SPP Southwest Power Pool
MARKET MONITORING UNIT

Southwest Power Pool
WESTERN ENERGY SERVICES

FREQUENTLY CONSTRAINED AREAS 2024 STUDY

DECEMBER 2024

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1 EXECUTIVE SUMMARY

Frequently Constrained Areas are areas of the market footprint that experience both high levels of congestion and are associated with one or more pivotal suppliers. A supplier is pivotal when some or all of its output is necessary for reliable operation of the electrical system within a defined area. The SPP Western Imbalance Service Tariff[1] defines Frequently Constrained Areas as:

> "an electrical area identified by the Market Monitor that is defined by one or more binding transmission constraints that are expected to be binding for at least five hundred (500) hours during a given twelve (12)-month period and within which one (1) or more suppliers are pivotal."

The SPP Market Monitoring Unit (MMU) analyzed real-time market data from October 1, 2023, through September 30, 2024. Additionally, the MMU evaluated recent trends through October 31, 2024. Based on our analysis, the MMU proposes Yellowstone, Montana as a Frequently Constrained Area (FCA). This area includes two unique resources.

The decrease in Frequently Constrained Areas results from an adjustment to the candidate area that was studied. The Yellowstone, Montana FCA represents the same area as identified by both Great Falls, Montana and Billings, Montana FCAs in the previous study. However, this FCA is determined by one constraint and impacts two resources which fall within a single BAA (WAUW). The results of this study are like the 2023 Frequently Constrained Area report, where various Upper Great Plains West (WAUW) constraints constituted a significant portion of the binding and pivotal supplier hours.

[1] SPP Western Imbalance Service Tariff Att. B Section 3.1.1 (Frequently Constrained Areas)

The SPP Market Monitoring Unit reevaluates the Frequently Constrained Area designations at least annually.[2]

Figure 1-1 Pivotal supplier hour heat map with Frequently Constrained Area resources

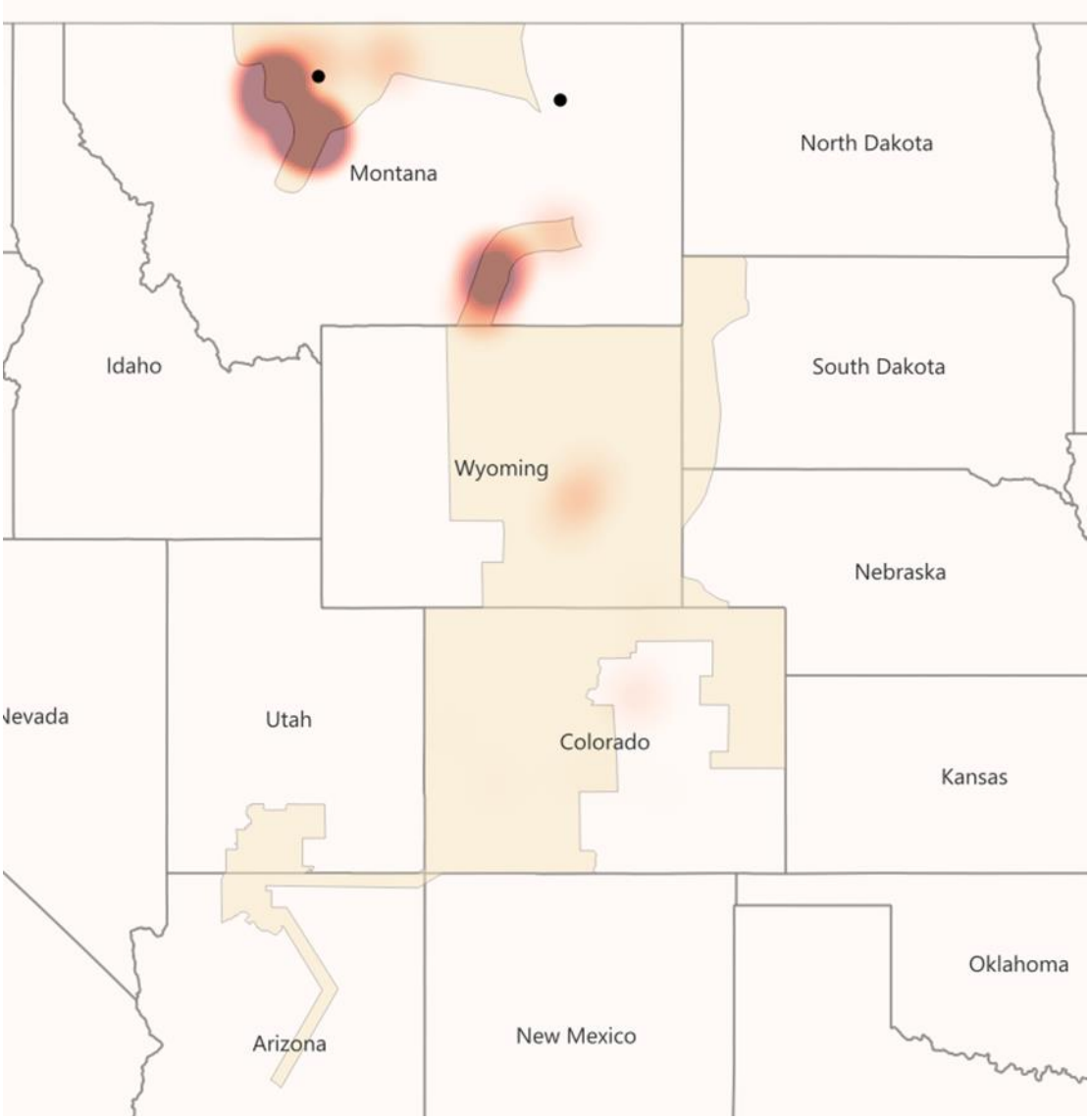


Figure 1-1 displays pivotal supplier hours in heat map form along with the locations of Frequently Constrained Area resources. The map highlights concentrations of pivotal supplier hours in the northern regions of the WEIS footprint. The resources, represented by black dots, are strategically positioned to alleviate congestion associated with the Yellowstone, Montana

[2] SPP Western Imbalance Service Tariff Att. B Section 3.1.1.3 (Changes to Frequently Constrained Area Designation)

Frequently Constrained Area. These resources can significantly influence pricing outcomes in this area. A primary factor contributing to the establishment of this Frequently Constrained Area is an ongoing phase-shifter transformer outage near Colstrip, Montana, specifically the Crossover substation.

Table 1-2 displays the resource count within the respective Frequently Constrained Areas.

Table 1-2 Frequently Constrained Area, resource count

FCA name, state	FCA resource count
Yellowstone, Montana	2
Total	**2**

2 METHODOLOGY

2.1 Data and study period

The study period runs from October 1, 2023 through September 30, 2024. The analysis incorporates western real-time balancing market (WRTBM) congestion and dispatch data, and resource parameter offers for online resources. Also included in the analysis is real-time transmission system topography, including but not limited to transmission elements, ratings, effective and termination times, temporary operating conditions, etc.

2.2 Study process

The study consists of the following process.

1. **Binding hours computation:** The study calculates binding hours for each modeled transmission constraint. A constraint counts as binding in a five-minute interval if the loading on the constraint is within the greater of five megawatts or two percent of the effective constraint limit.

2. **Pivotal supplier analysis:** The study calculates pivotal supplier hours for each modeled transmission constraint. A constraint counts as having a pivotal supplier during a five-minute interval if the supplier can cause a constraint to exceed its effective limit by decreasing generation on resources that provide congestion relief and by increasing generation on resources that exacerbate congestion. The submitted ramp rates, economic minimum, and economic maximum capabilities govern the dispatch of the potential pivotal supplier's resources. In this analysis, we consider a thirty-minute dispatch period to alleviate transitory exceedances. We account for the market's ability to react to the actions of the potential pivotal supplier by allowing a similar dispatch of all resources not owned or controlled by the potential pivotal supplier.

3. **Selection of evaluation areas, Frequently Constrained Area candidates, and Frequently Constrained Areas:** The geographical concentration of pivotal supplier hours determines the evaluation areas. Candidate areas meet the pivotal supplier hour test, in addition to the locational and electrical tests associated with the selection of primary and secondary constraints. Frequently Constrained Areas meet the evaluation area and candidate area requirements in addition to the financial impact test.

4. **Selection of primary constraints:** A primary constraint for the Frequently Constrained Area candidate is generally the constraint with the highest number of pivotal supplier hours within a given area. However, there are instances where additional individual primary constraints are considered within the same area. The areas are determined by evaluating pivotal supplier hours in conjunction with each constraint.

5. **Selection of secondary constraints:** Secondary constraints incorporate information from the primary constraint and test the results against other relevant constraints. This test is electrical in nature. First the test identifies resources with shift factors to the primary constraint(s) of less than or equal to negative five percent. This primary constraint resource group is then tested against all other constraints. Specifically, the test identifies the constraints where resources have shift factors less than or equal to negative three percent, relative to the same resource group identified by the primary constraint. Any constraints passing this test are secondary constraints.

   Unlike the Integrated Marketplace where the traditional N-1 constraint framework directs most dispatch, the Western Energy Imbalance Service market incorporates three constraint types: reliability, service flow, and energy imbalance. Service flow and energy imbalance constraints are design features of the WEIS market and are not found in the Integrated Marketplace.

   i. Reliability constraints are like the traditional N-1 constraints found in the Integrated Marketplace.

ii. Service flow constraints establish contractual limits rather than physical limits. These contractual limits align transmission usage with the contract terms of participating entities. When transmission usage nears the contractual limits, the market dispatches resources to alleviate the flow over the related transmission elements. Because the relevant contracts often govern limits, service flow constraints often encompass several transmission elements.

iii. Energy imbalance constraints enforce the supply adequacy of balancing authority areas. To fulfill this task, these constraints limit the flow of imbalance energy between specific balancing areas. When a particular balancing authority area has insufficient supply, congestion prices within that area increase to signal generation within the area to increase on-line capacity.

Study process steps four and five, apply to reliability and service flow constraints. Energy imbalance constraints are evaluated solely as primary constraints.

6. **Identify the Frequently Constrained Area candidate resources:** A resource is a Frequently Constrained Area candidate if it has an average shift factor of less than or equal to negative five percent to the constraints identified as primary and secondary constraints. This cut-off of negative five percent is consistent with the local market power test.[3]

7. **Impact analysis:** An impact analysis is used to determine the number of hours for which the Frequently Constrained Area candidate resource group has significant impacts on prices in the candidate area. For each five-minute interval in the study period, the resource price impacts on each defining constraint are calculated by multiplying the shadow price and the candidate resource's corresponding shift factor. The resource price impacts are then summed over the Frequently Constrained Area candidate defining constraints to obtain a five-minute price impact for each candidate resource. This

[3] SPP Western Imbalance Service Tariff Att. B Section 3.1 (Market Power Test)

calculation determines the contribution from the Frequently Constrained Area candidate constraints to the candidate resource's marginal congestion component of the locational marginal price.

Any interval for which a candidate resource's price impact exceeds the impact test threshold will count as a binding interval and is susceptible to the exercise of market power when a pivotal supplier is present. The market impact test incorporates a $5 threshold.[4]

A candidate area that meets the threshold more than 500 hours within the study period will be a Frequently Constrained Area. The importance of employing a threshold value accounts for periods when there is low cost relief capability in the Frequently Constrained Area. This low-cost relief prohibits a pivotal supplier from accruing significant benefits by pursuing a withholding strategy in the Frequently Constrained Area.

[4] This threshold has been used in the mitigation since February 1, 2021.

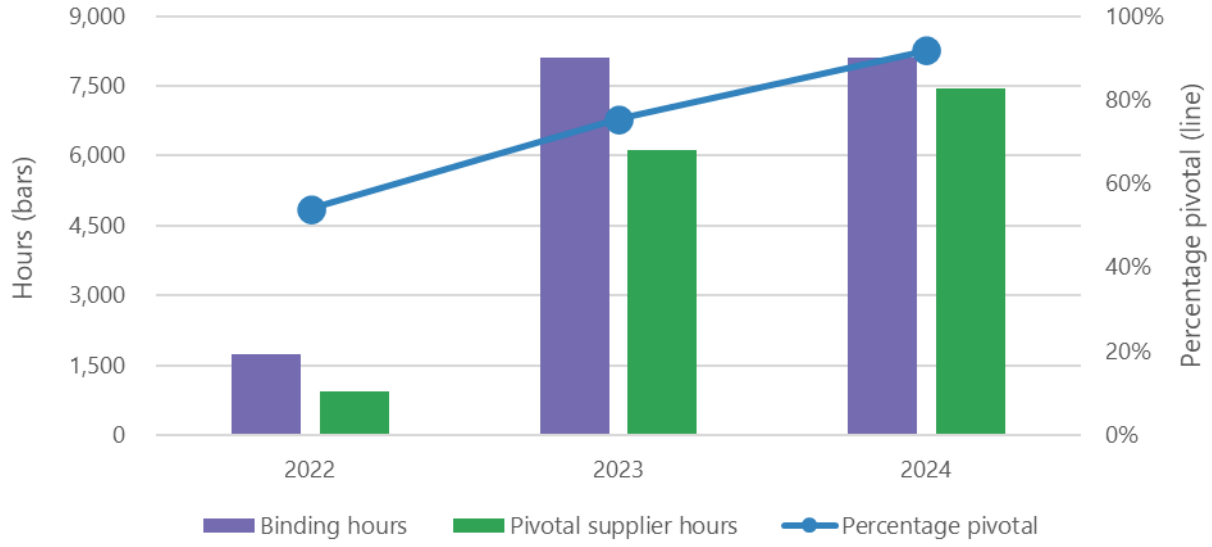
3 ANALYSIS

The Methodology section mentions several tests and processes which drive the results of the Frequently Constrained Area study. Those tests and processes generally fall into two main categories.

1. Computation and evaluation of binding and pivotal supplier hours
2. Quantifying the pivotal supplier(s) potential financial impact

With respect to the computation and evaluation of pivotal supplier hours, Figure 3-1 highlights the consistency in binding hours and material increase in pivotal supplier hours over the last two study periods. While 2023 and 2024 show a significant increase compared to 2022, it is important to acknowledge that the substantial structural changes to the WEIS footprint, driven by the addition of new market participants, contributed to this difference.

Figure 3-1 Binding hours and pivotal supplier hours, study period

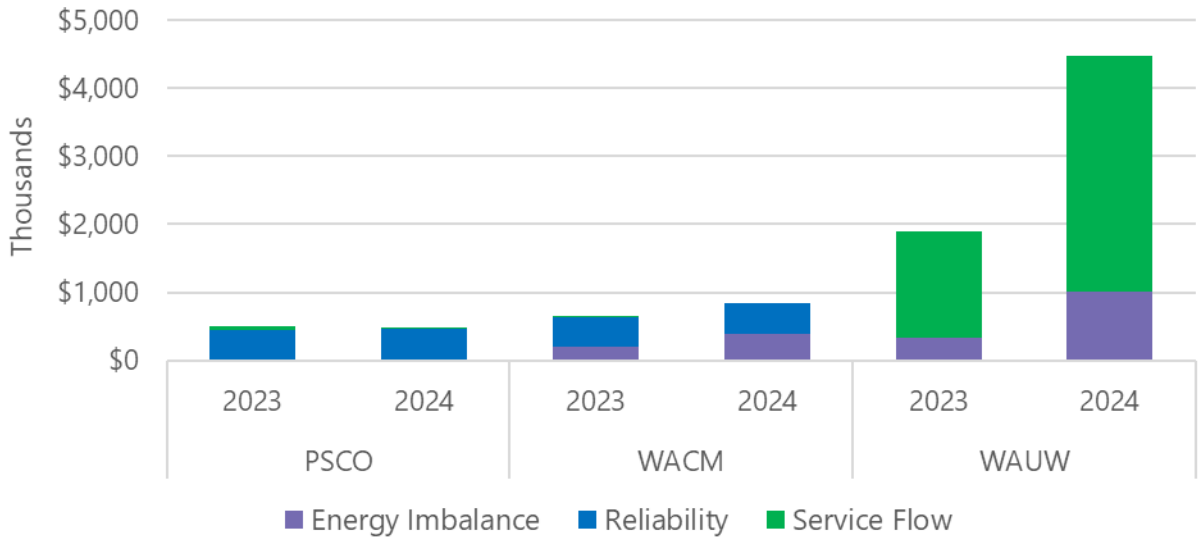


From 2023 to 2024, binding hours remained consistent while pivotal supplier hours increased just over 20 percent from roughly 6,000 hours to just under 7,500 hours. Additionally, the percentage of binding hours with at least one pivotal supplier increased materially from 75 percent in 2023 to 92 percent in 2024.

Regarding the financial impact test, the rise in binding and pivotal supplier hours can correlate with periods of increasing congestion. When assessing the potential financial impact of a pivotal supplier(s), congestion prices significantly influence the magnitude of the impact.

Figure 3-2 compares the total sum of shadow price for each constraint type[5] within a balancing authority area between the 2023 and 2024 FCA study periods. In the context of the FCA, a "shadow price" refers to the estimated cost of relieving a transmission constraint by one megawatt, essentially representing the change in total system production cost if a constraint on the power grid is slightly relaxed, calculated by re-dispatching power flows to accommodate the change; it signifies the marginal value of additional transmission capacity on a congested line.

Figure 3-2 Total sum of shadow price, by constraint type, BAA and study period

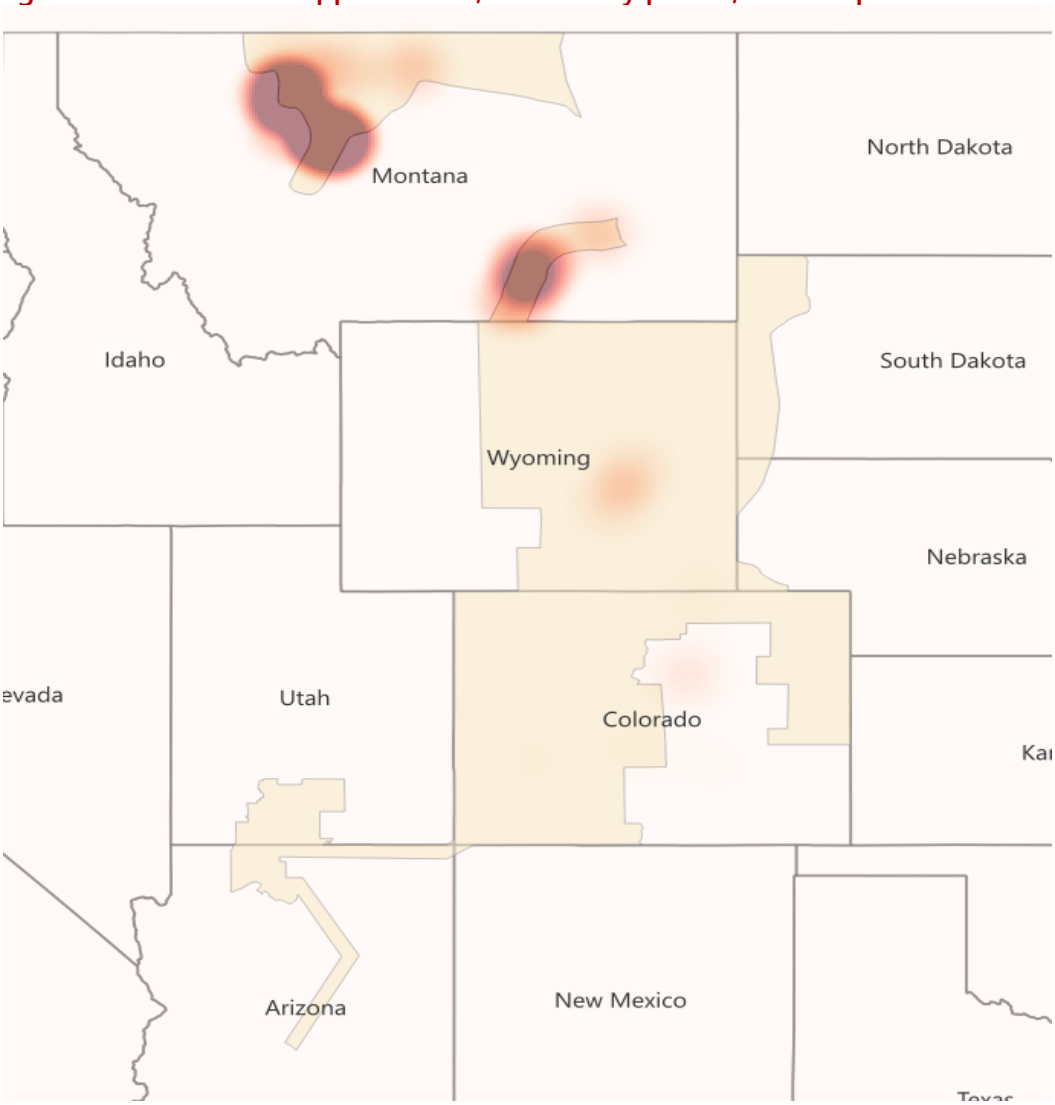


In Public Service Company of Colorado (PSCO) and Western Area Power Administration, Colorado Missouri (WACM), energy imbalance and reliability constraints drive most of the congestion outcomes. In Western Area Power Administration, Upper Great Plains West (WAUW), service flow constraints make up most of the congestion with some impact from energy imbalance issues. The primary reason for elevated service flow congestion in WAUW stems from a specific phase-shifting transformer outage.

[5] Refer to Section 2.2 for definitions of energy imbalance, reliability and service flow constraint types.

As previously mentioned, concentrations of binding and pivotal supplier hours factor into the selection of Frequently Constrained Areas evaluation areas. Figure 3-3 displays pivotal supplier hours in heat map form.

Figure 3-3 Pivotal supplier hours, 2023 study period, heat map



The map highlights the concentrations of pivotal supplier hours in the northern portion of the footprint.[6] The most significant concentrations of pivotal supplier hours surround Great Falls and Billings. These two areas (studied as one combined area) account for 77 percent of all

[6] The pivotal hour concentrations contribute to the process of selecting Frequently Constrained Area evaluation areas.

binding hours, and 88 percent of all pivotal supplier hours during the study period. Analysis of pivotal hour concentrations yielded one Frequently Constrained Area evaluation area.

Table 3-4 highlights this area, along with the resulting Frequently Constrained Area candidate and Frequently Constrained Area.

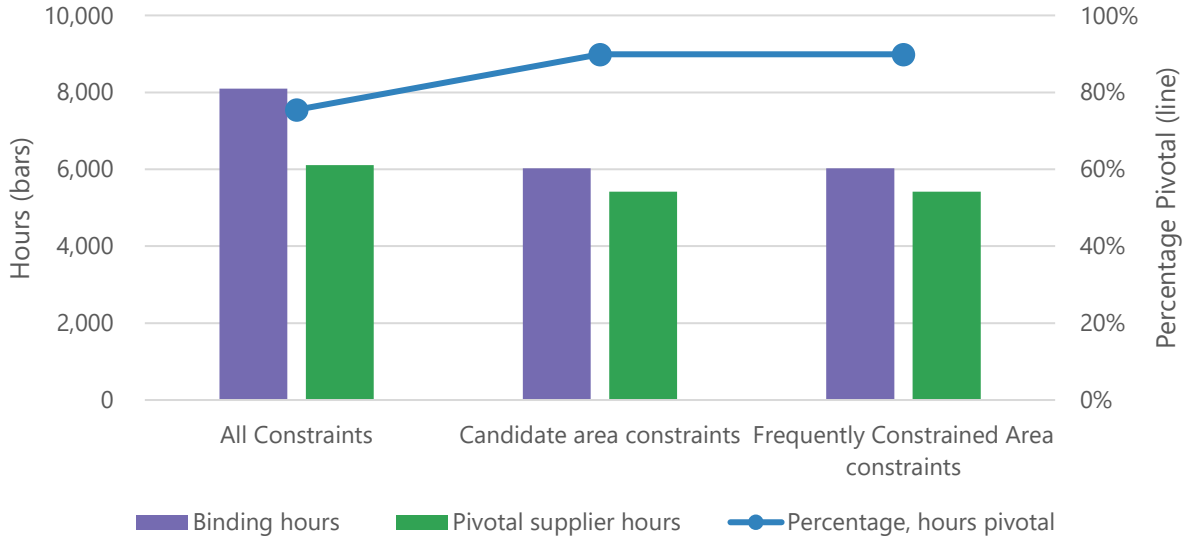
Table 3-4 Evaluation areas, candidate areas, and Frequently Constrained Areas

Evaluation areas[7] name, state	Candidate areas[8] name, state	Frequently Constrained Areas[9] name, state
Yellowstone, Montana	Yellowstone, Montana	Yellowstone, Montana

Yellowstone, Montana met the Frequently Constrained Area candidate requirements in addition to the impact test threshold.

Figure 3-5 shows binding and pivotal supplier hours concentrations by area classification.

Figure 3-5 Binding hours and pivotal supplier hours, by area classification, 2024



[7] Evaluation areas are determined by the geographical concentration of pivotal supplier hours.

[8] Candidate areas meet the pivotal supplier hour test, in addition to the locational and electrical tests outlined in the methodology.

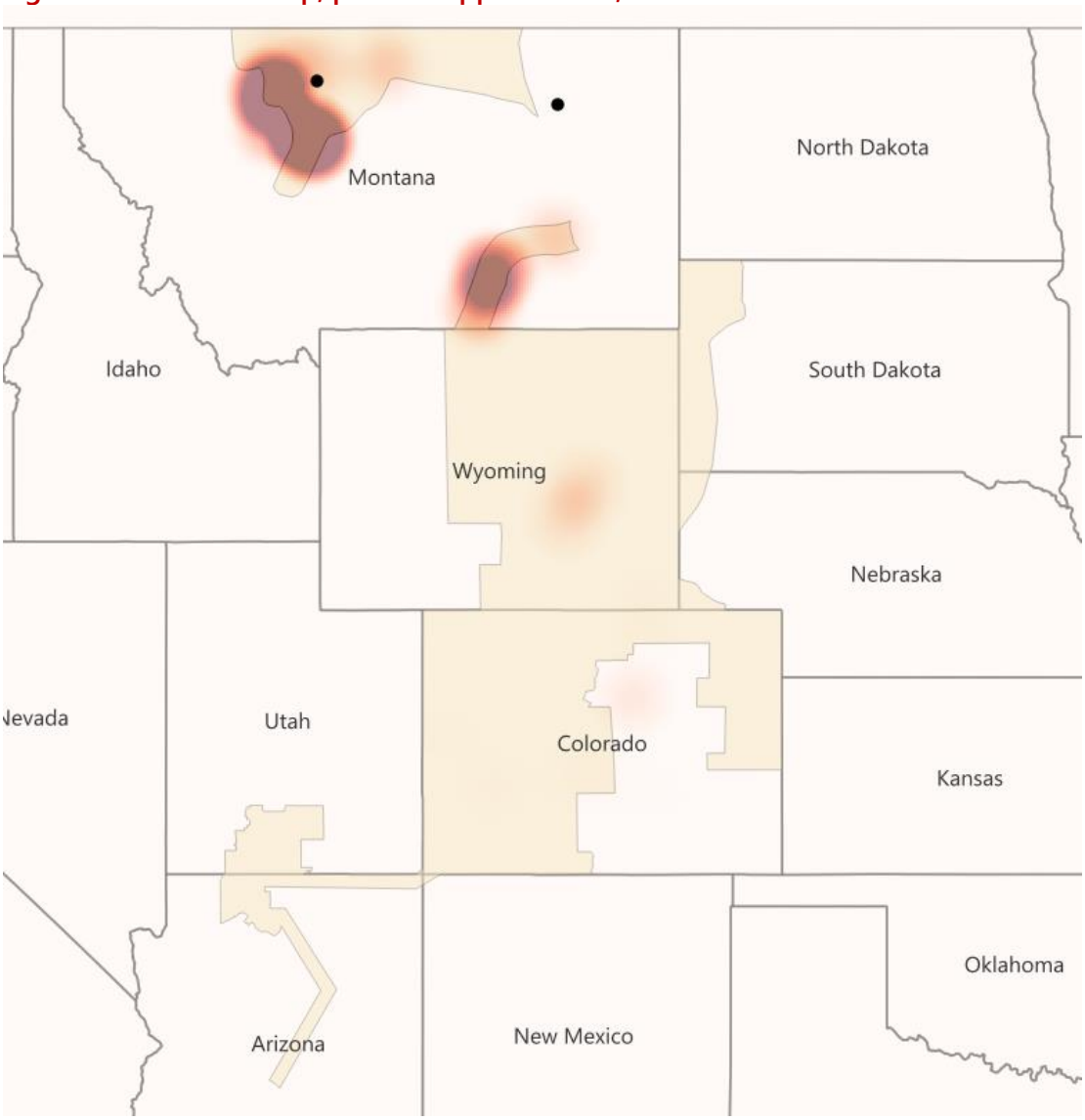
[9] Frequently Constrained Areas meet the candidate area requirements and the impact test requirements outlined in the methodology.

For the 2024 study period, the Frequently Constrained Area candidate makes up 100 percent of the study's total binding hours and 92 percent of the study's total pivotal supplier hours. Of note, all constraints carried a 75 percent ratio of pivotal supplier hours to binding hours. In general, when the constraints within these areas bind, there is at least one pivotal supplier 23 percent[10] more often than the other areas overall.

Figure 3-6 shows the pivotal supplier hours heat map and the Frequently Constrained Area candidate resources associated with the Frequently Constrained Area candidates.

[10] (92% - 75%) / 75% = 23%

Figure 3-6 Heat map, pivotal supplier hours, and FCA candidate resources



Customers and participants in the WEIS market benefit significantly from generator fuel diversity. Each type of fuel and its related generator have their own set of advantages and limitations. The combination of these diverse characteristics contributes to a more resilient and robust system overall.

A portion of the generators in the WEIS are situated away from population centers. To supply power to populated areas within individual balancing authority areas and across the WEIS, resources contend for the same transmission capacity. By definition, congestion arises as power

flows near transmission capacity. Additionally, WEIS congestion can arise from shortages in supply adequacy requirements within balancing authority areas.

Figure 3-7 identifies the Frequently Constrained Area candidate and candidate resources. The heat map calls attention to concentrations of pivotal supplier hours and candidate resource locations relative to the pivotal hour hotspots. During this year's study, the concentrations of pivotal supplier hours largely relate to a specific phase-shifting transformer outage. Given the current system conditions, it is probable that this candidate area and the associated candidate resources will continue to qualify as a candidate area and candidate resources until the Crossover substation is back in service.

This outage, and phase-shifting transformer outages in general, are of particular importance because phase-shifting transformers are a primary congestion management tool in the WEIS. In the WEIS, and much of the Western United States, phase-shifting transformers help alleviate congestion and manage the flow of electricity within the transmission network. They are valuable tools in grid management due to their ability to control the phase angle between input and output voltages. This capability offers numerous advantages in handling congestion, including but not limited to:

1. Controlling power flow: Phase-shifting transformers can redirect power flows, relieving congestion on heavily used lines and redistributing power to less congested paths.

2. Optimizing transmission paths: In regions where certain transmission lines might be heavily loaded, phase-shifting transformers help balance the flow of electricity by diverting power to less congested paths. This aids in preventing overloading of specific lines and helps in efficiently using the grid's infrastructure.

3. Improving grid stability: By managing the flow of power, phase-shifting transformers contribute to grid stability and reliability, by maintaining stable voltage levels.

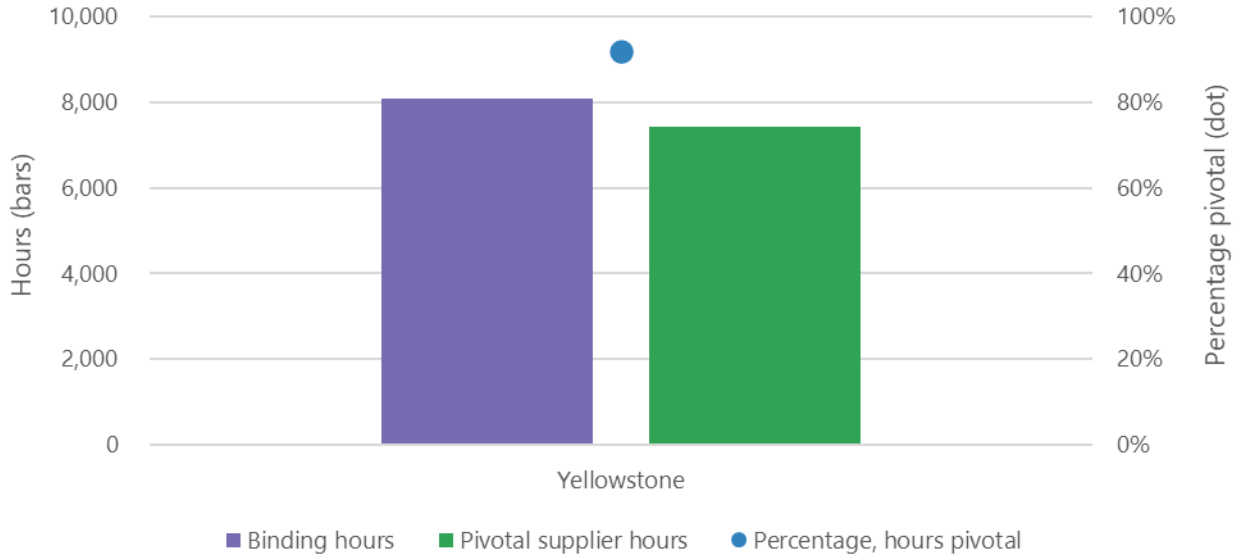
4. Facilitating renewable energy integration: Phase-shifting transformers can aid in integrating intermittent resources by efficiently managing the flow and distribution of power.

5. Minimizing costs and enhancing efficiency: By strategically regulating power flows, the use of phase-shifting transformers can potentially reduce the need for building new transmission infrastructure, thereby reducing cost to ratepayers.

In summary, the use of phase-shifting transformers, including the Crossover phase-shifting transformer, are crucial for efficiently managing power flow, alleviating congestion, and maintaining the stability and reliability of the network.

Figure 3-7 provides more information on the binding and pivotal supplier hours within the Frequently Constrained Area candidate for the 2024 study period.

Figure 3-7 Binding hours and pivotal supplier hours, FCA candidates



For the 2024 study period, we observed a significant concentration of both binding hours and pivotal supplier hours in this area. These pivotal supplier hours stem from the service flow constraint activated to manage the phase-shifting transformer outage.

Figure 3-8 Binding hours and pivotal supplier hours, by constraint type

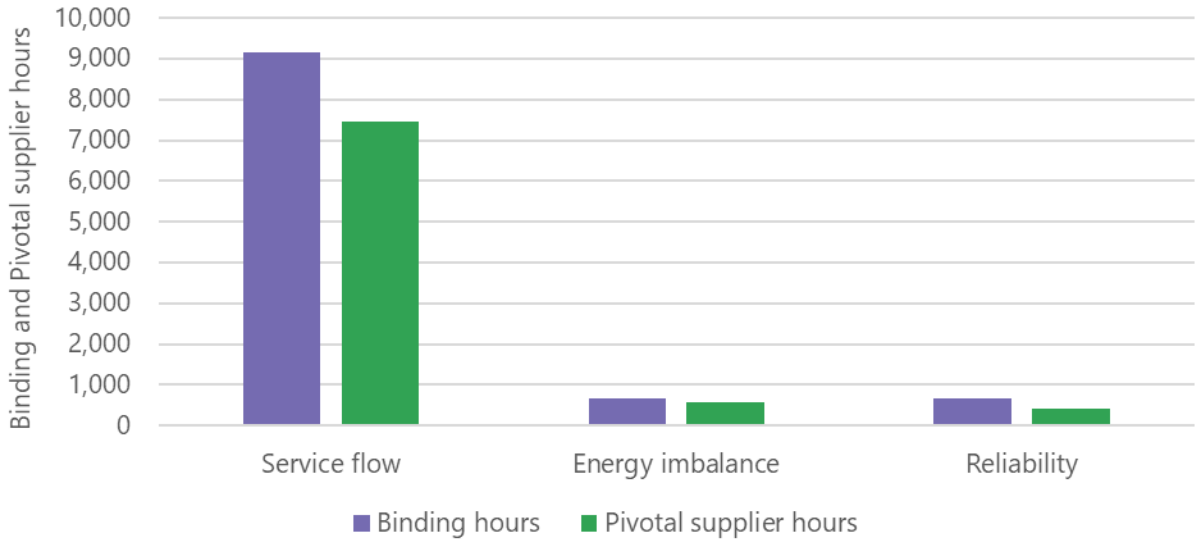


Figure 3-8 highlights the concentration of binding and pivotal supplier hours. Of note, most of these hours apply to WAUW service flow constraints. Specifically, the relevant constraint accounts for 88 percent of all service flow constraint binding hours and 100 percent of all service flow pivotal supplier hours.

Binding and pivotal supplier hours are constraint level calculations summed over the constraints within the Frequently Constrained Area candidates. Table 3-9 displays the constraint counts within each Frequently Constrained Area candidate.

Table 3-9 FCA candidate primary and secondary constraint counts

FCA candidate	Number of primary and secondary constraints	Percentage of pivotal supplier hours, primary constraint to all constraints
Yellowstone, Montana	1	100%
FCA candidate, total	**1**	**100%**

The candidate area exceeded 500 binding hours and 500 pivotal supplier hours for its respective constraint.

Table 3-10 lists the top binding constraints for the study period along with binding hours, pivotal supplier hours, and geographic area.

Table 3-10 Top ten binding constraints

Constraint name	Binding constraint hours	Pivotal supplier hours	Geographical Area
WSF_TEMP_002	8093	7436	Montana
WSF_HILN_EXP	828	0	Montana
WEI_WAUW	332	270	Montana
WTP011_92011	322	208	Wyoming
WEI_WACM	317	259	Wyoming
WSF_P30_TOT1	230	0	Colorado
WTP086_92086	96	80	Wyoming
WTP128_92128	32	22	Wyoming
WEI_PSCO	28	28	Wyoming
WTP133_92133	23	5	Colorado

WSF_TEMP_002	as defined by 12 elements.
WSF_HILN_EXP	as defined by 6 elements.
WEI_WAUW	WAUW energy imbalance constraint
WTP011_92011	Amasa – Difficulty 230 kV
WEI_WACM	WACM energy imbalance constraint
WSF_P39_TOT1	as defined by 3 elements.
WTP086_92086	LN LEET - MONR 230 kV for the loss of LN W_GREE - ARAP 230 kV
WTP128_92128	LN CCW - PON 230 kV for the loss of LN CABI - W_DILL 230 kV
WEI_PSCO	PSCO energy imbalance constraint
WTP133_92133	LN PAWN1 - STORY 230 kV for the loss of LN MSST - W_SMOK 345 kV

The top 10 constraints, ranked by binding hours, contributed just over 10,000 binding hours and slightly more than 8,000 pivotal supplier hours during the study period. In the previous study period, the top 10 constraints, ranked by binding hours, accounted for slightly more than 8,000 binding hours and 6,000 pivotal supplier hours. This equates to more than a 30 percent increase in binding hours and a 40 percent increase in pivotal supplier hours year over year.

Table 3-11 shows the number of resources included in the Frequently Constrained Area candidate and the corresponding capacity in the candidate area.

Table 3-11 Candidate resource summary

FCA candidate	Number of resources	Total capacity in megawatts	Potential relief capability in megawatts	Relief capability as percentage of total capacity
Yellowstone, Montana	2	116	114	98%

The total capacity is the sum of the registered maximum capacity of all resources in the Frequently Constrained Area candidate. An area's relief capability is the sum of each resource's registered maximum capacity multiplied by the constituent resource's average shift factor during the study period to a constraint in the Frequently Constrained Area candidate. The calculation represents an observed best-case potential relief capability.

The final step is to determine the number of hours the Frequently Constrained Area candidate was both binding and susceptible to the exercise of market power by applying a price impact test or impact analysis (see Study process.) The price impacts were computed for each five-minute interval in the study period. The results are represented and tested at the hourly granularity.

If the price impact on a single candidate resource exceeds the price impact threshold, then the Frequently Constrained Area candidate is deemed susceptible to the exercise of market power in the presence of a pivotal supplier.

Figure 3-12 Impact hours, by impact threshold tranches

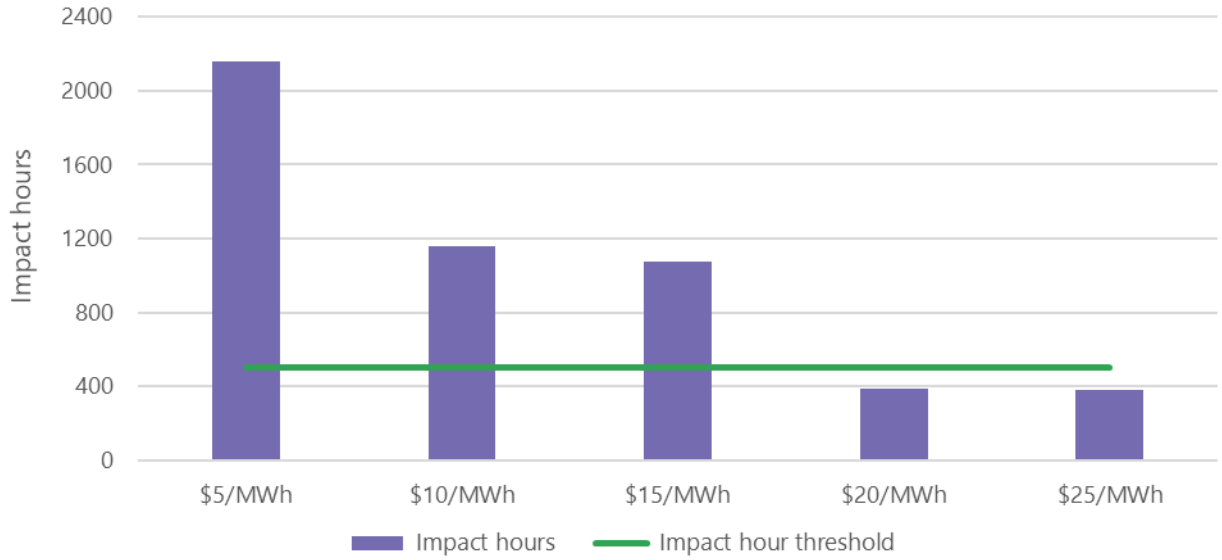


Figure 3-12 shows the general trend that as the impact test threshold rises, the number of hours exceeding that threshold decreases. For reference, the impact threshold in the Integrated Marketplace is $25/MWh as compared to $5/MWh in the WEIS. If the impact threshold in the WEIS were $25/MWh, Yellowstone, Montana would have failed the impact threshold test and

therefore not been deemed a Frequently Constrained Area. This illustrates the significance of the impact test threshold and prevailing market prices in determining Frequently Constrained Areas.

Table 3-13 provides a summary of the presently effective impact threshold over the study period. The candidate area consists of a single constraint.

Table 3-13 Impact analysis results

FCA Candidate	Binding hours over $5/MWh impact threshold	FCA total		
		Binding hours	Pivotal supplier hours	Percent hours with pivotal supplier
Yellowstone, Montana	2,158	8,093	7,436	92%

Conclusion

During this study period pivotal supplier hours and congestion increased materially. Given this development, the study results reflect the increase in participants' ability to exercise market power. As the resource mix and transmission infrastructure changes, so too will the flow of power and the ability of participants to influence market outcomes. The aim of the Frequently Constrained Areas study is to follow the tariff and limit the exercise of market power. Yellowstone, Montana passed the locational, electrical, and impact tests and therefore it is a proposed Frequently Constrained Area.

4 APPENDIX

4.1 Frequently Constrained Area constraints

Constraint name	Frequently Constrained Area	Element(s)
WSF_TEMP_002	Yellowstone, Montana	WSF_TEMP_002, listed as 12 elements.

4.2 Frequently Constrained Area resource details

Settlement location	Resource	Fuel type	FCA area
WAUW.UGPM.FTPECKWES	WAUW.UGPM.FTPECKWEST	Hydro	Yellowstone,
WAUW.NWMT.TIBERLLC	WAUW.NWMT.TIBERLLC	Hydro	Yellowstone,

4.3 Impact analysis, FCA candidates

FCA candidate	Binding hours over $5/MWh impact threshold	FCA total		
		Binding hours	Pivotal supplier hours	Percent hours with pivotal supplier
Yellowstone, Montana	2,158	8,093	7,436	92%

4.4 Frequently Constrained Area resource summary by fuel type and megawatt capacity

Fuel type (capacity MW)	FCA area Yellowstone, Montana
Coal	—
Fuel oil	—
Municipal solid waste	—
Natural gas	—
Other fuel	—
Hydro	116
Wind	—

4.5 Frequently Constrained Area resource summary by fuel type and resource count

Fuel type (number of resources)	FCA area Yellowstone, Montana
Coal	—
Fuel oil	—
Municipal solid waste	—
Natural gas	—
Other fuel	—
Hydro	2
Wind	—