hours (CCHs) in the ten-year dataset utilized by WRAP. During this five-day event, the small sample size of ROR resource generated consistently less than accredited. Although ROR resources represent only 5.43% of the total nameplate resources used in the WRAP modeling of the MIDC Subregion for Winter 2023-2024 as performed in the summer of 2022, WPP plans to monitor the performance of ROR during future events to determine whether the capacity accreditation methodology should be refined to better reflect actual performance. As a note, ELCC accreditation for ROR resources was previously tested and considered for the WRAP design but was determined to not be the best accreditation methodology for this resource type.

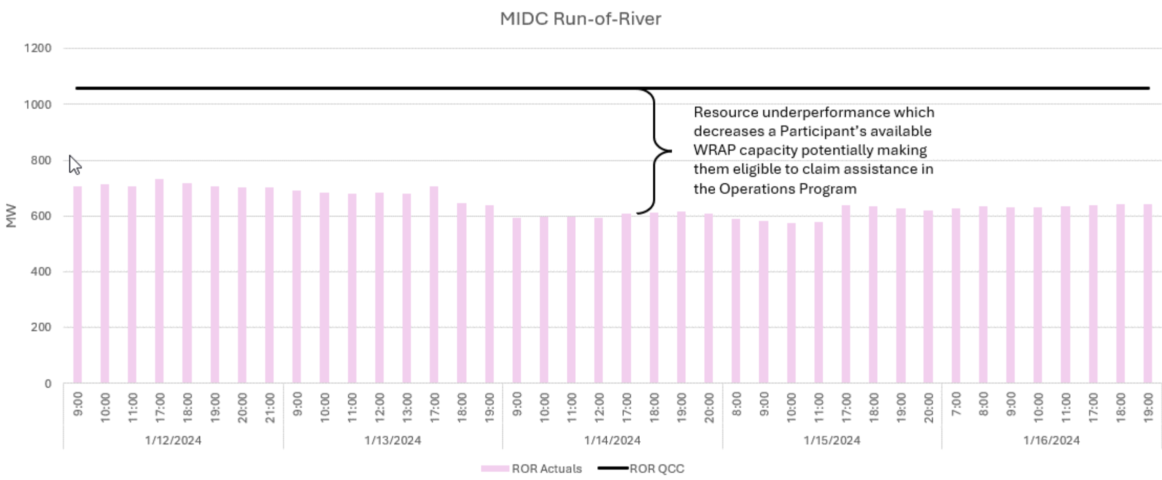

Figure 3. MIDC Run-of-River Hydro generation output relative to the capacity value accredited in the Advance Assessment and Forward Showing (QCC value)

2. Unit Forced Outages

Please note that while the figures in Section 1 showed resource performance (i.e., above the black line indicates more resource availability), the figures in this section show resource forced outages (i.e., above the black line indicates less resource availability).

Storage Hydro

One of the unique characteristics of storage hydro resources (which represent 62.21% of the total nameplate resources used in the WRAP modeling of the MIDC Subregion for Winter 2023-2024 as performed in the summer of 2022) is that due to fuel (water) considerations, operating conditions, and reservoir levels, there is not always a one-for-one reduction in QCC resulting from a forced outage (i.e., if a unit is forced out, but there is not enough water for it to run in addition to those units still available, the forced outage does not have an impact on the overall capacity of the hydro plant). The Resource Adequacy Participants Committee's (RAPC) Storage Hydro User Group (SHUG) developed a tool to calculate the effect of a forced outage on Storage Hydro QCC, but that tool was not available at the time of the Forward Showing for Winter 2023-2024 which took place between April and July of 2023.

For the purposes of this event analysis Participants were asked to provide the number of nameplate MWs that were unavailable during the event due to a forced outage or derate, rather than asking Participants to retroactively apply the tool to the Winter 2023-2024 Forward Showing data (which would be rather time consuming and not reflective of the data used at the FS Deadline). As noted above, using nameplate MWs versus QCC MWs likely means that the impact of forced outages would be overstated (some of the reported nameplate forced outages would not be forced outages in the current methodology, which accounts for lack of fuel/water). To correct for this overstatement, in this analysis the nameplate forced outage MWs were multiplied by the average % QCC of storage hydro resources as a proxy for the updated methodology developed by the SHUG.

Figure *4* indicates there were more forced outages in actuality than the historical forced outage factor would indicate, meaning that less capacity was available to the MIDC Subregion during the event than was assumed in the Forward Showing planning phase.

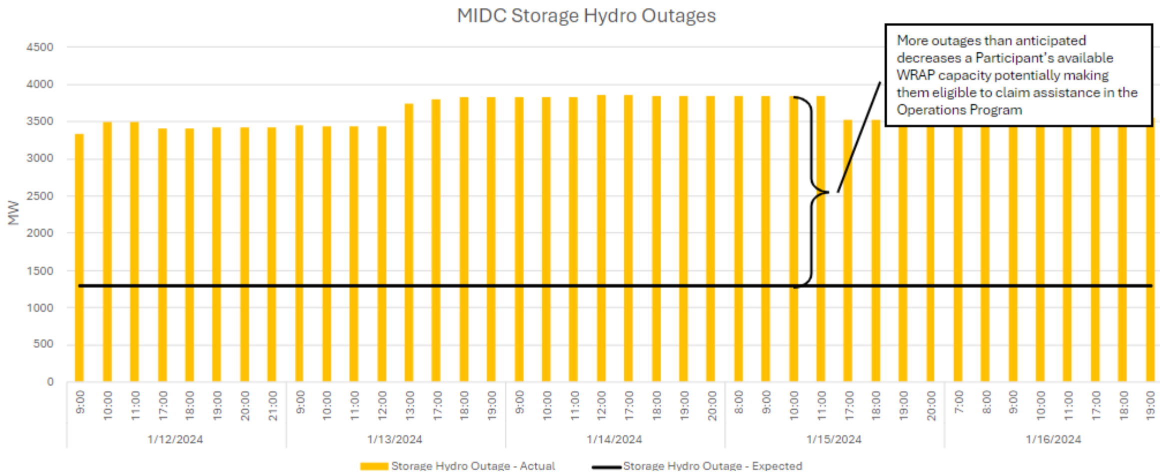

Figure 4. Actual Storage Hydro forced outages relative to Storage Hydro outages assumed (based on historical information) in the Advance Assessment and Forward Showing. More forced outages means that less capacity was available to the region than expected in the Forward Showing.

Thermal

Conversely, Figure *5* shows the actual aggregate Thermal resource forced outages was lower than the total historical forced outages calculated in the Advance Assessment, meaning that more capacity was available to the region from Thermals than expected at the Forward Showing.

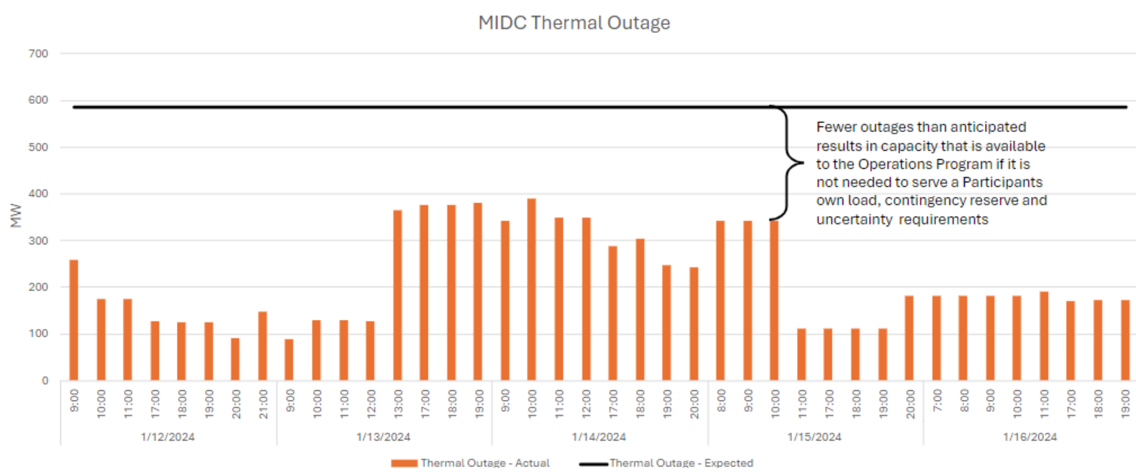

Figure 5. Actual Thermal forced outages relative to thermal forced outages assumed (based on historical information) in the Advance Assessment and Forward Showing. Less forced outages means that more capacity was available to the region than expected in the Forward Showing

3. Load

Load values during the event, as shown in Figure 6, were greater than the 1-in-2 load (P50 Peak Load Forecast) utilized in the Forward Showing for all hours analyzed, meaning Participants were more likely to be eligible for assistance in the Operations Program.

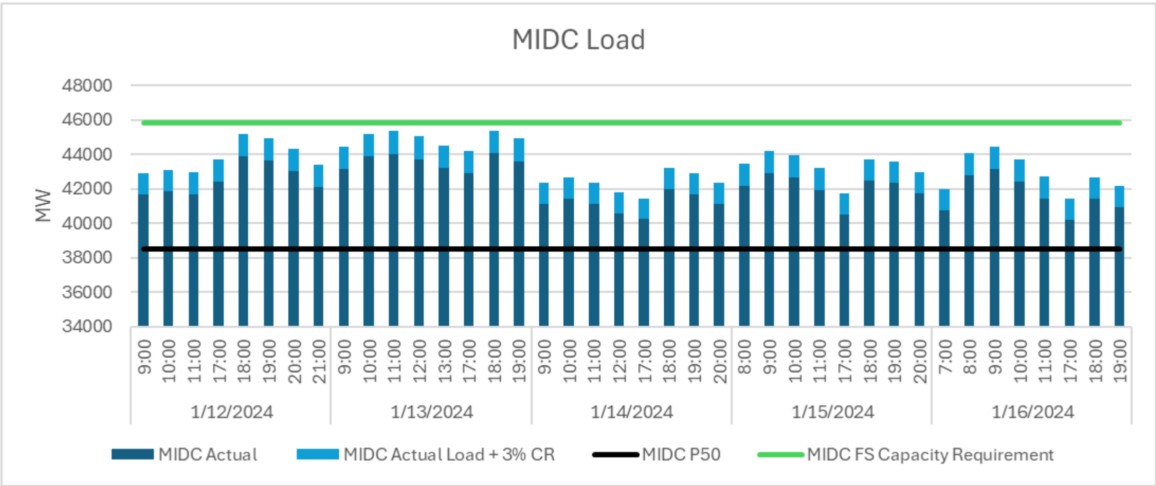

Figure 6. MIDC Load relative to sum of Participants' 1-in-2 peak (P50) loads.

4. Utilization of Available Capacity

The data from the previous sections can be compared to the top eight load hours of each day during the event to show that there was a net negative difference ranging from 3.8 GWs to 8.1 GWs between the values in the Forward Showing and actual values observed during the event.

The WRAP Sharing Calculation is shown below. The term "P50 Peak Load Forecast * (1 + PRM)" is the Forward Showing Capacity Requirement and represents the capacity a Participant should be bringing from the Forward Showing planning phase into the Operations Program. Positive values for the performance adjustments for forced outages, ROR and VERs increase a Participant's available capacity. The Load, Contingency Reserve, and Uncertainty terms (in MW) represent capacity that must stay with Participants to meet their individual requirements. If a Participant's Sharing Calculation is overall positive, they are eligible to potentially share with Participants that have a negative Sharing Calculation result in the Subregion.

Sharing Calculation =
P50 Peak Load Forecast * (1 + PRM) +
(Δ Forced Outages + Δ ROR + Δ VER) –
Load –
Contingency Reserves –
Uncertainty Factor

Note that the WRAP utilizes an Uncertainty Factor that keeps capacity with a Participant to account for the variability between the Preschedule Day forecasts and the actual need on the operating hour (i.e., helps minimize their risk of exposure). Given that this analysis is performed on actual data here, the Uncertainty Factor is not included.

Figure 7Figure 7 shows the Sharing Calculation (without the inclusion of an Uncertainty Factor) for the top eight load hours of each day during the event. On hours where the Sharing Calculation is negative, there would not have been enough capacity obligated by the WRAP Operations Program to meet all the calculated need. Participants can of course be calculated deficient while actually possessing surplus capacity beyond the requirements from WRAP; those needing additional capacity may also turn to markets (bilateral or future organized markets) to procure available surplus from neighbors within the region or from others outside the Northwest. Nevertheless, if all deficient MIDC Participants had opted-in to receive assistance, they would have needed to rely on voluntary capacity offered into the program that is in addition to the obligations calculated by the Sharing Calculation.

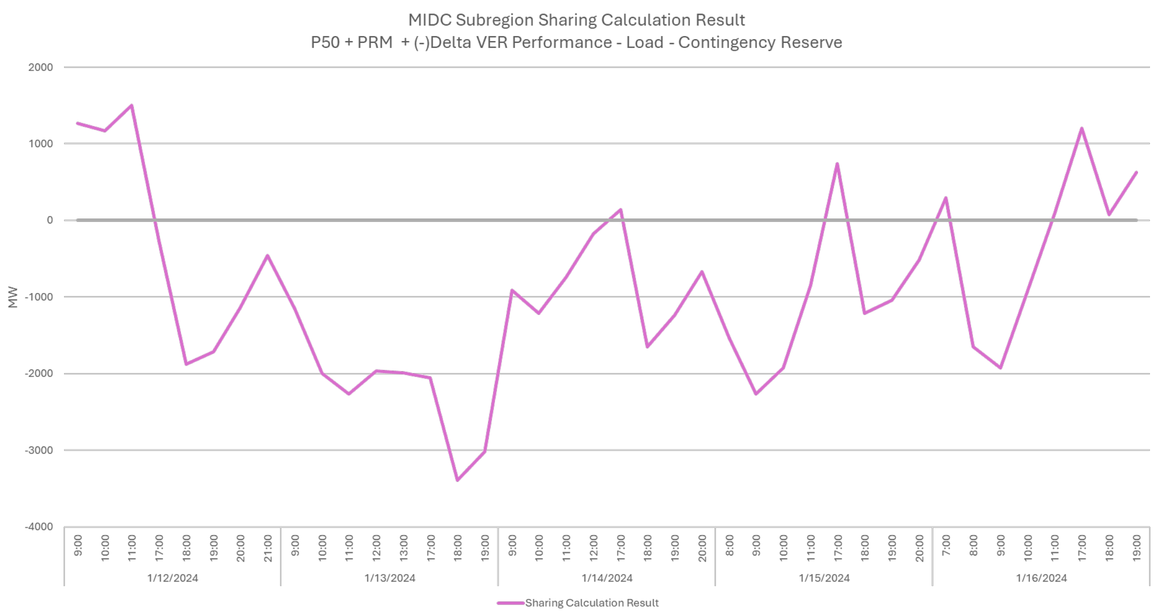

Figure 7. MIDC Subregion Proxy Sharing Calculation Result

In summary

- Without the benefit of capacity available from within the WRAP MIDC Subregion beyond WRAP requirements (i.e., Participants' own surplus or voluntary supply to the Operations Program) or imports, the combination of loads and resource performance would have resulted in conditions worse than those anticipated by the seasonal 1-in-10 reliability metric.

- It is critical to have a binding program with a broad geographic footprint and operational mechanisms to unlock diversity, both of which are a high priority for the WPP and WRAP Participants. WRAP does not currently have a mechanism for obligating capacity sharing between the two Subregions (Northwest/Mid-C and Southwest/SWEDE), but imports from outside the WRAP were available and essential for maintaining reliability during this event.
- Given that WRAP only calls on capacity relative to the 1-in-10 LOLE study, and Participants that have surplus can offer their additional capacity into the program, the ability to offer that voluntary supply that is above a Participant's Forward Showing Capacity Requirement is an important feature of the WRAP design and implementation, especially considering the nature of the stand-alone RA program.
- Continual and proactive monitoring of program performance is essential to ensuring the WRAP can deliver on its reliability goal. Access to timely and granular data is critical to such monitoring and to the functioning of the WRAP, particularly as it relates to the ability of WPP, Participants, and stakeholders to evolve the design of the program in response to these events.

Appendix: Storage Hydro Performance

In addition to reviewing the event by looking at the inputs to the WRAP Sharing Calculation, the WRAP Participants were particularly interested in the performance of Storage Hydro. As stated above, the Sharing Calculation takes into account Storage Hydro forced outages (and forced outages of all other resources) but does not include a term to account for Storage Hydro performance relative to expected performance (i.e., relative to its calculated QCC value). The decision to exclude Storage Hydro performance from the Sharing Calculation ensures that Participants' operational and water management decisions do not impact access or obligation to the shared pool of capacity in the Operations Program. The only resources with performance terms in the sharing calculation are variable energy resources (including wind, solar, or run-of-river) where fuel and fuel management for the resources has less Participant discretion.

Despite Storage Hydro performance data not being included in the WRAP Operations Program, WPP and WRAP Participants are interested in how the capacity accreditation methodology used for the Forward Showing compares to actual capacity of Storage Hydro plants during critical events. WRAP Participants with Storage Hydro resources in both Subregions provided performance data, including generation output (hourly), maximum capacity (hourly), and Forward Showing QCC (monthly). Figure 8 shows the aggregated Storage Hydro performance data over the top eight load hours for each day from January 12-16, 2024.

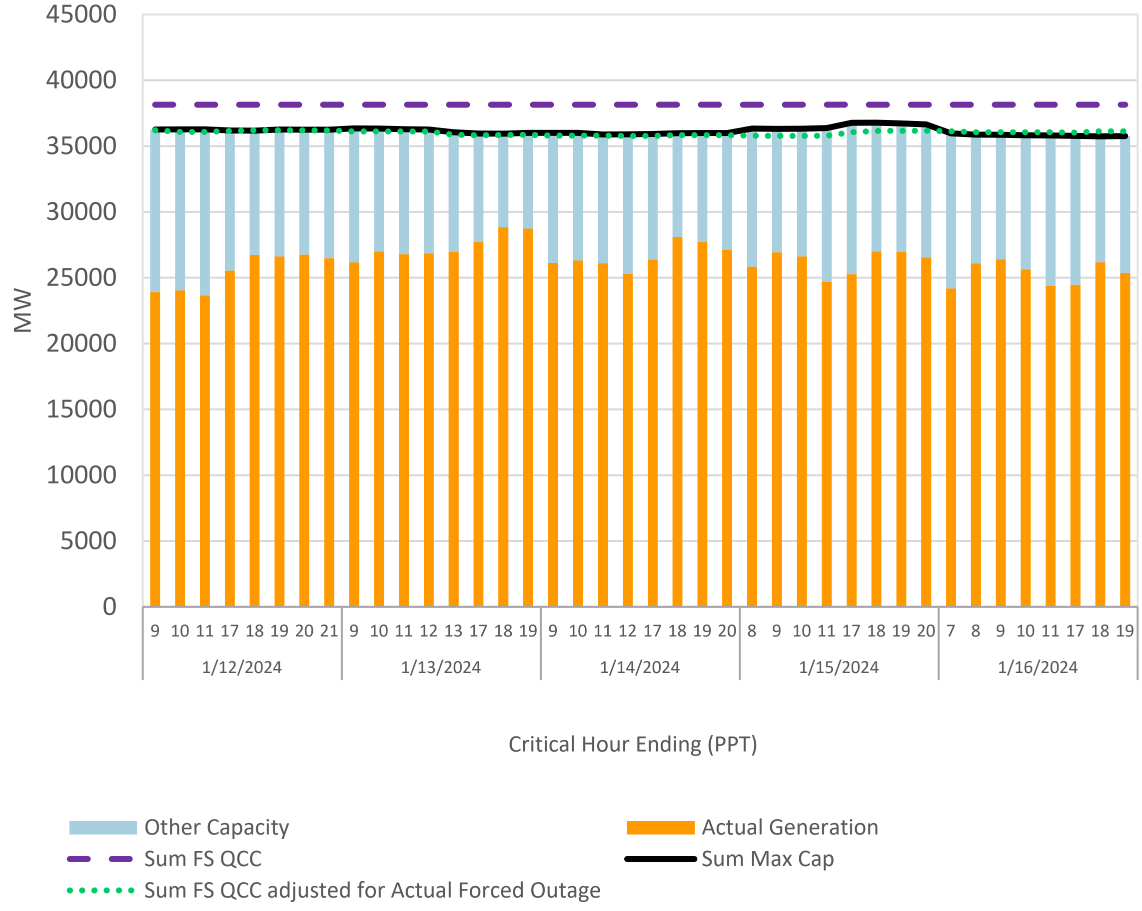

Figure 8. Storage Hydro actual generation and maximum capacity where 'other capacity' includes capacity available for reserves, load following, ramping, and uncertainty, etc.

There are two primary observations for further discussion. The first is the QCC value calculated in the Forward Showing is greater than the actual maximum capacity value reported for each of the top eight load hours of each day by at least 1300 MWs in aggregate. The difference between actual maximum capacity value and the QCC is almost entirely attributable to forced outages as noted in Section 2 above. The second is that during the event, the actual generation in aggregate was consistently less than the calculated QCC by at least 7000 MWs. While the magnitude of the difference is larger, this is not especially surprising and does not necessarily indicate a methodological issue – rather, it is likely a result of operational decisions (especially the expected use of Storage Hydro to carry reserves), the current non-binding nature of the WRAP, and other non-power priorities. Both observations are discussed below.

To further consider the first observation, included is a quick review the Storage Hydro QCC methodology: the methodology is based on the ability of Storage Hydro resources to maximize output during the capacity critical hours (CCHs), subject to operational limitations (such as available water in storage and all constraints that restrict the use of the Net Generating Capability) and non-power constraints (including, but not limited to, discharge limits, tailrace and forebay elevation limits, and rate of change limits of each plant). The methodology considers each resource's historical generation output, residual generating capability, water in storage, reservoir levels (if applicable), upstream discharge from cascaded dual plants, plant constraints, and historical forced outages over the most recent 10-year historical period. The QCC calculation of the Storage Hydro resource is based on how much historical generation could have been increased during CCHs through utilization of water in storage each day of the historical record, while respecting all operating constraints. The QCC is the monthly average of this hypothetical increased generation during the CCHs, for the same month of the historical record. The resulting QCC is determined as the average contribution to the CCHs for each Winter Season and Summer Season over the previous 10 Years. Participants then have the flexibility to walk down their Storage Hydro QCC in the Forward Showing if they believe the methodology does not accurately reflect their operational constraints. More information can be found in Business Practice Manual 105 Qualifying Resources.

In Figure 8 the aggregate Storage Hydro QCC line (the sum of all QCCs for Storage Hydro resources included by Participants in their Winter 2023-2024 Forward Showings for the month of January) is the purple-dashed top line while the maximum capacity line (summing the actual maximum capacity for each hour reported by Participants for the same Storage Hydro plants) is above it in solid dark blue. The green dotted line is the sum of the QCC values corrected for the actual forced outages during the event (the yellow bars above the black line in *Figure 4*); recall that the Storage Hydro QCC Methodology uses historical forced outages from the last 10 years, but the WRAP Sharing Calculation allows Participants experiencing higher than expected forced outages to include those to potentially increase their access to program capacity. It can be seen that most of the gap between the purple dashed line (sum of QCCs) and the black line (sum of maximum capacity) is due to higher than expected forced outages during this event.

In some hours, specifically on January 16, 2024, there is still a small gap between the sum of QCC adjusted for actual forced outage (green dotted line) and the sum of maximum capacity (black line). There are a few potential reasons for small gap: the Storage Hydro QCC methodology averages over a long period (10 years) while this analysis is a snapshot of a single event, and a project's ability to achieve maximum capacity varies with factors like net head, derates, outages, etc., so some variation around the average can be expected given the methodology and planned outages on Storage Hydro units during this time – this is permitted under WRAP so long as the Participant utilizes other capacity (e.g., from their surplus QCC or through a purchase) to fill the gap left by the planned outage, but may lead to a different resource portfolio from what was demonstrated at the time of the Forward Showing (this would show in this analysis as decreased capacity without context of replacement capacity procured).

As noted previously, Storage Hydro performance is not taken into account in the Operations Program sharing calculation to determine access to the WRAP capacity pool. This means any overstatement of Storage Hydro QCCs to meet the Forward Showing Capacity Requirement would be the responsibility of the Participant to resolve before accessing WRAP capacity (e.g., from additional surplus from their portfolio or imports), providing ample motivation to Participants and WPP alike to ensure accreditation is accurate. While much of the gap between the sum of QCC (purple dashed line) and sum of maximum capacity (black line) is explained by the actual forced outages during this event, Participants in the WRAP are committed to reviewing their QCC values before each Forward Showing, and specifically in light of events like the one in mid-January 2024, and making adjustments to their QCC values and forced outage information to ensure alignment when necessary.

Regarding the second observation, the actual generation (orange columns – representing sum of actual energy generation in each hour for the same Storage Hydro resources) in Figure 8 is consistently lower than the maximum capacity (solid blue line) throughout the event, with a minimum of around 7000 MWs in aggregate during the top 8 load hours of each day. However, it is important to note that energy production is far from the only reliability use of Storage Hydro resources – other uses include carrying operating reserves, ramping, and planning for uncertainty in supply and load (all of which are likely carried on Storage Hydro resources when possible). Storage Hydro resources generating less energy than their maximum capacity may still be fully utilized for reliability purposes.

Therefore, some practical reasons for this difference include Participants carrying reserves on Storage Hydro plants (intentionally not maximizing generation due to other reliability objectives), managing for longer-term energy requirements over the cold spell, or the averaging out of generation within the hour (i.e., a plant may have been running at maximum capacity for 30 minutes, then ramped down to follow load – the average would be displayed here). During the event, WRAP was in a non-binding phase, so there was no obligation on Participants to share excess capacity during the hours shown in Figure 8. It is conceivable that during binding operations, obligations in the Operations Program could signal Participants to manage their Storage Hydro differently, potentially increasing energy output on some high-load hours if operational flexibility was available.

Further, this analysis did not assess these more granular operating decisions, nor does WRAP request or review performance of other resources that do not impact the sharing calculation (actual energy generation from Thermal resources or contracts, for example). In fact, WRAP never dictates how Participants operate their resources – in binding WRAP operations, regardless of whether actual output from particular resources differs from QCC or maximum capacity, Participants will be responsible for the capacity value of those resources (either to serve their own load or the pool). Participants are always welcome to meet their capacity obligations in alternative ways (economic imports, running other resources, etc.).

In conclusion, while it is informative to look at the Storage Hydro generation output and maximum capacity over the cold weather event of January 12-16, 2024, there are significant unknowns regarding whether this is a good proxy for how Storage Hydro would perform under a binding WRAP with binding Forward Showing and Operations Program. Further, analysis from the perspective of the WRAP program is necessarily limited to capacity accreditation relative to a FS

Capacity Requirement, while acknowledging the multitude of non-generation reliability services provided by all dispatchable resources (including Storage Hydro). While WPP and WRAP Participants are committed to continually monitoring performance of Storage Hydro resources during critical events and collecting data regarding the program, any analysis will be constrained by the quality of the data.

For more information, visit https://www.westernpowerpool.org/about/programs/western-resource-adequacy-program or contact wrap@westernpowerpool.org.