INDEPENDENT REVIEW OF DISPATCHABLE CAPACITY NEEDS

B&V PROJECT NO. 415575
FINAL REPORT

REPARED FOR

Platte River Power Authority

16 OCTOBER 2023

BLACK & VEATCH

Table of Contents

LIST OF TABLES

LIST OF FIGURES

Acronym List

BESS	Battery Energy Storage System
BV	Black & Veatch
CTG	Combustion Turbine Generator
ELCC	Effective Load Carrying Capability
LDES	Long Duration Energy Storage
Platte River	Platte River Power Authority
RDP	Resource Diversification Policy
RICE	Reciprocating Internal Combustion Engine

1.0 Introduction

1.1 Background

The Platte River Power Authority (Platte River) requested Black & Veatch Management Consulting, LLC (Black & Veatch or BV) provide an independent review of dispatchable capacity needs. The Platte River Board of Directors passed a Resource Diversification Policy (RDP) in 2018 asking Platte River to proactively work towards a goal of providing 100% non-carbon energy by 2030. Platte River proposed a plan to meet the RDP objectives in its 2020 Integrated Resource Plan (2020 IRP). Pertinent features of this plan include retiring coal generation, maintaining existing peaking generation, adding wind and solar generation, adding energy storage, and adding additional dispatchable thermal generation.

The 2020 IRP recommended a reliable portfolio that can supply 85%+ noncarbon energy by 2030. The 2020 IRP recommended this portfolio due to the recognized non-availability of long duration energy storage (LDES) or other non-carbon emitting generation options by the 2030 timeframe. The IRP analysis results showed even with a large amount of four-hour duration energy storage, the 100% noncarbon plan would not meet system reliability criteria and had very high costs associated with procurement of LDES.

In 2022, Platte River proposed a portfolio RP22 which also didn't meet the 100% noncarbon goal by 2030 and recommended building some additional peaking capacity to meet future reliability needs.

Platte River is now developing the 2024 IRP. It is expected that the recommended future plan will include the need for building additional dispatchable thermal generation capacity to ensure reliability of supply. It is expected that the new capacity is needed to complement the intermittency of renewables, and to meet load during extended periods of low or no wind and solar generation (dark calm periods). It is expected that the new generation will run at low capacity factors. It is recognized that an 85%+ noncarbon plan is short of the 100% noncarbon goal, but this plan has the following recognized benefits:

- 85%+ carbon emittance reduction is a significant advancement from long and near-term historic carbon emissions
- This plan results in a more reliable system than a 100% noncarbon plan
- This plan is lower cost to the rate payers compared to a 100% noncarbon plan
- This plan has the built-in optionality to switch to lower or no carbon fuels (such as green hydrogen) for use in dispatchable thermal generation when they become available in the future.

1.2 Report Scope

The Black & Veatch team independently performed a review of Platte River's RP22 portfolio in detail. This report provides the results of the review, and a commentary on reliability characteristics of the formulated RP22 portfolio. BV also provides an independent assessment of the need for dispatchable thermal generation capacity to provide reliability, while achieving high levels of renewable penetration in 2030, when the Platte River system is forecast to have a peak demand of about 780 MW, and recommended strategies to progress towards a 100% noncarbon portfolio beyond 2030.

Certain statements made in this Report are forward looking. The achievement of certain events, results or performance contained in such forward-looking statements involve known and unknown risks and uncertainties that may cause actual events, results, or performance to be materially different than originally intended. Black & Veatch does not plan to update or revise any forward-looking statements when such events, results or performance occur.

In the assessment of the Projects, Black & Veatch has used and relied upon certain information provided by representatives of Platte River and others, and Black & Veatch assumes the information provided is true and correct and reasonable for the purposes of this Report. This Report summarizes Black & Veatch's assessment of the scenarios.

2.0 Reliability Drivers

The 100% non-carbon goals by 2030 will prompt Platte River to add renewable technologies, that are intermittent and non-dispatchable, for replacement of baseload coal units currently supplying reliable power to the system. The 2024 IRP portfolio is expected to be a mix of renewable, storage, and some dispatchable thermal generation to complement renewables and ensure reliability.

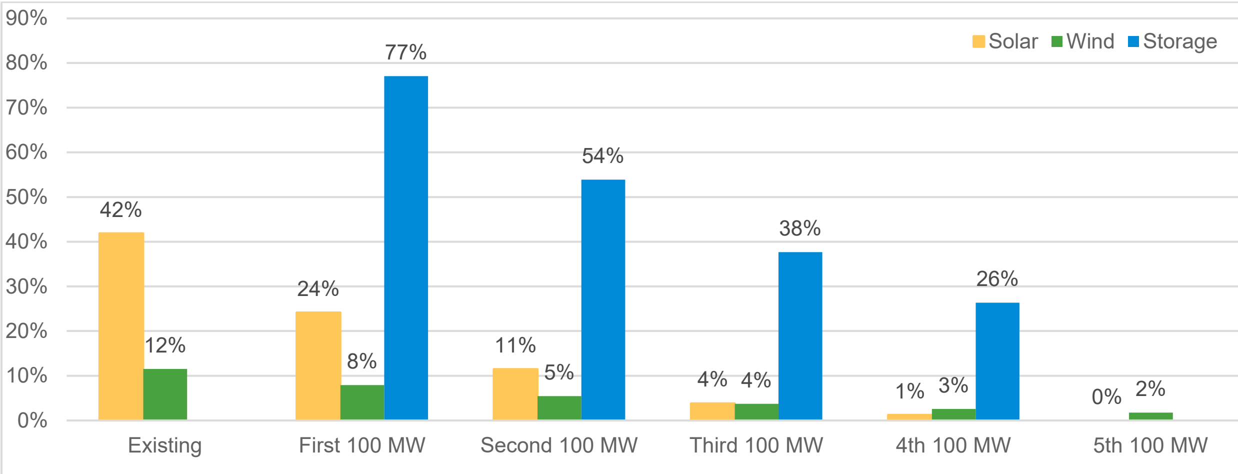
A limitation of renewable technologies is the derated or lower contribution of resource capacity to system planning reserve margins due to the intermittency and non-dispatchability of the technologies. The derate is quantified as the Effective Load Carrying Capability (ELCC) metric. Similarly, four-hour duration battery storage also has lower contributions to reserve margin due to the inability to supply power after four hours of discharge at full capacity without a period of unavailability for recharging. For explanation purposes, Table 2-1 below shows average ELCC values, as published for wind, solar, and storage assets for Xcel Energy (an electric utility company operating in Colorado with a 7.5 GW system peak demand) as part of its 2021 Resource Plan filing. The table shows that at installed capacity levels of less than 1000 MW (13.3% of peak), both solar and wind ELCC decreases to about 20%. The contributions of resource capacity decrease further at higher levels of renewable capacity installed.

Table 2-1: Average ELCC for Xcel Energy, 7.5GW Peak Load (2021 Resource Plan)

MW Range	Avg Wind	Avg Solar	Avg Batteries
0-1000 MW	19.4%	21.1%	70-89%
1001-2000 MW	14.5%	10.7%	70-89%
>2000 MW	11.3%	5.4%	70-89%

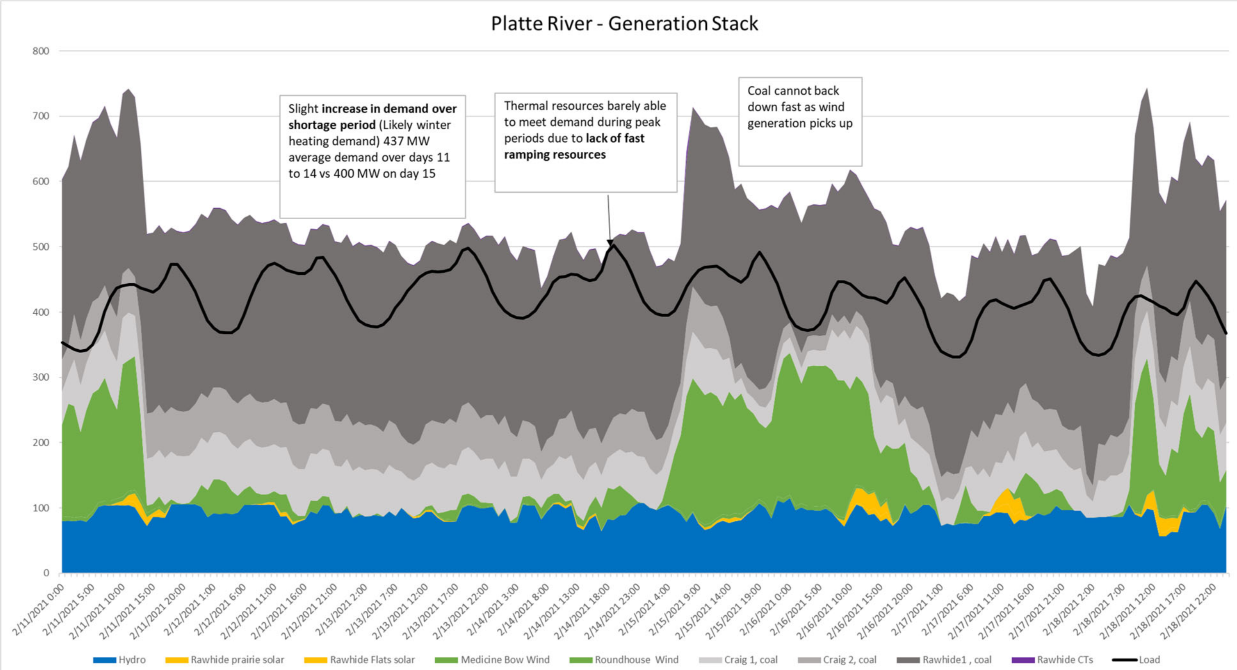
The RP22 portfolio assessed for Platte River is expected to perform similarly in the late years, 2030 onwards, where diminished capacity contributions from renewables will be observed with higher installed capacity of these intermittent and energy limited technologies. Figure 2-1 presents representative incremental ELCC percentages as calculated for Platte River's RP22 portfolio. The ELCCs are in line with Xcel energy's published ELCC trends where each 100 MW resource incremental addition results in declining contributions to reliability metrics.

Figure 2-1: Incremental ELCC values for Platte River portfolio (Representative)



As mentioned earlier, a key factor regarding renewables generation is the intermittent nature of their generation patterns. Weather is a major driver of renewable intermittency. To accurately capture realistic modeling behavior, the effect of weather disturbances ought to be correlated to renewable production. Platte River models the correlations through detailed research on extreme weather events, specifically the more severe events referred to as "Dark Calm" events. The dark calm periods are modeled as prolonged time periods in which all renewable generation, both wind and solar, are at very low generation levels or are not generating at the same time. For decarbonized portfolios with heavy reliance on renewables, an extended period of no renewable generation can result in severe system instabilities and reliability challenges. As an example, Figure 2-2 below presents an illustrative example of a dark calm event occurring in Platte River's system for more than 72 hours, from 2/11/2021 to 2/14/2021 during the winter storm Uri which caused severe system instabilities across ISOs like SPP and ERCOT in Texas; resulting in region-wide power prices to reach historical peak levels. Such weather events cause havoc for unprepared power grids. In Platte River's territory, there was very little wind and solar generation during this period and customer demand was met with coal and gas fired generation. Actually, Platte River was able to export to the neighboring utilities, and therefore, aided in regional grid reliability in these extreme weather conditions. The loss of renewable generation caused ramping up of thermal generation in the system to meet demand. With operational limitations of non-flexible thermal technologies, ramp up and down limitations can create uneconomical dispatch as well as reliability concerns based on unavailability of assets to dispatch.

Figure 2-2: Platte River's demand supply balance during the 2021 Dark Calm period.



Platte River has identified several historical dark calm events in multiple regions of the North American market and plans to incorporate portfolio effects of such events in modeling for the 2024 IRP capacity expansion analysis. The reason for considering dark calm events in resource expansion planning analyses is to develop a robust portfolio that meets reliability needs during the random occurrences of dark calm events. BV also modeled dark calm events based on renewable generation unavailability. Using the Plexos resource planning and simulation model, the renewables in Platte River's portfolio were assumed to be unavailable when a dark calm event occurred. The dark calm outages were randomly distributed across the year 2030, with an average duration of 72 hours in the year. Dark calm events were also modeled to affect the availability of energy for purchase from energy suppliers outside of Platte River's service territory. In circumstances when portfolio resources are not available due to an extended weather pattern, it is reasonable and prudent to assume neighboring regions would also be affected like what occurred during winter storm Uri. Hence, resource shortages across the region would result in limitations on available energy for purchase for the Platte River system to meet demand during renewable generation shortages. To simulate the probable limitations on energy available for purchase during the dark calm events, derates were applied to the market purchases to reduce purchases from surrounding locations during the dark calm events. Black & Veatch validated the overall functioning of the dark calm outage simulations via independent runs of the Plexos model to analyze the RP22 portfolio.

3.0 Study Methodology and Results

Plexos based stochastic simulations of the Platte River RP22 portfolio were conducted in which dark calm periods were randomly distributed across the year 2030. Also, an extreme case was formulized to model deterministic capacity requirements over a selected dark calm event occurrence. Three separate cases were considered in detail and are described in this section. The cases are:

- Stochastic simulation with new thermal resources
- Deterministic simulation of the extreme case with new thermal resources
- Deterministic simulation of the extreme case without new thermal resources

3.1 Stochastic simulation with new thermal resources

All system renewables were stochastically modeled to be on simultaneous outages to model dark calm periods. One hundred (100) stochastic draws were modeled for the analysis. There is a very high likelihood that peak system load and dark calm outage periods do not coincide given the random distribution of the outage duration. Consequently, the capacity required to avoid unserved energy or loss of load hours in the system, could be higher than that indicated by a finite number of draws in a stochastic modelling analysis.

Results of the stochastic analysis are shown in Table 3-1. Each column in in Table 3-1 shows results for a separate simulation. Platte River's RP22 case (labelled as Base) adds 166 MW of thermal generation, which resulted in a maximum unserved demand of 293 MW. This implies that in certain dark calm periods, the portfolio may be unreliable. If an additional one LMS100 unit with a capacity of 95 MW is added to the Base portfolio, the maximum unserved energy amount across all stochastic draws was reduced from 293 MW to 101 MW. Incrementally adding a Reciprocating Internal Combustion Engine (RICE) unit with a capacity of 18 MW eliminated unserved demand and there was no loss of load hours for the modeled system. These results imply that approximately 279 (166+95+18) MW of firm thermal capacity is required to ensure portfolio reliability as determined from the results of the stochastic run. The capacity additions to the portfolios are not exactly revealing of the unserved energy amount as there is some interplay between portfolio generating resources and other portfolio components of battery storage, market sales, and market purchases. To eliminate the unserved energy, different combinations of solar and battery capacity additions to the Base portfolio were evaluated. Adding 100 MW of solar capacity and 100 MW of 4-hr duration BESS to the Base portfolio, reduced the maximum unserved energy to 62 MW. Adding 200 MW of solar and 200 MW of BESS to the Base portfolio eliminated reported unserved energy from the modelled portfolio. Recognizing that renewables represent a significant portion of the Base portfolio, the relatively small solar and BESS capacity additions (200 MW each) eliminating unserved energy suggests that peak demand hours and simulated dark calm events are not coincidental in the stochastic samples. Since it is possible that the events could occur coincidentally, a deterministic Plexos simulation with the dark calm period occurring during peak demand hours was developed to analyze the bookend extreme case for system reliability needs. The results of the bookend extreme case analysis are discussed in Section 3.2 below.

Table 3-1: Capacity mix and resulting maximum unserved energy from stochastic runs

Resource Plan with New Additions	Base Optimal Expansion	Base + 95 MW Thermal	Base + 113 MW Thermal	Base + 100 MW Solar & 100 MW Battery	Base + 200 MW Solar & 200 MW Battery
Thermal MW	166	261	279	166	166
MW Wind	300	300	300	300	300
MW Solar	300	300	300	400	500
MW Li-Ion Battery - 4hrs	200	200	200	300	400
Total New Resources Added	966	1061	1079	1166	1366
Maximum Unserved Energy (MW)	**293**	**101**	**0**	**62**	**0**

3.2 Deterministic simulation of the extreme case with new thermal resources

For the modelling of the bookend case of the capacity required for full system reliability, the seventy-two (72) hours duration dark calm period was set to occur on the peak load day of the year. The peak load day occurs in the month of July. The Base portfolio for this deterministic case represents about the same level of maximum unserved energy as the stochastic run. Thermal capacity was incrementally added to the Base portfolio. With the addition of one LMS100 and two RICE units (131 MW total additional capacity) no unserved energy occurred with this portfolio as shown in the column labeled "Base + 131 MW Thermal" (with 166 + 131= 297 MW thermal capacity) in Table 3-2. To determine the equivalent capacity of renewable resources needed to obtain a similar level of system reliability as the Base + 131 MW Thermal portfolio as described above, high levels of solar and battery were added to the Base portfolio. The dark calm periods affect this additional solar capacity since dark calm periods affect all renewables in the local geographic area. Adding 1 GW of solar and 1 GW of storage resulted in maximum unserved energy of 229 MW. An additional 50 MW of Solar capacity and 50 MW of BESS (for total of 1050 MW solar capacity and 1050 MW of 4-hr duration BESS capacity) eliminated unserved energy from the modeled portfolio. Thus, the results indicate that 1050 MW of solar capacity additions plus 1050 MW of BESS capacity additions are an equivalent replacement of 131 MW flexible thermal capacity additions from a system reliability perspective as shown in Table 3-2 below.

Table 3-2: Capacity mix and resulting maximum unserved energy from deterministic extreme case run

Resource Plan with New Additions	Base Optimal Expansion	Base + 95 MW Thermal	Base + 131 MW Thermal	Base + 1000 MW Solar & 1000 MW Battery	Base + 1050 MW Solar & 1050 MW Battery
Thermal MW	166	261	279	166	166
MW Wind	300	300	300	300	300
MW Solar	300	300	300	1300	1350
MW Li-Ion Battery - 4hrs	200	200	200	1200	1250
Total New Resources Added	966	1061	1097	2966	3066
Maximum Unserved Energy (MW)	**293**	**103**	**0**	**229**	**0**

3.3 Deterministic simulation of the extreme case without new thermal resources

To further evaluate renewable capacity additions equivalency to flexible thermal generation in the Base portfolio, a deterministic Plexos model was configured in which the flexible thermal capacity of the Base portfolio was removed from the portfolio and renewable capacity was added to replace the flexible thermal capacity. The results are shown in Table 3-3 below. The column labeled "Base Optimal Expansion" shows the Base portfolio with 166 MW of thermal capacity. When this thermal capacity is removed, the maximum unserved energy increased to 502 MW from 293 MW as shown in the column labeled "Base without Flexible Thermal" in Table 3-3 below. Varying levels of renewable resources and BESS were added to test the reliability of the portfolio. Even with the addition of 5,000 MW of solar capacity and 5,000 MW of BESS capacity, the maximum unserved energy is 488 MW, which is about 67% more than the 293 MW of maximum unserved energy in the Base portfolio. With a peak load of about 750 MW, an unserved energy of 488 indicates that more than half (about 53%) of the customers could be without power during extreme weather conditions. Thus, to effectively match the reliability performance of 166 MW of flexible thermal capacity in the portfolio, significantly more than 5,000 MW of solar capacity additions and 5,000 MW of four-hour duration BESS will be required. The results displayed in Table 3-3 indicate the reliability effects of replacing flexible dispatchable capacity with non-dispatchable renewable generation capacity that is prone to intermittency even when it is paired with a large quantity of four-hour duration BESS.

Table 3-3: Capacity mix and resulting maximum unserved energy, portfolio stochastically assessing equivalency of thermal and renewable capacities

Resource Plan w/ New Additions	Base Optimal Expansion	Base without Flexible Thermal	Base without Flexible Thermal + 5,000 MW Solar & 5,000 MW BESS
Thermal MW	166	0	0
MW Wind	300	300	300
MW Solar	300	300	5,300
MW Li-Ion Battery – 4 hrs	200	200	5,200
Total New Resources Added	966	800	10,800
Maximum Unserved Energy (MW)	**293**	**502**	**488**

4.0 Results and Recommendations

4.1 Thermal and Renewable Capacity Equivalency

Based on the foregoing discussion, it is concluded that new fast ramping dispatchable thermal capacity is vital to ensure the future reliability of Platte River's supply portfolio after replacing coal fired generation with non-dispatchable and intermittent renewable generation to meet carbon emission reduction requirements. Through the Plexos modeling evaluation conducted as part of this study, Black & Veatch has identified an additional need of 113 MW fast ramping capacity on top of the 166 MW included in the base RP22 portfolio. So, the recommended range of dispatchable thermal capacity is 166 to 279 MW.

In an "average" weather pattern case, the equivalent reliability can be achieved through 200 MW solar and 200 MW 4-hr duration battery technology with the base case addition of 166 MW of dispatchable thermal generation. Estimated technology capital costs are presented in Table 4-1. One hundred thirteen MW of thermal capacity additions will cost approximately, $122 million; while the equivalent solar and storage portfolio assessed would cost approximately, $519 million excluding tax credits, and $363 million with Investment Tax Credits (ITCs). The Inflation Reduction Act allows for an ITC credit of 30% of the capital costs for solar and storage in 2030. Overall capital cost of the renewable portfolio would be much higher than installing firm reliable thermal capacity.

Table 4-1: Technology Capital Cost Assumptions (2022$)

Resource Type	10x0 18V50SG (RICE)	2x0 LMS100 PA+	Lithium Iron Phosphate BESS (4 Hour)	Solar Photovoltaic - Single Axis Tracking	Wind - On Shore
$/kW	$1,420	$1,020	$1,546	$1,051	$1,478

For the extreme case assessed from the deterministic models, 131 MW of additional thermal capacity (on top of the base thermal capacity of 166 MW) is required for robustness and is considered equivalent to 1,050 MW of solar capacity plus 1,050 MW of BESS capacity, from a system reliability perspective. The cost for these additional resources is estimated to be $148 million and $2.8 billion ($1.96 billion with ITCs), respectively. Thus, system modeling shows that using only renewables and BESS to fulfill reliability requirements results in significantly higher resource cost.

Without the addition of 166 MW of dispatchable thermal capacity, 5,000 MW of solar capacity and 5,000 MW of BESS capacity, with an estimated capital cost of approximately $13 billion ($9.1 billion with ITCs), will not provide the same level of reliability as the 166 MW of dispatchable thermal capacity as shown by this analysis.

Based on the results of the independent analysis performed by Black & Veatch, Platte River would need to build 166-279 MW of dispatchable thermal generation capacity plus planned renewable and storage capacity in 2030 when coal generation is replaced to meet the goals of the RDP.

4.2 Lowering of CO2 emissions from thermal capacity during next decade

The RDP policy will result in retirement of existing coal units in efforts to decarbonize the portfolio by 2030. As discussed in Section 1.0 of this report, BV recommends reliance on a balanced portfolio that includes flexible thermal capacity in addition to renewable and storage capacity to provide high reliability of the Platte River system. The best method to further achieve the decarbonization target is to progressively use green hydrogen fuel as and when it becomes available during in the future.

Green hydrogen has increasingly been considered as a potentially effective mechanism to decarbonize the hard-to-abate sectors, including the power sector. Hydrogen fueled combustion turbines will provide fast ramping dispatchable capacity that could play the same critical role as natural gas generators in maintaining grid reliability, albeit with zero carbon emissions. Combustion turbine and engine generator manufacturers are developing engines and turbines that could utilize a substantial percentage of hydrogen blended with natural gas and eventually 100% hydrogen to fuel the units. Firing of 100 percent hydrogen is expected to be achievable at large scales in the future. The advancements of the technology over time are expected to be able to satisfy decarbonization goals for Platte River's portfolio. The hydrogen fuel cost would be higher than natural gas costs by 3 to 10 times in the initial years of adoption until hydrogen infrastructure and turbine technology is further developed.