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Power Grid Engineering & Markets

2025 Integrated Resource Plan Reliability Validation

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PREPARED FOR

Liberty-Empire

PREPARED BY

PowerGEM

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ABBREVIATIONS USED IN REPORT

CC	Combined Cycle Generator
CRA	Charles River Associates
CT	Combustion Turbine Generator
DR	Demand Response
EE	Energy Efficiency
EFOR	Equivalent Forced Outage Rate
EIA	Energy Information Authority
EIDB	Eastern Interconnection Data Base
ELCC	Effective Load Carrying Capability
EOY	End-of-year
EUE	Expected Unserved Energy
GADS	Generating Availability Data System
GDP	Gross Domestic Product
IRP	Integrated Resource Plan
LFE	Economic Load Forecast Error
LOLE	Loss of Load Expectation
NERC	North American Electric Reliability Corporation
NOAA	National Oceanic and Atmospheric Administration
NREL	National Renewable Energy Laboratory
NSRDB	National Solar Radiation Database
TTF	Time to Fail
TTR	Time to Repair
SAM	NREL System Advisory Model
SERVM	PowerGEM's Strategic Energy and Risk Evaluation Model
SPP	Southwest Power Pool

EXECUTIVE SUMMARY

Liberty-Empire engaged PowerGEM to perform a resource adequacy study that includes post expansion plan reliability verification for selected portfolios including the preferred resource plan.

The objective of this effort was to prepare a comprehensive resource adequacy framework that could be used to assess resource plans provided by Liberty-Empire. The modeling utilized the Strategic Energy Risk Valuation Model ("SERVM"). SERVM is a state-of-the-art multi-area reliability and economic simulation tool to support resource adequacy decisions.

The simulations result in full distributions of reliability metrics in both summer and winter seasons, such as Loss of Load Expectation, Loss of Load Hours, and Expected Unserved Energy for a Base Case across 40+ years of weather, load forecast growth uncertainty, and thousands of unit performance draws. After the expansion plans were built, they were run through SERVM to understand the reliability for both near-term and long-term years. In this analysis five of the portfolios were simulated for study years 2029, 2032, and 2040. Additional sensitivities were conducted to provide Liberty-Empire with further insight into the selected expansion plans.

RESOURCE ADEQUACY FRAMEWORK

Since reliability events are high impact and low probability, many scenarios must be considered to accurately assess the reliability of the Liberty-Empire system. For this analysis, SERVM utilized 43 years of historical weather and load shapes (1980-2022), 5 points of economic load growth forecast error, and 40 iterations of Monte Carlo unit outage draws for each scenario to represent the full distribution of realistic scenarios. The number of yearly simulation cases for each scenario is 8,600 (See Figure 2 for more detail). Weather years were each given equal probability while the load forecast error multipliers were given associated probabilities.

Three years were chosen to represent the planning horizon for this analysis: 2029, 2032, and 2040.

Five IRP portfolios were provided by Charles River Associates (CRA), who conducted the Liberty-Empire IRP analysis. CRA provided the details behind each plan including the portfolios and unit characteristics. The five portfolios, described in the Model Development section, are "Portfolio 1", "Portfolio 1 (No Firm Solar)"[1], "Portfolio 4" (selected as the Preferred Resource Plan), "Portfolio 7", and "Portfolio 12".[2] Each of these portfolios were simulated for the three study years, resulting in fifteen total scenarios.

[1] Portfolio 1 (No Firm Solar) is a side contingency studied by Liberty-Empire, although is not a formal IRP plan.
[2] Plans are detailed in Volume 6, Section 3 of this IRP.

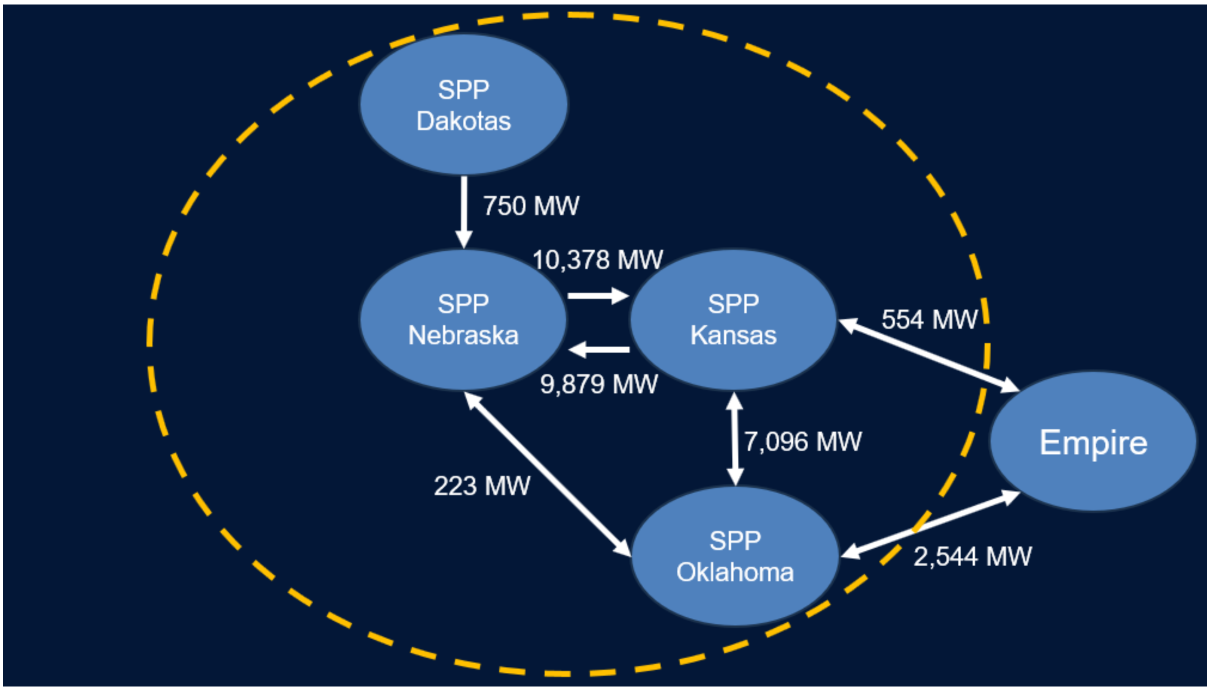
Additional sensitivities were simulated for some of the scenarios to better understand capacity shortfalls, market assistance, and performance during extreme weather years.

Reliability metrics for capacity shortfalls have been defined by the industry for decades and are most often measured using the metric of Loss of Load Expectation (LOLE). LOLE is reported in terms of expected events per year. For this study, the common reliability target of 0.1 LOLE (or 1 day every 10 years) was selected as the reliability standard. To meet this standard, plans must be in place to have adequate capacity such that firm load is expected to be shed once in a 10-year period.

TOPOLOGY

Liberty-Empire was modeled with four neighboring Southwest Power Pool ("SPP") regions, referred to as "SPP Dakotas", "SPP Kansas", "SPP Nebraska", and "SPP Oklahoma." They were modeled with import and export transfer limits as indicated in Figure 1 below. Liberty-Empire is part of SPP and the reliability benefits that provides should be recognized within the simulation modeling.

Figure 1: Study Topology



RELIABILITY RESULTS

Figure 2, Figure 3, and Figure 4 show the capacity by unit class of the portfolios and the resulting LOLE from the simulations. Measuring against the 0.1 days/year LOLE standard, all the portfolios are reliable in 2032 and 2040. In 2029, Portfolio 1 and Portfolio 12 are slightly unreliable at an LOLE of 0.12 days/year and Portfolio 7 is less reliable with an LOLE of 0.19 days/year. Portfolio 1 and Portfolio 12 have slightly less dispatchable capacity than Portfolio 4 (Preferred Plan), while Portfolio 7 has significant solar in place of the dispatchable capacity making it less reliable in 2029. In 2032 and 2040, the portfolios have enough capacity to meet the 0.1 days/year LOLE standard.

Figure 2: 2029 Results

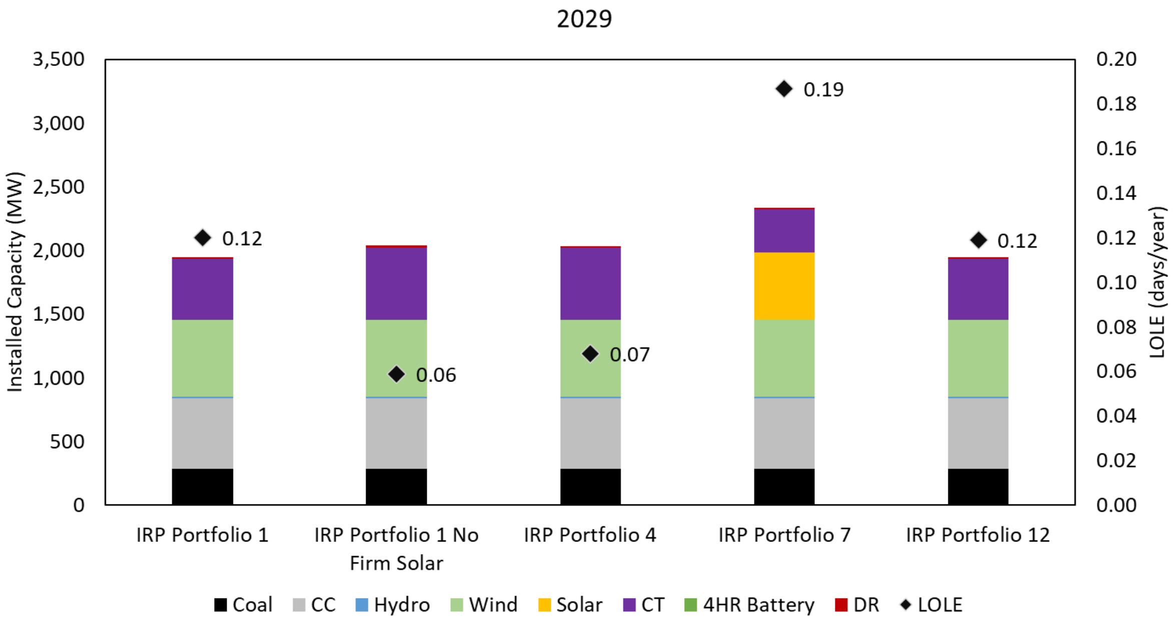


Figure 3: 2032 Results

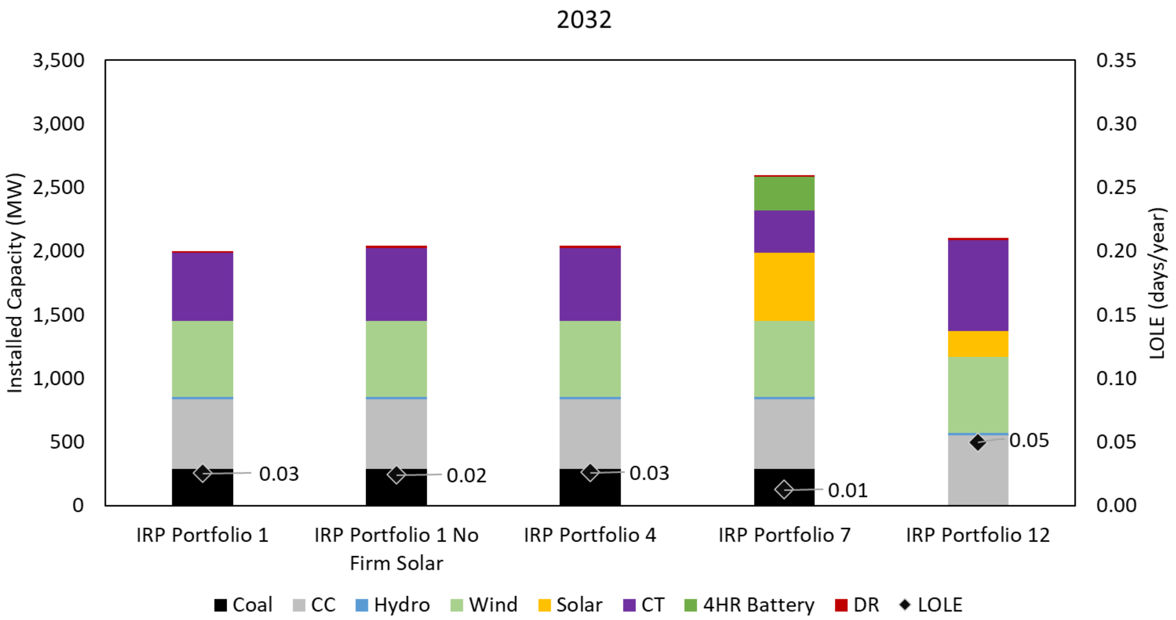
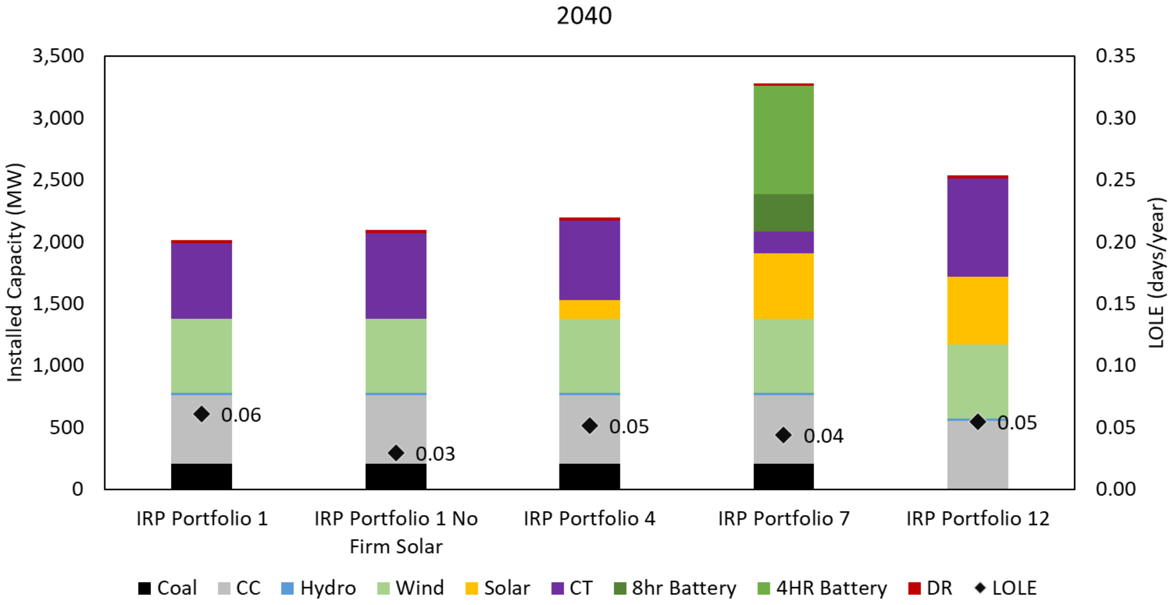


Figure 4: 2040 Results



From a seasonal LOLE perspective, the results show that most of the LOLE occurs in the summer in 2029 but begins to shift to the winter season in 2040 as it is assumed that SPP continues to add solar which shifts risk to the winter.

As discussed later in the report, Liberty-Empire receives significant benefit from being interconnected with SPP. The island case showed that the market provides approximately 100 MW of benefit versus Liberty-Empire being an islanded system.

CONCLUSIONS

Overall, the resource adequacy analysis shows that the five IRP portfolios developed by CRA for Liberty-Empire are reliable in years 2029, 2032, and 2040, with the exception of Portfolio 1, Portfolio 7, and Portfolio 12 in the 2029 study year. Portfolio 1 and Portfolio 12 have less dispatchable capacity than Portfolio 4 (Preferred Plan) and Portfolio 7 likely did not build enough dispatchable capacity with its solar to meet the 0.1 standard in 2029. The analysis suggests that the resource adequacy inputs used in the IRP by CRA were reasonable and produced portfolios that meet the 1 day in 10-year standard in future study years.

MODEL DEVELOPMENT

STUDY TOPOLOGY

SERVM's transmission topology model utilized for this study was based upon load and resource profiles for Liberty-Empire and the rest of SPP, including SPP Dakotas, SPP Nebraska, SPP Kansas, and SPP Oklahoma. Figure 5 and Table 1 below shows the configuration of the study model with its associated transmission interface connections using a pipe and bubble configuration. Input data for the SPP region was provided by CRA.

Figure 5: Study Topology

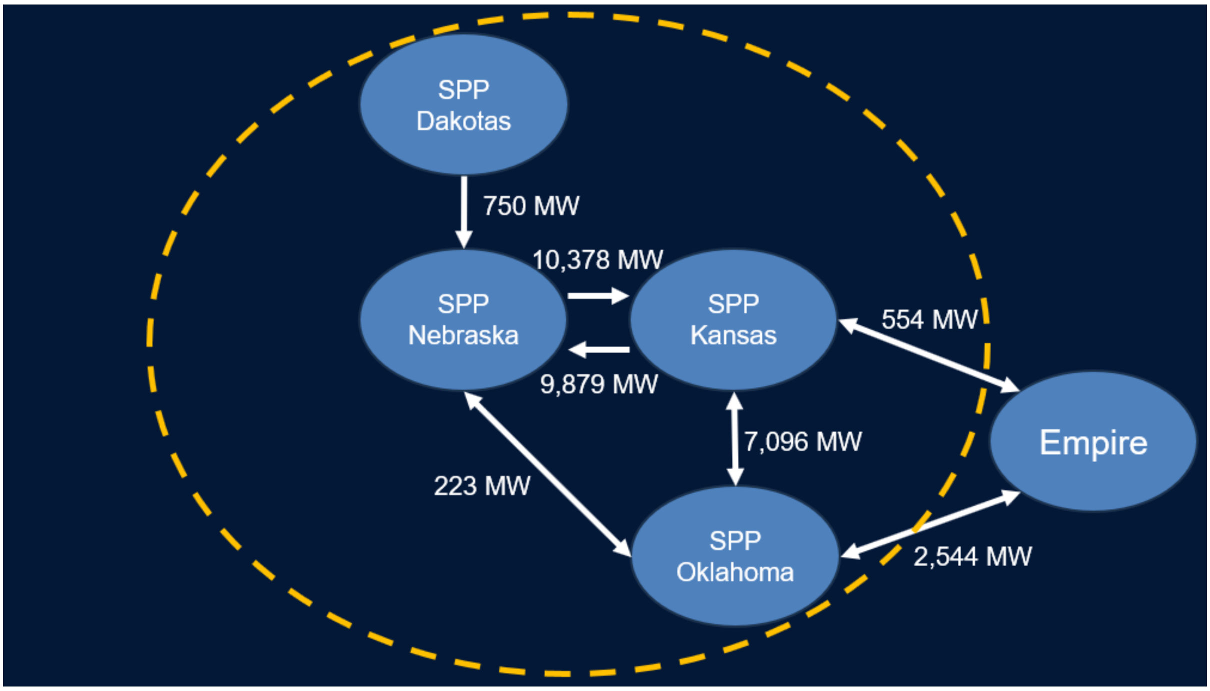


Table 1: Modeled Transmission

Region A	Region B	Capacity Limit In (B->A)	Capacity Limit Out (A->B)
SPP Oklahoma	Empire	2,544	2,544
SPP Dakotas	SPP Nebraska	0	750
SPP Nebraska	SPP Oklahoma	223	223
SPP Nebraska	SPP Kansas	9,879	10,378
SPP Kansas	Empire	554	554
SPP Kansas	SPP Oklahoma	7,096	7,096

SOUTHWEST POWER POOL DEVELOPMENT

The basis for the SPP SERVM model used in this study was the data included in PowerGEM's Eastern Interconnection Database (EIDB). PowerGEM's EIDB was developed and is maintained using publicly available data from sources such as the Energy Information Authority (EIA) Form 860, available documents from the North American Reliability Corporation (NERC), various publicly available Integrated Resource Plans (IRPs), and FERC Forms.

CRA provided PowerGEM with capacity targets by resource class for the four SPP regions modeled. PowerGEM began with its internal EIDB SPP model and adjusted capacity to meet the CRA targets. CRA also provided PowerGEM with load forecasts for each of the SPP regions, shown in Table 2 below.

Table 2: SPP Peak Load Forecast by Region (MW)

Study Year	SPP Oklahoma	SPP Dakotas	SPP Nebraska	SPP Kansas
2029	28,131	5,385	7,725	17,193
2032	28,981	5,547	7,958	17,712
2040	31,370	6,004	8,614	19,174

To more closely align with SPP's own modeling, incremental cold weather generator outages were included. These outage inputs came directly from SPP's own Correlated Outage Report[3]. The aggregate outages were reduced 50% to reflect system improvements during extreme cold weather.

Finally, generic expansion capacity was added to calibrate the aggregate SPP region to an LOLE of 0.1 days/year. This step is taken to ensure that Liberty-Empire results include the assumption that SPP will be at its target reliability rather than being overbuilt or underbuilt. The resulting SPP aggregate buildout is included in Table 3 below.

Table 3: SPP Aggregate Capacity

Unit Type	2029	2032	2040
Battery	1,014	2,228	11,278
Biomass	137	137	137
CC	7,814	7,814	8,814
Coal	17,651	11,313	1,849
CT	11,933	12,346	12,140
DR	1,866	1,881	1,925
Exp CT	6,800	12,050	14,850
Hydro	1,566	1,566	1,566
IC	1,457	1,457	1,457

3 https://www.spp.org/documents/68693/correlated%20outages%20report.pdf

Unit Type	2029	2032	2040
LFG	29	29	29
Nuclear	2,069	2,069	2,069
Oil	1,801	1,801	1,801
PSH	421	421	421
Solar	8,122	20,022	41,622
ST	10,404	9,917	9,674
Wind	36,541	39,157	43,295
Total	101,809	116,391	145,110

PEAK DEMAND FORECAST

For this study the peak demand forecast for Liberty-Empire was provided by CRA and is shown in Table 4 below.

Table 4: Liberty-Empire Peak Load Forecasts

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[redacted]

LOAD MODELING

Load shapes were developed for each of the 43 weather years, 1980-2022. These load shapes were developed based on trends and relationships between load and weather for the years 2019-2023. A neural network was trained using weighted hourly historical temperatures from the National Oceanic and Atmospheric Administration (NOAA) and other key variables. The Springfield, MO NOAA weather station was used to develop the temperature variables.

In addition to temperature, the neural net was provided with training variables that included day of week, hour of day, hour of week, 8-hour rolling average temperature, 24-hour rolling average temperature, and 48-hour rolling average temperature. “Networks” were created for Winter, Summer, and Shoulder periods. These trained networks were then applied to the NOAA weather data for the historical years 1980-2022 to develop synthetic load shapes for each of the 43 weather years. The development of the 43 synthetic load shapes results in a diverse set of annual peak loads. Within SERVM, these shapes will be scaled such that the median of the annual peak loads will equal the weather normal peak load for both summer and winter. The figures below show the summer and winter peak load variance resulting from the 43 synthetic load shapes. The variance is shown in terms of its divergence from the weather normal peak load on a percentage basis.

Figure 6: Summer Peak Load Variability

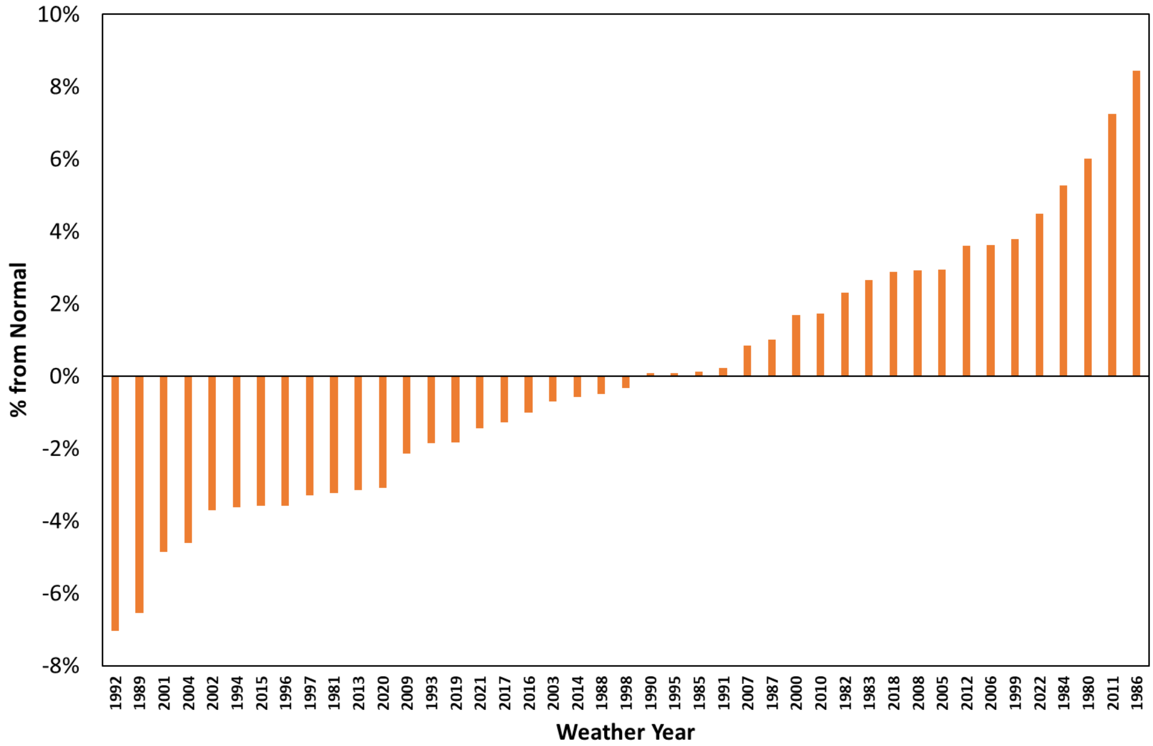
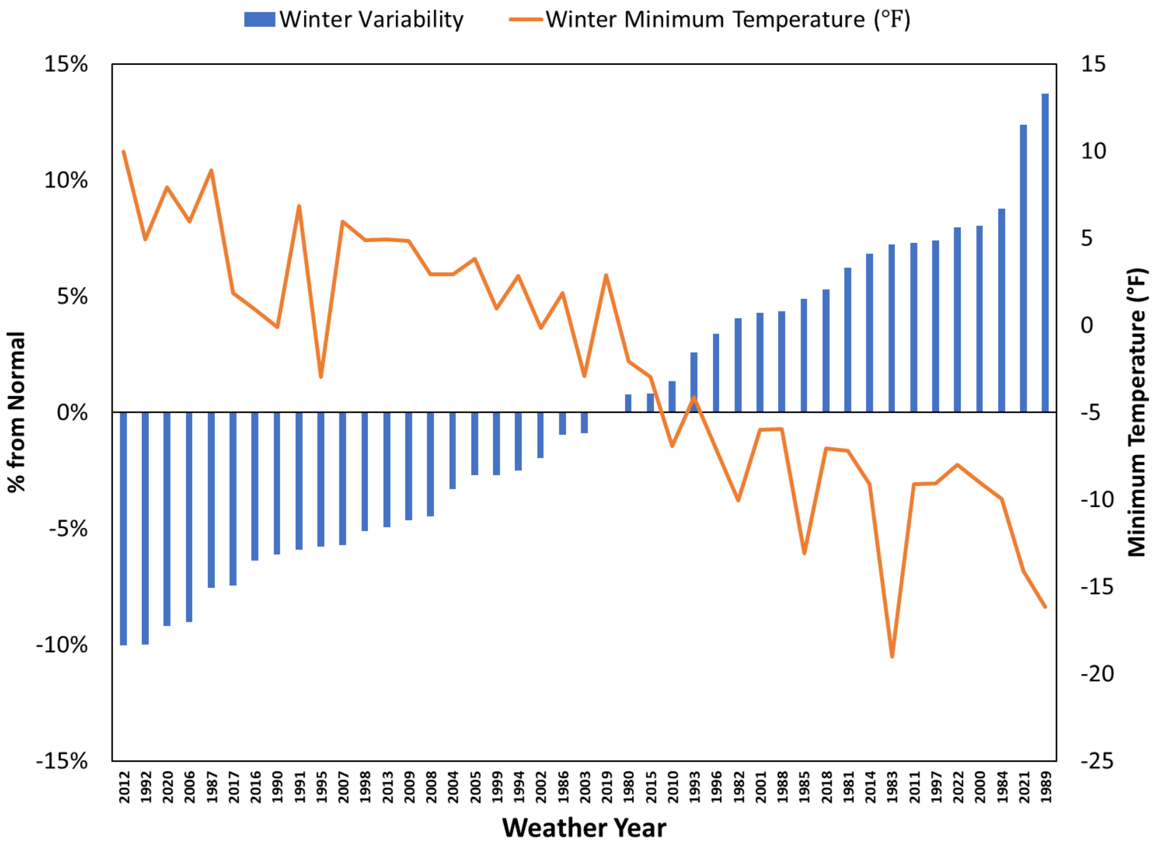


Figure 7: Winter Peak Load Variability



ECONOMIC FORECAST ERROR

Five Load Forecast Error (LFE) multipliers with their associated probabilities were applied to each of the 43 historical load shapes in the simulations. The LFE multipliers simulate the expected probability that the peak demand forecast would be missed because of errors in the forecast of national economic indicators. The multipliers were developed by looking at the historical error in the 4-year out forecast GDP assuming a peak electric demand sensitivity to changes in GDP of 0.4% per 1% change in GDP. The set of LFE multipliers along with their probability of occurrence used in this study are shown in Table 5 below.

Table 5: Load Forecast Error Weighting

Economic Load Forecast Error	Probability Weighting
-4%	7.9%
-2%	24.0%
0%	36.2%
2%	24.0%
4%	7.9%

LIBERTY-EMPIRE RESOURCE MODELING

The following table shows the list of conventional resources and their corresponding summer and winter generating capabilities available to Liberty-Empire for the 2029 study year, excluding any expansion plan additions or retirements.

Table 6. Liberty-Empire Conventional Resource Capacities

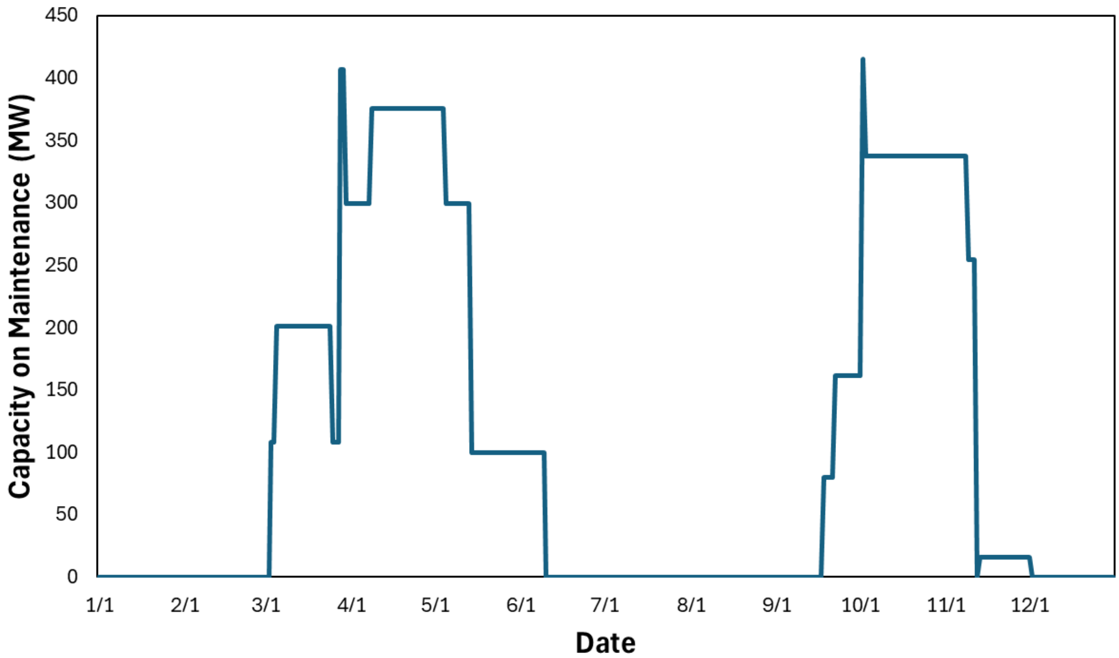
Unit Name	Unit Category	Summer Capacity	Winter Capacity
Riverton 12	CC	254	295.1
State Line	CC	299	327.4
Iatan 1	Coal	76.2	76.2
Iatan 2	Coal	108	108
Plum Point	Coal	100	100
Empire Energy Center 1	CT	81	91.1
Empire Energy Center 2	CT	80	89.8
Empire Energy Center 3&4	CT	83	110.7
State Line 1	CT	93	116.8

To model the transition from summer ratings to winter ratings, technology curves were developed for each unit that adjusted the maximum capacity of the resource based on ambient temperature. These units were modeled with various specifications and dispatch constraints that were provided by CRA.

These specifications include ramp rates, startup and shutdown profiles, minimum uptimes, minimum downtimes, heat rates, and variable costs.

SERVM can model planned maintenance as an annual rate in percentage of hours. SERVM schedules planned maintenance in seasons where there would not typically be an expectation of reliability concerns. This determination is made by looking at all available weather year net load shapes and developing a schedule that is least likely to cause reliability concerns. Thus, while it may be generally expected that planned maintenance will not create reliability issues, there may be some weather years in which that is not the case. The scheduled maintenance for Liberty-Empire units is shown below in Figure 8 and the maintenance rates used for Liberty-Empire units are in Table 8.

Figure 8: Modeled Planned Maintenance



SERVM models forced outages using multiple sets of time to fail (TTF) and time to repair (TTR) inputs for both full and partial outages. Each resource has its own set of TTF and TTR inputs that are used to establish that resource's equivalent forced outage rate (EFOR). Using Monte-Carlo techniques, a TTF value is chosen randomly for each generating resource. That resource is then allowed to operate until it reaches the TTF threshold, at which point it is forced offline. Once it is forced offline, a TTR value is chosen randomly to determine how long the resource will be unavailable. That resource remains offline until it reaches the TTR threshold, at which point it is once again made available, and a new TTF variable is chosen for the resource. TTF and TTR values for Liberty-Empire were developed using three years of historical NERC GADS data. The EFOR values resulting from these TTF/TTR values were then compared to five years of historical performance data and recommendations for the final EFOR values to be used in this study were made. The TTR and TTF values were then modified appropriately so that the resulting EFOR values would match the Liberty-Empire recommendations. The forced outage rates for the Liberty-Empire existing thermal units are shown below in Table 7.

Table 7: Maintenance Rate and EFOR Values

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EXPANSION UNIT MODELING

Assumed unit specifications for capacity expansion units were provided by CRA and are summarized in Table 8 below, including block size, heat rate, round trip efficiency, forced outage rate, and variable operating and maintenance costs.

Table 8: Capacity Expansion Unit Specifications

Technology Type	Block Size (MW)	Heat Rate (Btu/kWh)	Round Trip Efficiency (%)	Forced Outage Rate (%)	VOM (2023/MWh)
Frame CT	240	9,768		5%	$5.51
Gas Aeroderivative	50	9,224		5%	$5.70
Gas RICE	50	8,298		5%	$6.86
Gas RICE (Distributed)	2	9,403		5%	$16.00
Solar (Single Axis Tracking)	50				
Solar (Distributed)	5				
4 hour Li-Ion Storage	50		90%		
8 hour Li-Ion Storage	50		90%		

In addition to the resources above, CRA provided four demand side management (DSM) bundles that could be selected in the expansion plans. These bundles have varying seasonal capacities that can be found in Table 9 and Table 10. These bundles were restricted to being dispatched 100 hours per year with a maximum of one dispatch per day.

Table 9: Winter DSM Bundle Capacity (MW)

Year	High Cost	Mid Cost	Low Cost	DSR
2029	0.24	1.64	1.69	2.57
2032	0.51	3.52	3.46	3.31
2040	1.05	4.65	8.10	3.16

Table 10: Summer DSM Bundle Capacity (MW)

Year	High Cost	Mid Cost	Low Cost	DSR
2029	0.17	2.08	1.82	2.12
2032	0.36	4.46	3.72	2.86
2040	0.76	7.57	8.93	2.74

WIND RESOURCE MODELING

Wind profiles were produced using hourly data for 2016 to 2018 for SPP[4]. Wind profiles for 1980 to 2016 and 2019 to 2022 were selected by using the daily wind profiles from the day that most closely matched the peak load out of all the days +/- 15 days of the source day for the 2016 to 2018 interval. The profiles for the remaining years 2016 to 2018 came directly from the normalized raw data.

[4] https://portal.spp.org/pages/hourly-generation-capacity-by-fuel-type

Figure 9: January Average Wind Profile

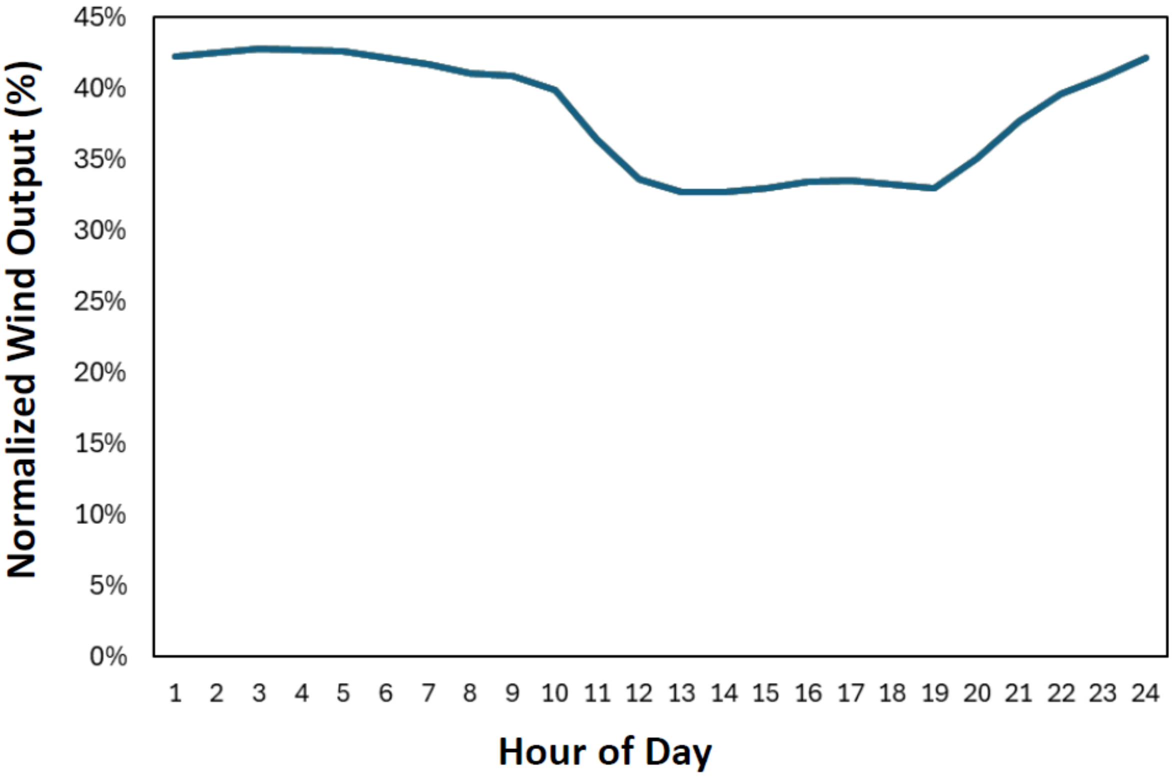
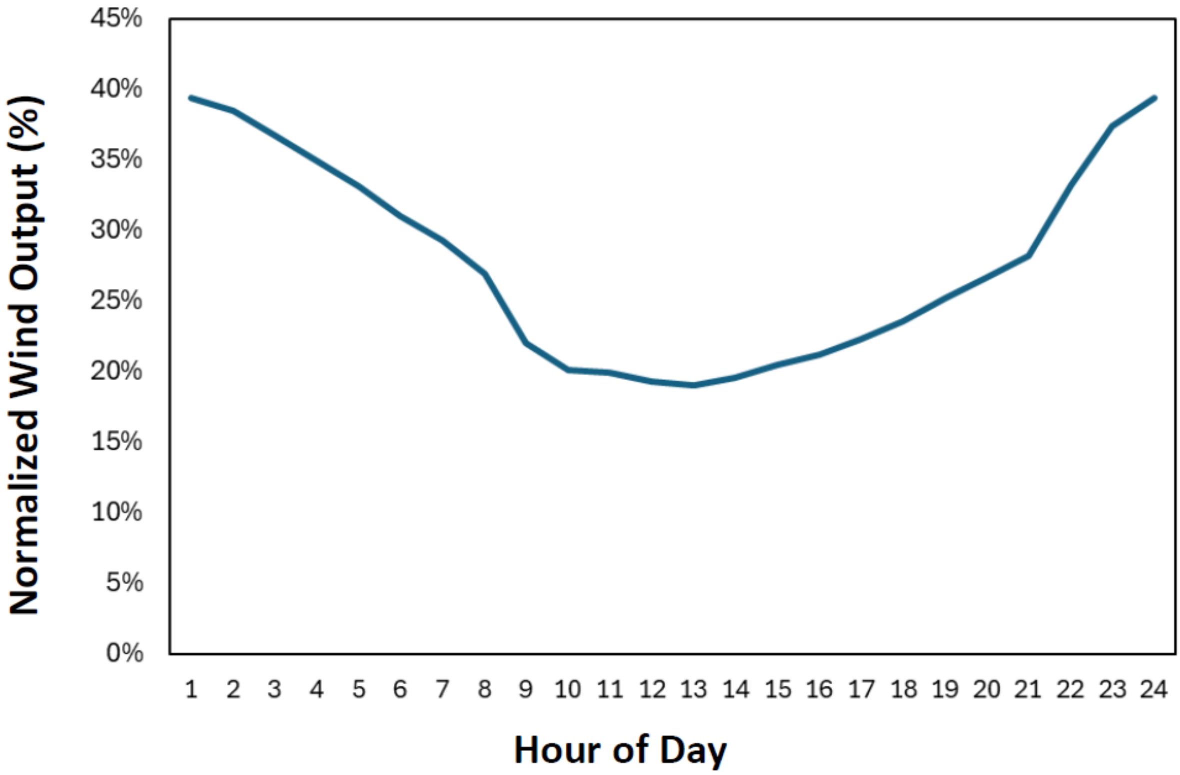


Figure 10: July Average Wind Profile

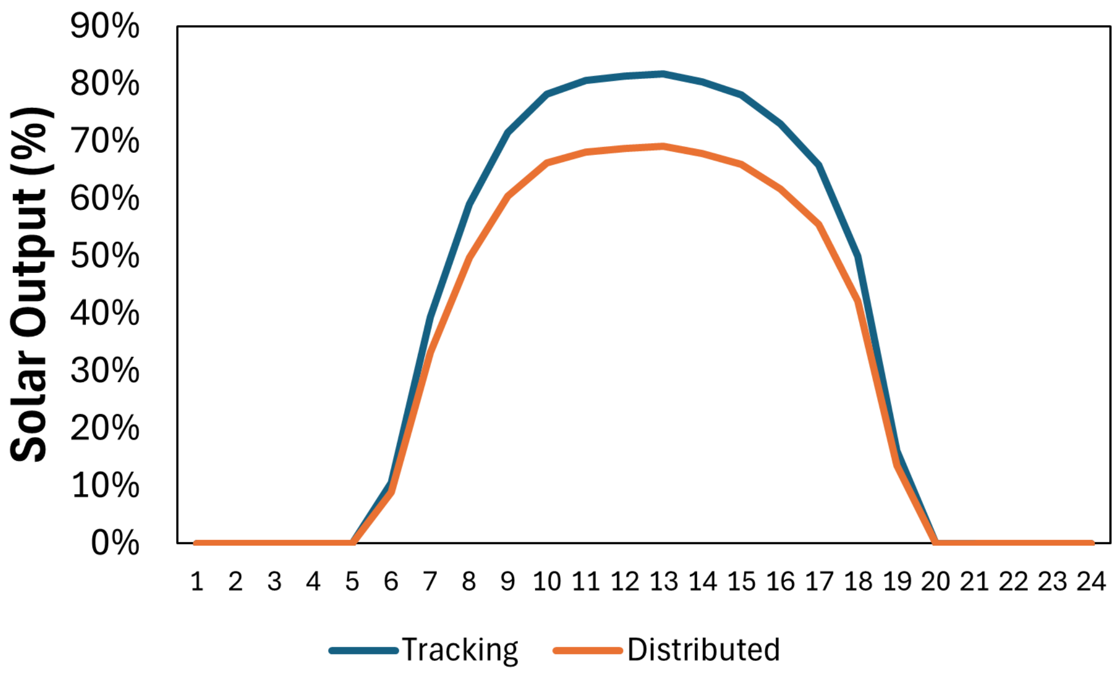


SOLAR RESOURCE MODELING

For this study, a Central Missouri Tracking solar profile was modeled was used for both the tracking and distributed expansion plan units. To create the profiles for each of our weather years, irradiance data for the Central Missouri location was downloaded from the National Renewable Energy Laboratory (NREL) National Solar Radiation Database (NSRDB) Data Viewer for the years 1998 to 2022[5]. The data obtained from the NSRDB Data Viewer was input into NREL's System Advisor Model (SAM)[6] for each year and location to generate the hourly solar profiles based on the solar weather data for fixed and tracking solar plants. Solar profiles for 1980 to 1997 were selected by using the daily solar profiles from the day that most closely matched the peak load for the Liberty-Empire load out of all the days +/- 3 days of the source day for the 1998 to 2022 interval. The profiles for the remaining years 1998 to 2022 came directly from the solar shape output data from SAM.

CRA provided target capacity factors for both the distributed and tracking expansion solar units. Inverter Loading Ratios (ILR) provided were applied to the PowerGEM Central Missouri Tracking profiles so that the capacity factor targets were met. The distributed solar capacity factor is 22.8% while the tracking solar is 26.8%. Figure 11 and Figure 12 below show the average July and January solar output of the final profiles used in the simulations.

Figure 11. Average July Solar Profiles



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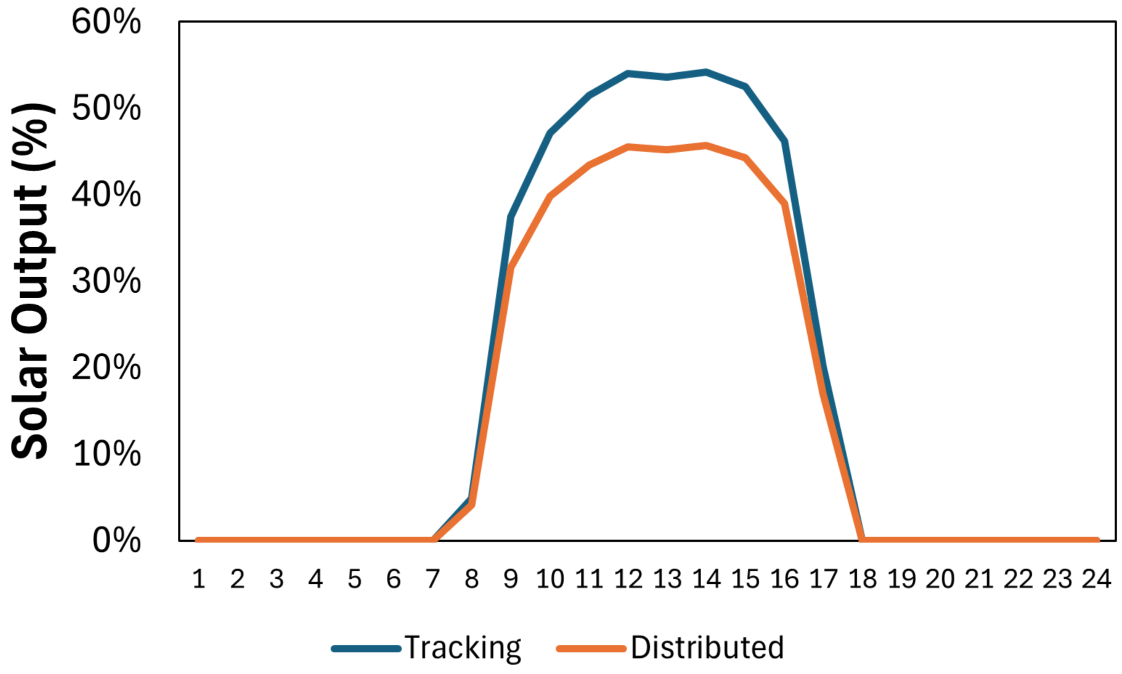
[5] https://maps.nrel.gov/nsrdb-viewer/
[6] https://sam.nrel.gov/

Figure 12. Average January Solar Profiles



ANCILLARY SERVICES MODELING

SERVM commits resources to meet energy needs plus ancillary service requirements, which are defined as SERVM model inputs. In real-world operation, these ancillary services are needed for uncertain movement in net load or sudden loss of generators during the simulations. Within SERVM, these include regulation up and down, spinning reserves, load following reserves, and quick start reserves. An LOLE event was determined when there was not sufficient generation to serve load, regulation up, and spinning requirements. The regulation plus spin requirement was assumed to be 4% of load for this analysis.

EXPANSION PLANS

CRA provided IRP capacity expansion plan schedules and unit specifications for the five Liberty-Empire portfolios. Resource additions include solar, storage, and natural gas units. Portfolio 7 only adds solar and storage resources. The schedules note resources coming online as early as 2027 and as late as 2044. Each portfolio adds resources to the existing portfolio and includes planned retirements of some of the existing units. The Base portfolio and retirement units are listed in Table 11 and Table 12 below.

Table 11: Liberty-Empire Base Portfolio (Summer MW)

Unit Name	Unit Category	Capacity
Riverton 12	CC	247
State Line	CC	316
Iatan 1	Coal	84
Iatan 2	Coal	105
Plum Point	Coal	100
Empire Energy Center 1	CT	80
Empire Energy Center 2	CT	82
Empire Energy Center 3&4	CT	87
State Line1	CT	90
Liberty-Empire Interruptible	DR	8
Ozark Beach Hydro	Hydro	4
Kings Point	Wind	149
Neosho Ridge	Wind	301
North Fork Ridge	Wind	149

Table 12: Expansion Plan Retirements

Unit Retired	Portfolio 1	Portfolio 1 (no Firm Solar)	Portfolio 4	Portfolio 7	Portfolio 12
Energy Center #1-2	12/31/2035	12/31/2035	12/31/2035	12/31/2035	12/31/2035
Riverton #10-11	11/13/2026	11/13/2026	11/13/2026	11/13/2026	11/13/2026
Iatan #1	12/31/2039	12/31/2039	12/31/2039	12/31/2039	12/31/2031
Iatan #2	N/A	N/A	N/A	N/A	12/31/2031
Plum Point (Owned)	N/A	N/A	N/A	N/A	12/31/2031
Plum Point (Contract)	8/31/2040	8/31/2040	8/31/2040	8/31/2040	12/31/2031

Capacity additions are listed by resource type and in-service year for each of the five portfolios in Table 13 through Table 17.

Table 13: Liberty-Empire Portfolio 1 Additions by Type and Year (Summer MW)

Resource	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Gas Aero							50								
Gas Aero (Colo)[7]				50											
Gas Aero (KP)[8]				100											
Gas RICE (DIST)															6
Gas Frame CT											240				

Table 14: Liberty-Empire Portfolio 1 (No Firm Solar) Additions by Type and Year (Summer MW)

Resource	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Gas Aero															50
Gas RICE (DIST)															
Gas Frame CT				240							240				

Table 15: Liberty-Empire Portfolio 4 Additions by Type and Year (Summer MW)

Resource	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Gas RICE (DIST)															
Gas Frame CT				240							240				
Solar										150					
Storage (LI 4hr-DIST)															

[7] Gas collocated with firm solar.
[8] Gas collocated with Kings Point Wind.

Table 16: Liberty-Empire Portfolio 7 Additions by Type and Year (Summer MW)

Resource	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Solar		300	200												
Solar (DIST)		10	10	10											
Storage (LI 4hr-DIST)			2	2	2	2	2	2	2	2	2	2	2	2	
Storage (LI 4hr)					50	100	100	100	100	100	100	100		50	50
Storage (LI 8hr)										100	100	100			

Table 17: Liberty-Empire Portfolio 12 Additions by Type and Year (Summer MW)

Resource	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Gas Aero (Colo)[9]				50											
Gas Aero (KP)[10]				100											
Gas RICE (DIST)								2							
Gas Frame CT							240				240				
Solar							200	200	50	100					
Storage (LI 4hr-DIST)						1	2								

Differing combinations of DSM bundles were selected for each of the expansion portfolios. The bundles selected for each portfolio are shown below in Table 18.

[9] Gas collocated with firm solar.
[10] Gas collocated with Kings Point Wind.

Table 18: Expansion Portfolio DSM Bundles

DSM Bundle	IRP Portfolio 1	IRP Portfolio 1 (No Firm Solar)	IRP Portfolio 4	IRP Portfolio 7	IRP Portfolio 12
High Cost	Included	Included	Included		Included
Mid Cost	Included	Included	Included	Included	Included
Low Cost	Included	Included	Included		Included
DSR		Included		Included	

STUDY RESULTS

Annual LOLE results and portfolio compositions are shown for each portfolio under each of the three study years in Table 19, Table 20, and Table 21 In general, the results indicate that this collection of portfolios are reliable, particularly in the later study years, where LOLE remains well below the 0.1 days/year standard. LOLE values in these years range between approximately 0.01 days/year and 0.06 days/year.

In the study year 2029, Portfolio 1 (No Firm Solar) and Portfolio 4 (Preferred Plan) are considered reliable with LOLE values of 0.06 days/year and 0.07 days/year respectively. Portfolio 1, Portfolio 7, and Portfolio 12 exceed the standard with LOLE values of 0.12 days/year, 0.19 days/year, and 0.12 days/year, respectively. Portfolio 7 LOLE results are high due to that portfolio only adding large amounts of solar and a small amount of storage prior to end-of-year (EOY) 2029. Furthermore, Portfolio 1 and Portfolio 12 are adding smaller amounts of dispatchable capacity gas resources (150 MW by EOY 2029) than Portfolio 1 (No firm Solar) and Portfolio 4 (Preferred Plan) which add more dispatchable capacity by EOY 2029 (240 MW gas).

Table 19: 2029 Portfolio Capacity and Simulation Results

Unit Class	Portfolio 1	Portfolio 1 (No Firm Solar)	Portfolio 4	Portfolio 7	Portfolio 12
4HR Battery (MW)	0	0	0	4	0
CC (MW)	553	553	553	553	553
Coal (MW)	284	284	284	284	284
CT (MW)	483	570	570	337	483
DR (MW)	12	14	12	12	12
Hydro (MW)	16	16	16	16	16
Solar (MW)	0	0	0	530	0
Wind (MW)	600	600	600	600	600
Total (MW)	1,948	2,037	2,035	2,336	1,948
LOLE (days/year)	0.12	0.06	0.07	0.19	0.12
LOLH (hours/year)	0.30	0.16	0.18	0.34	0.31
EUE (MWh)	20.46	11.51	12.93	27.91	21.55

In study year 2032, all portfolios meet the 0.1 days/year LOLE standard, with LOLE values ranging from 0.01 days/year to 0.05 days/year. Overall, the results in this year are lower than those in 2029 driven primarily by some capacity additions and SPP market support. SPP adds a significant amount of solar which provides Liberty-Empire benefit during summer load shed events. Portfolio 12 has a higher LOLE in 2032 than IRP Portfolio 1 despite adding more dispatchable capacity due to having earlier retirement dates of existing coal units.

Table 20: 2032 Portfolio Capacity and Simulation Results

Unit Class	Portfolio 1	Portfolio 1 (No Firm Solar)	Portfolio 4	Portfolio 7	Portfolio 12
4HR Battery (MW)	0	0	0	260	3
CC (MW)	553	553	553	553	553
Coal (MW)	284	284	284	284	0
CT (MW)	531	570	570	337	715
DR (MW)	17	19	17	15	17
Hydro (MW)	16	16	16	16	16
Solar (MW)	0	0	0	530	200
Wind (MW)	600	600	600	600	600
Total (MW)	2,001	2,042	2,039	2,595	2,104
LOLE (days/year)	0.03	0.02	0.03	0.01	0.05
LOLH (hours/year)	0.04	0.04	0.05	0.02	0.08
EUE (MWh)	3.14	2.54	3.05	1.71	7.07

In study year 2040, all portfolios again meet the LOLE standard with values between 0.03 days/year and 0.06 days/year. By this time, large amounts of dispatchable capacity have been added to all portfolios.

Table 21: 2040 Portfolio Capacity and Simulation Results

Unit Class	Portfolio 1	Portfolio 1 (No Firm Solar)	Portfolio 4	Portfolio 7	Portfolio 12
8hr Battery (MW)	0	0	0	300	0
4HR Battery (MW)	0	0	0	874	3
CC (MW)	553	553	553	553	553
Coal (MW)	208	208	208	208	0
CT (MW)	609	690	642	176	789
DR (MW)	25	28	25	18	25
Hydro (MW)	16	16	16	16	16
Solar (MW)	0	0	150	530	550
Wind (MW)	600	600	600	600	600
Total (MW)	2,011	2,095	2,194	3,275	2,536
LOLE (days/year)	0.06	0.03	0.05	0.04	0.05
LOLH (hours/year)	0.14	0.06	0.12	0.13	0.11
EUE (MWh)	11.50	5.30	10.13	26.36	7.16

Table 22, Table 23, and Table 24 below show a comparison of the seasonal LOLE values for each of the Liberty-Empire portfolios. Portfolio 7 has the most winter LOLE because solar resources provide lower capacity value in the winter when peak periods are in the early morning or evening when solar isn't contributing energy.

Table 22: 2029 Liberty-Empire LOLE by Season

Portfolio	Summer LOLE (Days/year)	Winter LOLE (Days/year)
Portfolio 1	0.11	0.01
Portfolio 1 No Firm Solar	0.05	0.01
Portfolio 4	0.06	0.01
Portfolio 7	0.15	0.04
Portfolio 12	0.10	0.01

Table 23: 2032 Liberty-Empire LOLE by Season

Portfolio	Summer LOLE (Days/year)	Winter LOLE (Days/year)
Portfolio 1	0.02	0.01
Portfolio 1 No Firm Solar	0.02	0.01
Portfolio 4	0.02	0.01
Portfolio 7	0.01	0.01
Portfolio 12	0.04	0.01

Table 24: 2040 Liberty-Empire LOLE by Season

Portfolio	Summer LOLE (Days/year)	Winter LOLE (Days/year)
Portfolio 1	0.03	0.03
Portfolio 1 No Firm Solar	0.02	0.01
Portfolio 4	0.03	0.02
Portfolio 7	0.00	0.04
Portfolio 12	0.03	0.02

SENSITIVITIES

ESTIMATING CAPACITY ADJUSTMENTS

In the 2029 study year, Portfolio 1, Portfolio 7, and Portfolio 12 were above the target LOLE metric of 0.1 days/year. A sensitivity was performed to determine how much additional capacity is needed to reduce LOLE in those portfolios to 0.1 days/year. Portfolio 12 was selected for the analysis because it had the highest base case LOLE. Incremental levels of perfect capacity[11] were added to calculate how sensitive Liberty-Empire LOLE is to capacity additions. Table 25 below shows the additional perfect capacity needed to achieve LOLE of 0.1 days/year for the selected portfolios. In 2032 and 2040 all portfolios were seen as reliable from a resource adequacy perspective.

Table 25: Capacity Additions for LOLE of 0.1 days/year

Study Year	Portfolio 1 Capacity Need (MW)	Portfolio 7 Capacity Need (MW)	Portfolio 12 Capacity Need (MW)
2029	20 MW	50 MW	10 MW

[11] Perfect capacity was modeled as a gas turbine that can dispatch instantly with no ramping constraints and has no outages or required maintenance.

ISLAND SENSITIVITY

To assess the impact that the modeled SPP transmission connections had on the modeled Liberty-Empire region's LOLE, a sensitivity was performed where the transmission ties were turned off. Portfolio 4 (Preferred Plan) in the 2029 study year was chosen for this analysis. The Liberty-Empire region was modeled as an island, and LOLE increased from 0.07 days/year to 0.29 days/year. Incremental amounts of perfect capacity were then added to determine the perfect capacity required to restore LOLE to the base case value of 0.07 days/year. The analysis concluded that the SPP transmission ties effectively provided 100 MW of perfect capacity to the Liberty-Empire region.

EXTREME WEATHER SENSITIVITY

To better understand how each portfolio performs in harsh summer and winter weather conditions, the worst weather year for each season was selected and system LOLE for the worst weather year was compared to the seasonal LOLE of the base case which incorporates an average of all the weather years. This was analyzed for 2029 and 2040 as shown in Figure 13, Figure 14, Figure 15, and Figure 16. In general, the extreme weather comparisons took a similar shape as the Base Case seasonal LOLE. Base case summer or winter LOLE varied due to resource makeup, and the extreme weather year LOLE followed suit. It is likely the interconnection Liberty-Empire has with SPP in the modeling dampens any major differences between the portfolios in these extreme years.

Figure 13: 2029 Summer Extreme Weather Analysis

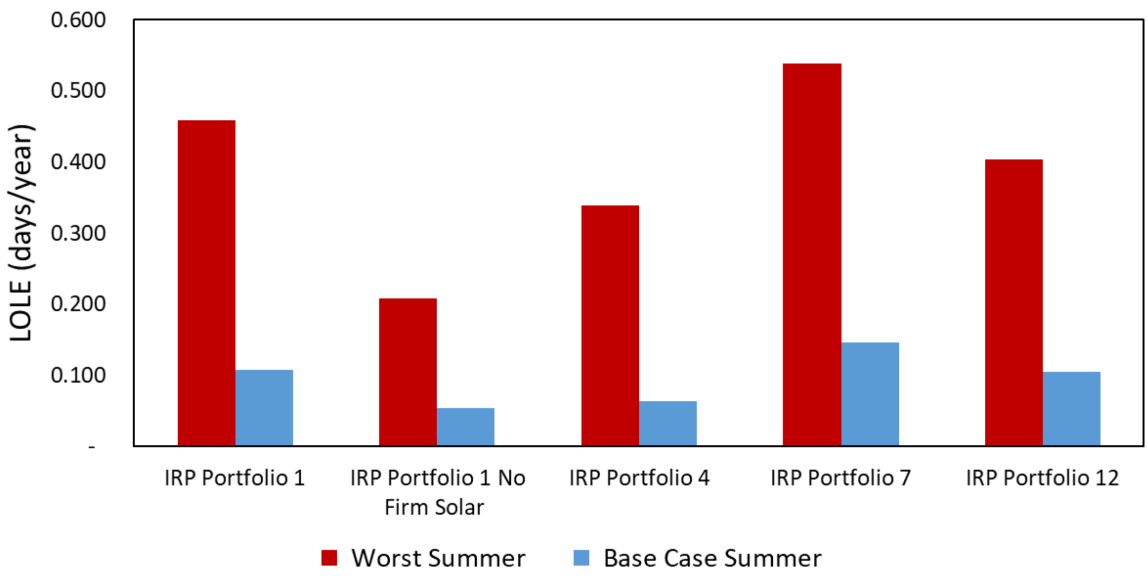


Figure 14: 2029 Winter Extreme Weather Analysis

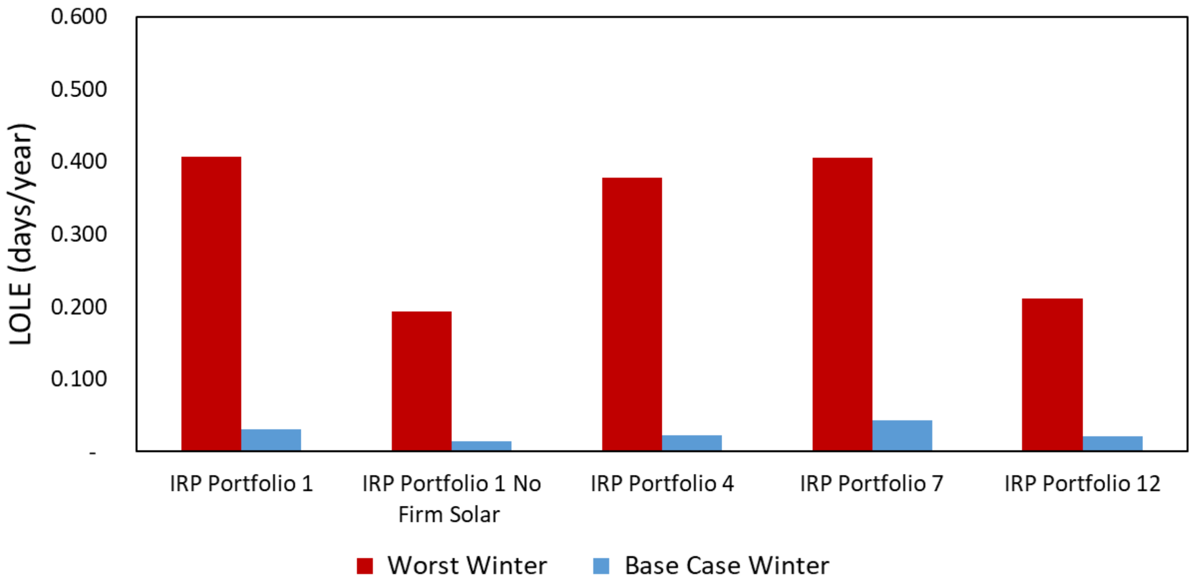


Figure 15: 2040 Summer Extreme Weather Analysis

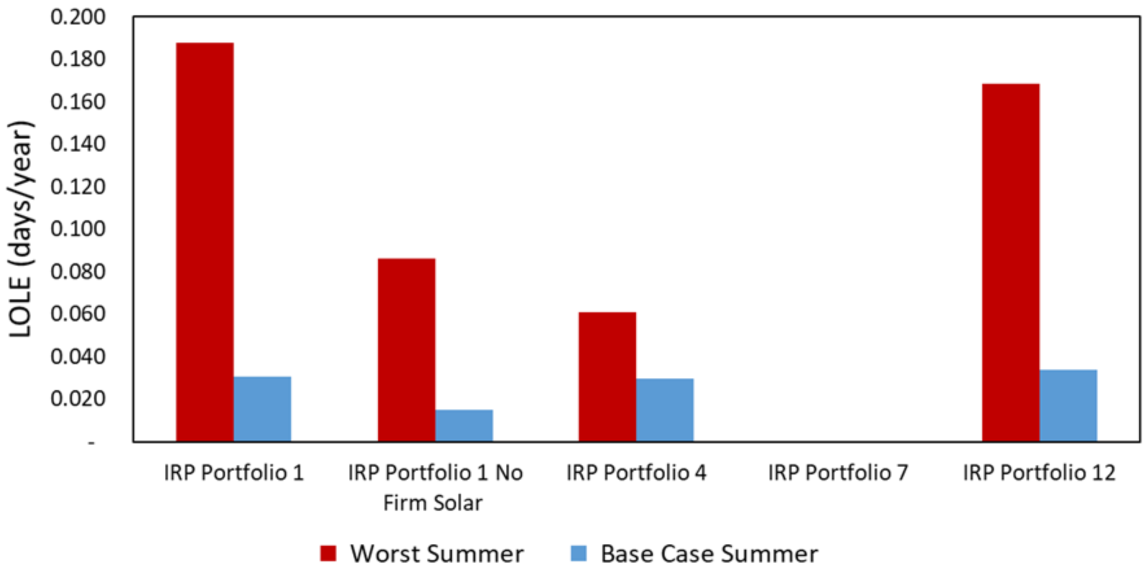


Figure 16: 2040 Winter Extreme Weather Analysis