2022 ELCC Wind and Solar Study Report

SPP Resource Adequacy

November 2022

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EXECUTIVE SUMMARY

As retirements of conventional resources and the penetration of renewable resources in the SPP Balancing Authority (BA) Area increases over time, it becomes critical to correctly assess the capacity value of renewable resources. Over-valuing renewable resources' contribution can result in lower levels of system reliability and increased risks of potential unserved load; while under-valuing can result in additional cost. Meeting the requirement of SPP policy and governing documents, Staff performed an Effective Load Carrying Capability (ELCC) study to assess the capacity value of existing renewable capacity in the SPP BA Area. ELCC is defined as the amount of incremental load a resource can reliably serve, while also considering probabilistic parameters of unserved load.

Implementation of the ELCC policy is to be used as the official accreditation method for wind and solar facilities in the SPP BA Area, effective June 1, 2023. This method replaced the previous accreditation methodology outlined in the SPP Planning Criteria. Likewise, the results of this method will be used by SPP entities beginning with the 2023 Resource Adequacy Workbook submissions outlined in Attachment AA of the SPP Tariff.

Wind Resources

The 2022 ELCC study results indicate that with increasing penetrations of wind resources, the capacity value provided by those resources, as a percentage of nameplate capacity generally tends to decrease. The results indicate the total capacity available from wind to be 4,896 MW in the summer season and 5,268 MW in the winter season for the installed nameplate capacity of 32,467 MW. Upon increasing the total installed capacity to 40,000 MW of wind, the accredited capacity totaled 6,054 MW in the summer season and 6,390 MW in the winter season. On a percentage basis, the summer ELCC value of the resources decreases from 17% with 32,467 MW of wind to 15% of 40,000 MW. The winter ELCC value of the resources decreases from 18% with 32,467 MW of wind to 16% of 40,000 MW, which is illustrated in Figure 1. This graph also illustrates trends of declining ELCC percentage with respect to increase in wind penetration.

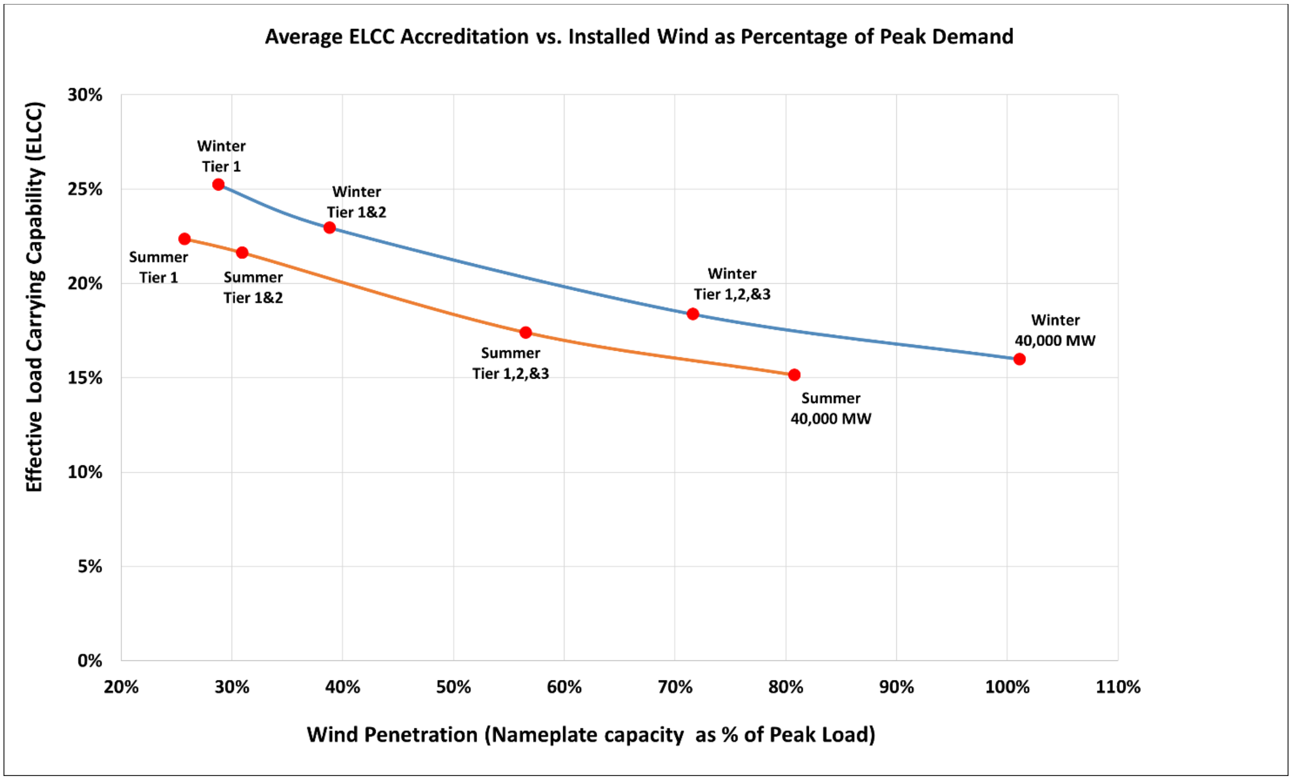

Figure 1. 2022 Average ELCC Accreditation

Based on the results, Tier nameplate values were calculated, and individual wind resources were allocated into Tier 1, Tier 2, and Tier 3. For the summer season, Tier nameplate amount was 13,211 MW, 2,808 MW, and 16,448 MW for Tier 1, 2 and 3, respectively. The accredited ELCC amounts were 2,952 MW, 404 MW, and 1,978 MW for Tier 1, 2, and 3, respectively as shown in Table 1. Table 2 shows the winter season, Tier nameplate amount was 11,745 MW, 4,274 MW, and 16,448 MW for Tier 1, 2 and 3, respectively. The accredited ELCC amounts were 2,949 MW, 654 MW, and 2,083 MW for Tier 1, 2, and 3, respectively as shown in Table 2.

Table 1. Summer Wind ELCC Tier Result

2022 Allocated ELCC Summer Wind by Tier (MW)			
	TIER 1	TIER 2	TIER 3
Tier ELCC (MW)	2,952	404	1,978
Tier Nameplate (MW)	13,211	2,808	16,448
Tier ELCC (%)	22%	14%	12%

Table 2. Winter Wind ELCC Tier Result

2022 Allocated ELCC Winter Wind by Tier (MW)			
	TIER 1	TIER 2	TIER 3
Tier ELCC (MW)	2,949	654	2,083
Tier Nameplate (MW)	11,745	4,274	16,448
Tier ELCC (%)	25%	15%	13%

Solar Resources

Historical output from the previous ELCC study was incorporated to the current amount of installed solar facilities (562 MW) to determine the accredited capacity. The results from the 2022 Solar ELCC study indicates the total capacity available from solar to be 383 MW in the summer season and 186 MW in the winter season for the installed capacity of 562 MW.

Tier allocation based on the result were 181 MW and 202 MW for summer Tier 1 and 3, respectively (Table 3). And 87 MW and 86 MW for winter Tier 1 and 3, respectively (Table 4). The ELCC results shown in Table 3 and Table 4 consider only weather years 2017 to 2021 due to lack of installed solar capacity prior to 2017. Tier 2 did not have any allocation because no entities exceeded the allotted Tier 1 amount. The ELCC results for weather years 2017 and 2018 were derived from the 2020 ELCC Study. An additional ELCC Solar study analyzing higher penetration of installed solar will be finalized early 2023 in a separate report.

Table 3. Summer Solar ELCC Tier Result

2022 Summer ELCC Solar			
	TIER 1	TIER 2	TIER 3
Tier ELCC (MW)	181	0	202
Tier Nameplate (MW)	235	0	327
Tier ELCC (%)	77%	0%	62%

Table 4. Winter Solar ELCC Tier Result

2022 ELCC Winter Solar			
	TIER 1	TIER 2	TIER 3
Tier ELCC (MW)	87	0	86
Tier Nameplate (MW)	235	0	327
Tier ELCC (%)	37%	0%	26%

1.1 ACKNOWLEDGEMENTS

The stakeholder review process was an integral part in this study, and SPP staff appreciates the participation and oversight of the Supply Adequacy Working Group (SAWG).

SPP SYSTEM ELCC STUDY

2.1 ELCC OVERVIEW

Effective Load Carrying Capability (ELCC) is defined as the amount of incremental load a resource can reliably serve, while also considering probabilistic parameters of unserved load. The magnitude of incremental load served which is derived in the ELCC analysis becomes the basis of the resource's accreditation. ELCC has been used for determining the capacity value of resources since the 1960's when Garver demonstrated the use of Loss of Load Probability (LOLP) in the calculation of ELCC[1]. There are other utilities, Independent System Operators (ISOs), and Regional Transmission Organizations (RTOs) that utilize ELCC practices to determine capacity value of variable resources.

Using ELCC practices, a facility's accreditation (measured in MW) is a fractional probabilistic measure of the facility's nameplate rating that can be relied on to serve load. ELCC can express the value that generation contributes to a system as penetration of the specific resource type increases. Underestimating the contribution of variable generation resources to help meet system peaks can result in the need for additional generation capacity and higher system costs. Overestimating the ability of such variable generation resources to help serve system peaks can result in lower levels of system reliability and increased risks of potential unserved load.

The results of an ELCC study are dependent upon the selection of a specific reliability target. SPP utilizes the reliability metric of 1 day in 10 years (or 0.1 day/year), which is also used in the SPP Loss of Load Expectation (LOLE) analysis to determine the adequate planning reserve margin for the SPP BA Area. In order to determine the seasonal ELCC accreditation, LOLE that occurred in the summer was exclusively used to determine the summer accredited capacity and LOLE that occurred in the winter was used to determine the winter accredited capacity.

[1] Garver, "Effective Load Carrying Capability of Generating Units," Aug. 1966

2.2 SOFTWARE

The SPP Wind and Solar ELCC Study utilized the Strategic Energy Risk Valuation Model (SERVM) software package from Astrapé Consulting. SERVM is a production-cost software, which performs a Security Constrained Economic Dispatch while utilizing a Monte-Carlo algorithm when varying the uncertainty of load and availability of capacity through multiple simulations.

2.3 MODEL INPUTS AND ASSUMPTIONS

Many of the model inputs and assumptions (such as unit parameters, external transfers, DC Tie considerations, etc.) for the ELCC study were the same used in the 2021 Loss of Load Expectation (LOLE) Study[2]. The key differences in these assumptions were the exclusion of transmission limitations between modeled areas and the use of load forecast uncertainty, as well as performing the ELCC analysis for each weather year independently. Curtailed amounts of wind and solar generation, as provided and tracked in the SPP Marketplace, were added back into the hourly generation profiles used in the ELCC study and allocation process.

Perfect negative generation was added to the model in order to achieve the 0.1 day per year reliability threshold. The same amount of negative generation was added to each hour in the simulation. This generation was modeled in SERVM as a perfect generator with no outages to provide a constant negative capacity. The ELCC analysis is performed with multiple weather years using historical data in order to account for any unusual high or low "outliers" in the data. ELCC is performed on data from one historical year at a time, thus only one accredited capacity value is derived per season for each modeled weather year.

2.3.1 WIND TIER DETERMINATION

Various levels of nameplate capacity were modeled and analyzed to calculate the accredited capacity for all wind resources. The analysis represents 32,467 MW of installed wind divided into three tiers: Tier 1, Tier 2, and Tier 3. Tiers are determined based on Designated Resources (with service confirmed by June 1 of each calendar year) for the designated amount as shown on the Network Integration Transmission Service (NITS) agreement. If necessary, single

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[2] 2021 SPP LOLE Study Report

facilities may be analyzed across multiple tiers and will be allocated capacity based on the appropriate tier.

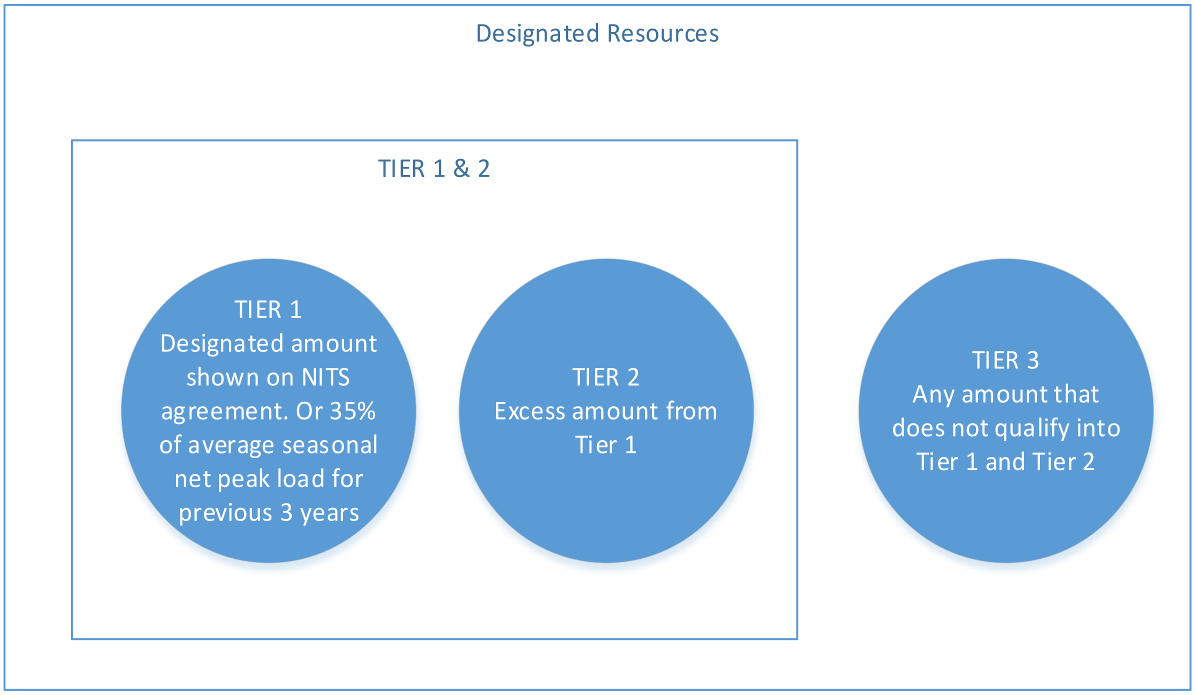

Figure 2: Tier Diagram for Wind

The maximum amount for Tier 1 is 35% of the Load Responsible Entity's (LRE) average seasonal net peak load for the previous three years. Through communication by SPP, the LRE designated whether a facility in its NITS agreement should be studied in Tier 1 or Tier 2 if the entity exceeded the Tier 1 threshold. Tier 1 has priority in the study and has its ELCC capacity value determined first, followed by tier 2 and Tier 3. Tier 2 is the designated amounts of wind Designated Resources in an LRE's NITS agreement in excess of 35% of the LRE's average seasonal net peak load for the previous three years.

Tier 3 is the amount of all studied wind resources not included in Tier 1 and Tier 2. If the resources analyzed in Tier 1 and 2 did not have firm transmission service on the full contract or ownership amount, the remaining nameplate rated capability of the resource was studied in Tier 3. Wind facilities registered in the SPP Integrated Marketplace by June 1, 2022, not identified through the 2022 Workbook submission process were assigned to Tier 3, assuming there was no confirmed Firm Transmission Service by June 1, 2022. This method and analysis reflects the approved ELCC policy for wind and solar resources. Table 5 below shows an example for the situation where three entities are purchasing nameplate capacity from an individual facility and how that facility could be divided into separate tiers.

Table 5. Tier Designation Example

Plant Name	Nameplate (MW)	Purchasing Entity	Firm Service Granted (MW)	Summer Contract (MW)	Summer Tier	Winter Contract (MW)	Winter Tier
Wind Facility A	300	LRE 1	200	200	1	200	1
		LRE 2	50	28	1	28	1
				22	1	22	2
		LRE 3	0	50	3	50	3

For summer season, Tier 1 included 41%, or 13,211 MW, of all studied nameplate wind; Tier 2 included 9%, or 2,808 MW, of all studied nameplate wind; and, Tier 3 included of 51%, or 16,448 MW, of all studied nameplate wind. For winter season, Tier 1 comprised 36%, or 11,745 MW, of all studied nameplate wind; Tier 2 comprised 13%, or 4,274 MW, of all studied nameplate wind; and, Tier 3 comprised 51%, or 16,448 MW, of all studied nameplate wind. There were 40 out of 61 Load Responsible Entity (LRE) utilized wind resources to meet Resource Adequacy Requirement (RAR), and 14 out of 40 LREs exceeded the Tier 1 threshold. Tier 1 threshold for wind in the SPP system was 18,190 MW for the summer season and 15,386 MW for the winter season when considering all LREs in the footprint.

Penetrations of wind up to 40,000 MW were analyzed. The additional penetration amount of wind was applied by scaling the existing wind locations to reach a SPP wind nameplate of 40,000 MW. The scaling approach was chosen as to not predict where future wind installations would be located, which could inaccurately bias the results for any future installed capacity. The 40,000 MW capacity value was studied and calculated solely for trending purposes to not reanalyze historical weather years as more wind is installed on the SPP system.

The 2022 ELCC wind analysis was performed on weather years 2019 to 2021. The results for weather years 2012 to 2018 were derived from the 2020 ELCC Study as to not re-run those historical weather years. The results from each season of each weather year were then averaged together to produce an average ELCC value for each tier.

2.3.2 SOLAR TIER DETERMINATION

For the solar portion of the ELCC study, 562 MW of installed solar resources were divided into Tier 1 and Tier 3. There were 12 LREs utilized solar resources to meet RAR. But no LRE exceeded their allotted Tier 1 amount. Subsequently, there was no allocation for Tier 2 (Figure 3). In terms of Tier composition for the summer season, Tier 1 comprised 42%, or 235 MW, of all studied nameplate solar; and, Tier 3 comprised 58%, or 327 MW, of studied nameplate solar. The installed nameplate solar analyzed for each tier did not change between the summer season and winter season.

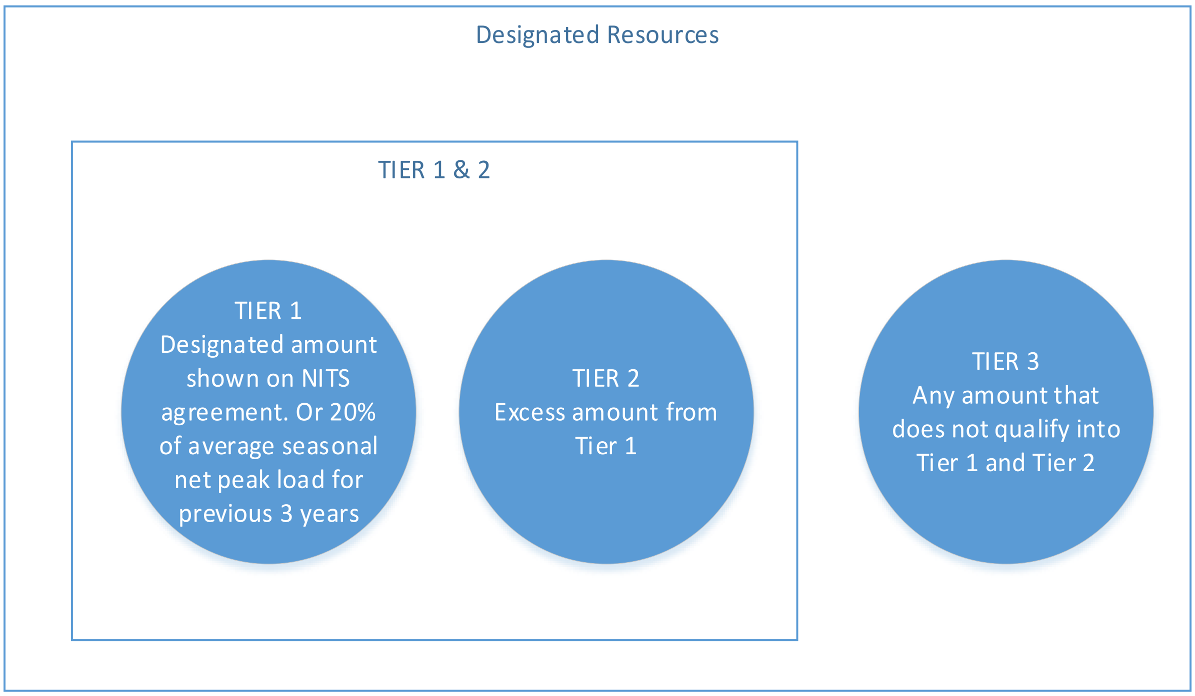

Figure 3: Tier Diagram for Solar

Because over half of these solar resources (>185MW) came into operation in January 2017 or later, the 2022 ELCC solar study only utilized weather years 2017 to 2020 to derive the average ELCC value for each tier. An additional ELCC Solar study analyzing higher penetration of installed solar will be finalized early 2023 in a separate report.

2.4 STUDY METHOD

In order to measure the ELCC of a particular resource, reliability effects need to be isolated for that resource. The basic concept of an ELCC analysis focuses on two situations: one including the resource(s) of interest and the other excluding them from the system. For the wind and solar studies, the benchmark SPP system, also referred to as the base case, is defined as system load supplied by all other resource types in the SPP footprint that are not being evaluated in the instant analysis. For example, the wind ELCC Study base case included load, conventional resources, all solar resources, and all other resources except for wind. The base case and subsequent change cases focused on the resource type being analyzed while all other resources remain constant between the cases.

For the wind ELCC study, Change Case A considered Tier 1 wind resources; Change Case B considered Tier 1 and Tier 2 wind resources; and Change Case C considered all wind resources. The wind ELCC study values related to each case are shown below in Table 6. The values for the solar ELCC study are shown below in Table 7. Change case B was not relevant for the solar study because there were no Tier 2 solar resources in the 2022 ELCC study.

Table 6. System Wind ELCC Calculation Example

Case	Wind resources assigned to case	Nameplate wind for Summer Season (MW)	Nameplate wind for Winter Season (MW)
Wind Base Case	No wind resources	0	0
Wind Change Case A	Tier 1 wind resources	13,211	11,745
Wind Change Case B	Tier 1 and Tier 2 wind resources	16,019	16,019
Wind Change Case C	All wind resources	32,467	32,467

Table 7. System Solar ELCC Calculation Example

Case	Solar resources assigned to case	Nameplate solar for Summer Season (MW)	Nameplate solar for Winter Season (MW)
Solar Base Case	No solar resources	0	0
Solar Change Case A	Tier 1 solar resources	235	235
Solar Change Case B	Tier 1 and Tier 2 solar resources	N/A	N/A
Solar Change Case C	All solar resources	562	562

The base case and all subsequent change cases were analyzed by adding the same amount of load (also referred to as perfect negative generation) in every hour of the assessment period until an LOLE threshold of 0.1 days/year is achieved. The amount of perfect negative generation added in each change case was compared to the amount of load added in the base case to derive an ELCC MW for each change case in each weather year, shown in Figure 4 and Figure 5. Then, the resulting ELCC MW for each weather year is averaged together to produce an average ELCC MW for each case.

Figure 4: Diagram of System with Wind or Solar Resources

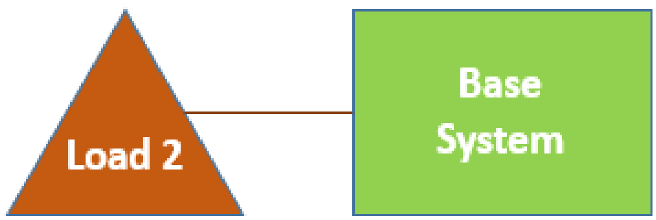

Figure 5: Diagram of System without Wind or Solar Resources

2.5 SIMULATION

Thirty (30) random seed[3] representations were applied to each scenario to create additional variation in unit availability and dispatch between simulations. This is defined as one case. Thirty (30) iterations were applied to each case to reach statistical convergence and reduce the standard error between results. In total, 900 iterations (30 iterations x 30 seed values) were applied to each wind and solar scenario.

2.6 RESULTS

Wind Resources

Figure 6 shows the results for each weather year at different levels of installed nameplate wind capacity for the summer season, and Figure 7 shows the results for each weather year for the winter season. As the penetration of installed nameplate capacity increases, the capacity value

[3] A random seed representation assigns a pre-commitment outage and maintenance schedule before the simulations begin. As the amount of randomly generated seed values increases, the variability in iterations increases as well.

as a fraction of the installed nameplate capacity decreases. This is due to the impact of wind's effect compared to on-peak hours when demand is at its highest, i.e. the highest expectation for lost load. Table 8 shows the ELCC accredited percentage and cumulative ELCC percentage of each wind scenario for the summer season, and Table 9 shows the same values for the winter season. The vertical lines represent the cumulative nameplate values in relation to the assigned tier amounts.

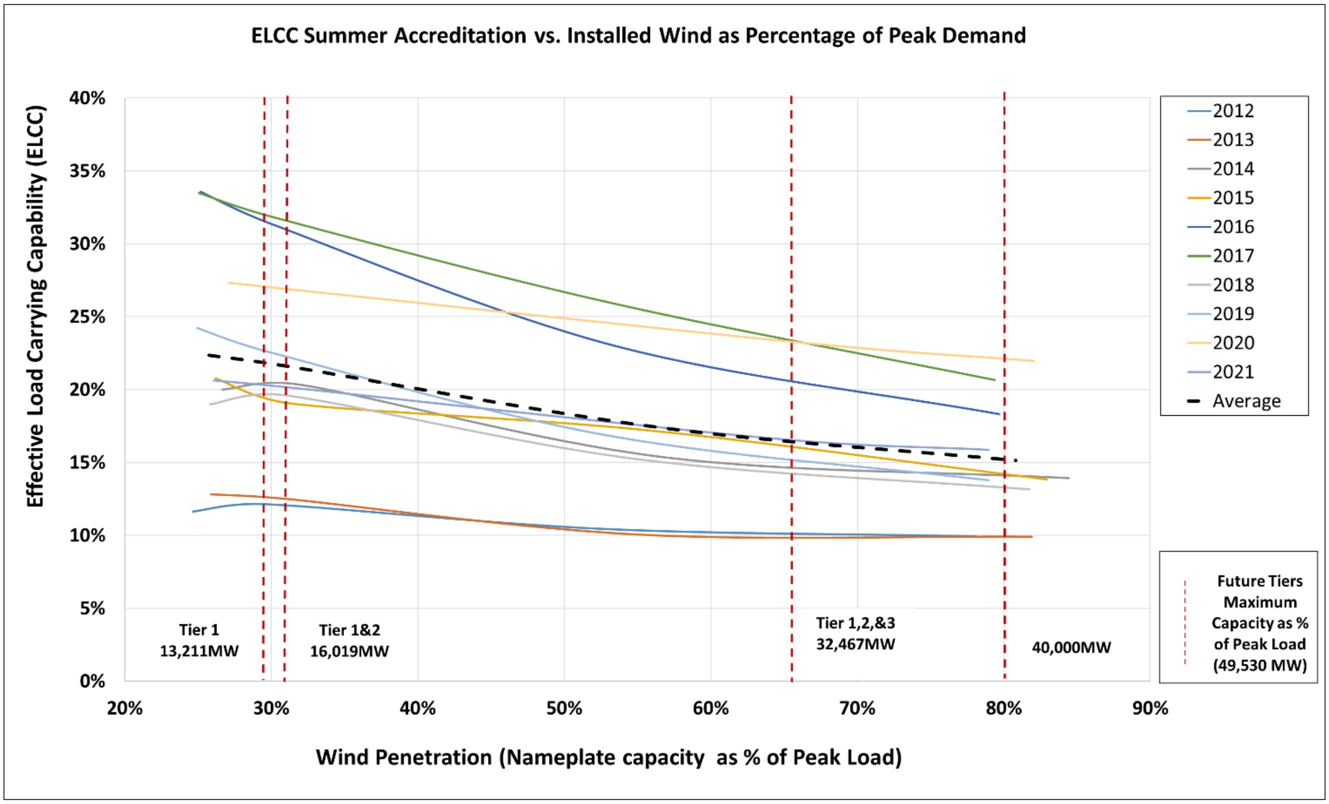

Figure 6: ELCC Summer Wind Results by Weather Year

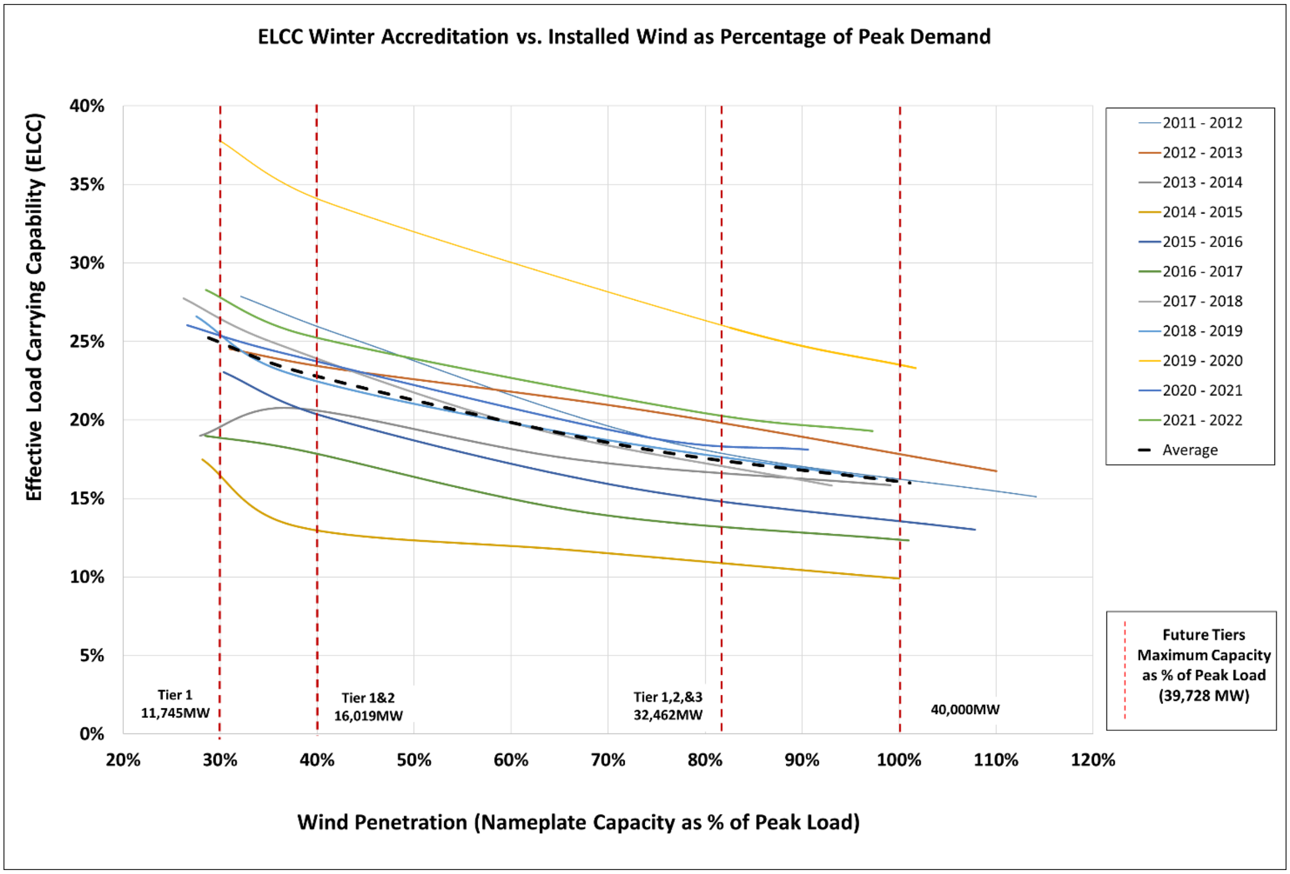

Figure 7: ELCC Winter Wind Results by Weather Year

Table 8. ELCC Summer Wind Results by Weather Year

2022 Cumulative ELCC Summer Wind Results (%)				
YEAR	TIER 1 (13,211 MW)	TIER 1 & 2 (16,019 MW)	TIER 1, 2, & 3 (32,467 MW)	40,000 MW
2012	12%	12%	11%	10%
2013	13%	12%	10%	10%
2014	20%	18%	14%	13%
2015	20%	19%	16%	14%
2016	33%	30%	21%	18%
2017	34%	32%	24%	21%
2018	19%	19%	14%	12%
2019	24%	22%	16%	15%
2020	27%	26%	23%	22%
2021	21%	20%	17%	16%
Average	22%	21%	16%	15%

Table 9: ELCC Winter Wind Results by Weather Year

2022 Cumulative ELCC Summer Wind Results (%)				
Year	TIER 1 (11,745 MW)	TIER 1 & 2 (16,019 MW)	TIER 1, 2, & 3 (32,467 MW)	40,000 MW
2011 - 2012	26%	22%	16%	14%
2012 - 2013	22%	22%	18%	16%
2013 - 2014	20%	20%	17%	16%
2014 - 2015	16%	14%	11%	10%
2015 - 2016	22%	19%	14%	13%
2016 - 2017	19%	17%	13%	12%
2017 - 2018	29%	25%	18%	16%
2018 - 2019	26%	23%	18%	17%
2019 - 2020	38%	34%	25%	23%
2020 - 2021	28%	25%	21%	19%
2021 - 2022	29%	26%	21%	20%
Average	25%	22%	18%	16%

After determining the average ELCC wind value for each tier, an incremental average ELCC value was assigned to each tier utilizing the average ELCC MW from the applicable base and change cases as to not over allocate the total ELCC MW of the system. The resulting wind ELCC MW and nameplate wind for each tier is shown below in Table 10. The methodology for allocating the ELCC accredited amount for each tier is addressed in the "Allocation" section of this report as well as the SPP Planning Criteria.

Table 10. Incremental Average ELCC for Wind

Wind Tier	Incremental Tier Method	Nameplate Wind of Tier (MW)	Incremental average ELCC MWs for each Tier (MW)	Tier ELCC percentage (%)
Tier 1	Difference in Wind Base Case and Wind Change Case A	Summer = 13,211 Winter = 11,745	Summer = 2,952 Winter = 2,949	Summer = 22% Winter = 25%
Tier 2	Difference in Wind Change Case A and Wind Change Case B	Summer = 2,808 Winter = 4,274	Summer = 404 Winter = 654	Summer = 14% Winter = 15%
Tier 3	Difference in Wind Change Case B and Wind Change Case C	Summer = 16,448 Winter = 16,448	Summer = 1,978 Winter = 2,083	Summer = 12% Winter = 13%

Solar Resources

Table 11 and Table 12 show the cumulative ELCC percentage of each solar scenario for the summer season and the winter season, respectively.

Table 11. ELCC Solar Summer Results by Weather Year

2022 Cumulative ELCC Summer Solar Values (%)		
	TIER 1 (235 MW)	TIER 1, 2, & 3 (562 MW)
2017	68%	72%
2018	100%	88%
2019	56%	34%
2020	83%	79%
Average	77%	68%

Table 12. ELCC Solar Winter Results by Weather Year

2022 Cumulative ELCC Winter Solar		
	TIER 1 (235 MW)	TIER 1, 2, & 3 (562 MW)
2016-2017	36%	30%
2017-2018	9%	18%
2018-2019	51%	38%
2019-2020	51%	37%
Average	37%	31%

After determining the average ELCC wind value for each tier, an incremental average ELCC value was assigned to each tier utilizing the average ELCC MW from the applicable base and change cases as to not over allocate the total ELCC MW of the system. The resulting wind ELCC MW and nameplate wind for each tier is shown below in Table 13. The methodology for allocating the ELCC accredited amount for each tier is addressed in the "Allocation" section of this report as well as the SPP Planning Criteria.

Table 13. Incremental Average ELCC for Solar

Wind Tier	Incremental Tier Method	Nameplate wind of Tier (MW)	Incremental average ELCC MWs for each Tier (MW)	Tier ELCC percentage (%)
Tier 1	Difference in the solar base case and solar Change case A	Summer = 235 Winter = 235	Summer = 181 Winter = 87	Summer = 77% Winter = 37%
Tier 2	Difference in solar Change case A and wind Change case B	N/A	N/A	N/A
Tier 3	Difference in wind Change case B and wind Change case C	Summer = 327 Winter = 327	Summer = 202 Winter = 86	Summer = 62% Winter = 26%

2.7 ALLOCATION

Once the system-wide accredited capacity value has been determined for each tier, individual resources of the applicable tier will then receive a share of the total system-wide accredited capacity compared to the total historical average capacity value of all other wind or solar facilities in the applicable tier. The amount of share for each resource is determined by the production of each resource corresponding to an assigned hourly load shape. Tier 1 and 2 wind or solar resources will use the average production output from the top three percent (3%) load hours, for each applicable season, of the individual LRE for which the generation is contracted or designated to serve. Tier 3 resources will use average historical production output from the top three percent (3%) load hours for each applicable season of the SPP BA Area's load. An example is given below -

> Example: A 100 MW nameplate wind resource was analyzed in Tier 1 and the average production output from the top three percent (3%) load hours for the summer season

was determined to be 30 MW. After performing this calculation for all wind resources, the total average production output from all Tier 1 wind resources was determined to be 4,363 MW. Comparing the average summer season ELCC MW of Tier 1 to the average production output of all wind resources of Tier 1, the ratio applied to all resources in Tier 1 is 67.59% (2,949 MW / 4,363 MW). Applying this ratio to the production output of the individual resource, the resource would receive 20.28 MW (30 x 67.59%) of accredited ELCC MW.

The accredited ELCC value for the SPP system will be fully allocated such that no ELCC values are remaining after completion of the ELCC Study. The results were posted to a secure website for each individual entity to maintain confidentiality.

CONCLUSION

The concept(s) of ELCC is to accurately estimate the value of wind and solar resources relied upon to meet system capacity needs for planning reserve purposes. Consistent with approved policy, business practices, and criteria, SPP performed an ELCC analysis for the installed wind amount of 32,467 MW and has determined the ELCC available for wind is 4,896 MW in the summer season and 5,268 MW in the winter season. The analysis also determined that the ELCC available for 562 MW of installed solar is 383 MW (68%) for the summer season and 186 MW (33%) for the winter season.

APPENDIX A: LIST OF ACRONYMS

BA	Balancing Authority
ELCC	Effective Load Carrying Capability
ISO	Independent System Operator
LFU	Load Forecast Uncertainty
LOLE	Loss of Load Expectation
LOLP	Loss of Load Probability
LRE	Load Responsible Entity
MW	Megawatt
Tariff	Open Access Transmission Tariff
RTO	Regional Transmission Organization
SAWG	Supply Adequacy Working Group
SERVM	Strategic Energy & Risk Valuation Model
SPP	Southwest Power Pool