

2014 WIND AND SOLAR CAPACITY CONTRIBUTION STUDY

Introduction

The capacity contribution of wind and solar resources, represented as a percentage of resource capacity, is a measure of the ability for these resources to reliably meet demand. For purposes of this report, PacifiCorp defines the peak capacity contribution of wind and solar resources as the availability among hours with the highest loss of load probability (LOLP). PacifiCorp calculated peak capacity contribution values for wind and solar resources using the capacity factor approximation method (CF Method) as outlined in a 2012 report produced by the National Renewable Energy Laboratory (NREL Report)¹.

The capacity contribution of wind and solar resources affects PacifiCorp's resource planning activities. PacifiCorp conducts its resource planning to ensure there is sufficient capacity on its system to meet its load obligation at the time of system coincident peak inclusive of a planning reserve margin. To ensure resource adequacy is maintained over time, all resource portfolios evaluated in the integrated resource plan (IRP) have sufficient capacity to meet PacifiCorp's net coincident peak load obligation inclusive of a planning reserve margin throughout a 20-year planning horizon. Consequently, planning for the coincident peak drives the amount and timing of new resources, while resource cost and performance metrics among a wide range of different resource alternatives drive the types of resources that can be chosen to minimize portfolio costs and risks.

PacifiCorp derives its planning reserve margin from a LOLP study. The study evaluates the relationship between reliability across all hours in a given year, accounting for variability and uncertainty in load and generation resources, and the cost of planning for system resources at varying levels of planning reserve margin. In this way, PacifiCorp's planning reserve margin LOLP study is the mechanism used to transform hourly reliability metrics into a resource adequacy target at the time of system coincident peak. This same LOLP study was utilized for calculating the peak capacity contribution using the CF Method. Table 1 summarizes the peak capacity contribution results for PacifiCorp's east and west balancing authority areas (BAAs).

Table 1 – Peak Capacity Contribution Values for Wind and Solar

	East BAA			West BAA		
	Wind	Fixed Tilt Solar PV	Single Axis Tracking Solar PV	Wind	Fixed Tilt Solar PV	Single Axis Tracking Solar PV
CF Method Results	14.5%	34.1%	39.1%	25.4%	32.2%	36.7%

¹ Madaeni, S. H.; Sioshansi, R.; and Denholm, P. "Comparison of Capacity Value Methods for Photovoltaics in the Western United States." NREL/TP-6A20-54704, Denver, CO: National Renewable Energy Laboratory, July 2012 (NREL Report). <http://www.nrel.gov/docs/fy12osti/54704.pdf>

Methodology

The NREL Report summarizes several methods for estimating the capacity value of renewable resources that are broadly categorized into two classes: 1) reliability-based methods that are computationally intensive; and 2) approximation methods that use simplified calculations to approximate reliability-based results. The NREL Report references a study from Milligan and Parsons that evaluated capacity factor approximation methods, which use capacity factor data among varying sets of hours, relative to the more computationally intensive reliability-based effective load carrying capability (ELCC) metric. As discussed in the NREL Report, the CF Method was found to be the most dependable technique in deriving capacity contribution values that approximate those developed using the ELCC Method.

As described in the NREL Report, the CF Method “considers the capacity factor of a generator over a subset of periods during which the system faces a high risk of an outage event.” When using the CF Method, hourly LOLP is calculated and then weighting factors are obtained by dividing each hour’s LOLP by the total LOLP over the period. These weighting factors are then applied to the contemporaneous hourly capacity factors for a wind or solar resource to produce a weighted average capacity contribution value.

The weighting factors based on LOLP are defined as:

$$w_i = \frac{LOLP_i}{\sum_{j=1}^T LOLP_j}$$

where w_i is the weight in hour i , $LOLP_i$ is the LOLP in hour i , and T is the number of hours in the study period, which is 8,760 hours for the current study. These weights are then used to calculate the weighted average capacity factor as an approximation of the capacity contribution as:

$$CV = \sum_{i=1}^T w_i C_i,$$

where C_i is the capacity factor of the resource in hour i , and CV is the weighted capacity value of the resource.

To determine the capacity contribution using the CF method, PacifiCorp implemented the following two steps:

1. A 500-iteration hourly Monte Carlo simulation of PacifiCorp’s system was produced using the Planning and Risk (PaR) model to simulate the dispatch of the Company’s system for a sample year (calendar year 2017). This PaR study is based on the Company’s 2015 IRP planning reserve margin study using a 13% target planning reserve margin level. The LOLP for each hour in the year is calculated by counting the number of iterations in an hour in which system load could not be met with available resources and dividing by 500 (the total number iterations). For example, if in hour 9 on January 12th there are two iterations with Energy Not Served (ENS) out of a total of 500 iterations, then the LOLP for that hour would be 0.4%.²

² 0.4% = 2 / 500.

2. Weighting factors were determined based upon the LOLP in each hour divided by the sum of LOLP among all hours. In the example noted above, the sum of LOLP among all hours is 143%.³ The weighting factor for hour 9 on January 12th would be 0.2797%.⁴ The hourly weighting factors are then applied to the capacity factors of wind and solar resources in the corresponding hours to determine the weighted capacity contribution value in those hours. Extending the example noted, if a resource has a capacity factor of 41.0% in hour 9 on January 12th, its weighted annual capacity contribution for that hour would be 0.1146%.⁵

Results

Table 2 summarizes the resulting annual capacity contribution using the CF Method described above as compared to capacity contribution values assumed in the 2013 IRP.⁶ In implementing the CF Method, PacifiCorp used actual wind generation data from wind resources operating in its system to derive hourly wind capacity factor inputs. For solar resources, PacifiCorp used hourly generation profiles, differentiated between single axis tracking and fixed tilt projects, from a feasibility study developed by Black and Veatch. A representative profile for Milford County, Utah was used to calculate East BAA solar capacity contribution values, and a representative profile for Lakeview County, Oregon was used to calculate West BAA solar capacity contribution values.

Table 2 – Peak Capacity Contribution Values for Wind and Solar

	East BAA			West BAA		
	Wind	Fixed Tilt Solar PV	Single Axis Tracking Solar PV	Wind	Fixed Tilt Solar PV	Single Axis Tracking Solar PV
CF Method Results	14.5%	34.1%	39.1%	25.4%	32.2%	36.7%
2013 IRP Results	4.2%	13.6%	n/a	4.2%	13.6%	n/a

Figure 1 presents daily average LOLP results from the PaR simulation, which shows that loss of load events are most likely to occur during the spring, when maintenance is often planned, and during peak load months, which occur in the summer and the winter.

³ For each hour, the hourly LOLP is calculated as the number of iterations with ENS divided by the total of 500 iterations. There are 715 ENS iteration-hours out of total of 8,760 hours. As a result, the sum of LOLP is 715 / 500 = 143%.

⁴ 0.2797% = 0.4% / 143%, or simply 0.2797% = 2 / 715.

⁵ 0.1146% = 0.2797% x 41.0%.

⁶ In its 2013 IRP, PacifiCorp estimated capacity contribution values for wind and solar resources by evaluating capacity factors for wind and solar resources at a 90% probability level among the top 100 load hours in a given year.

Figure 1 - Daily LOLP

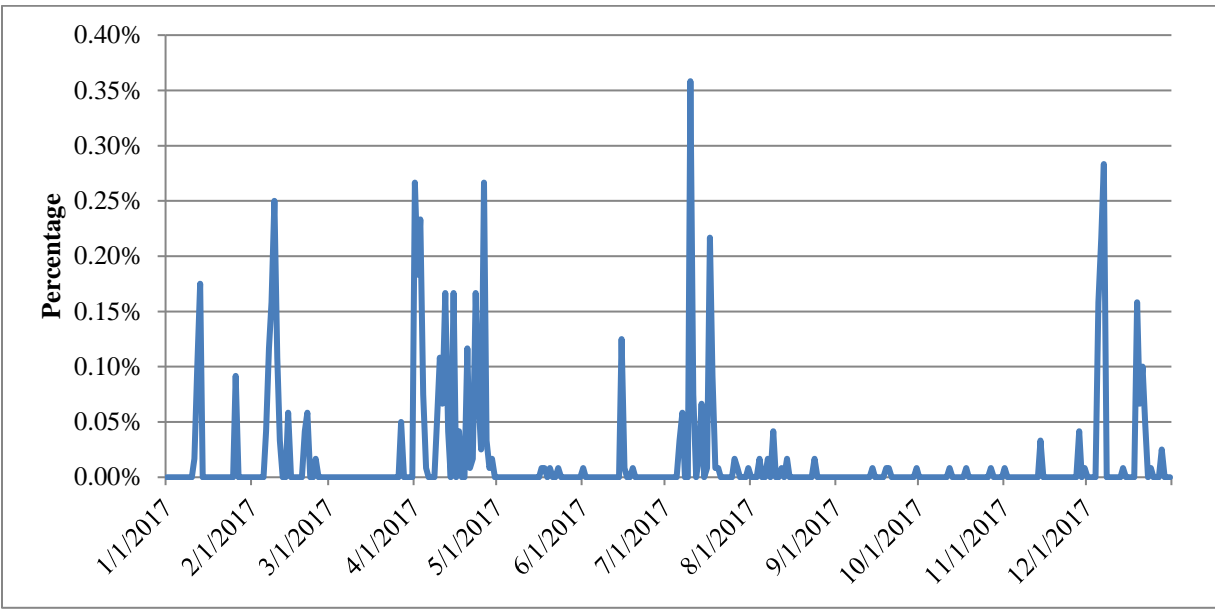
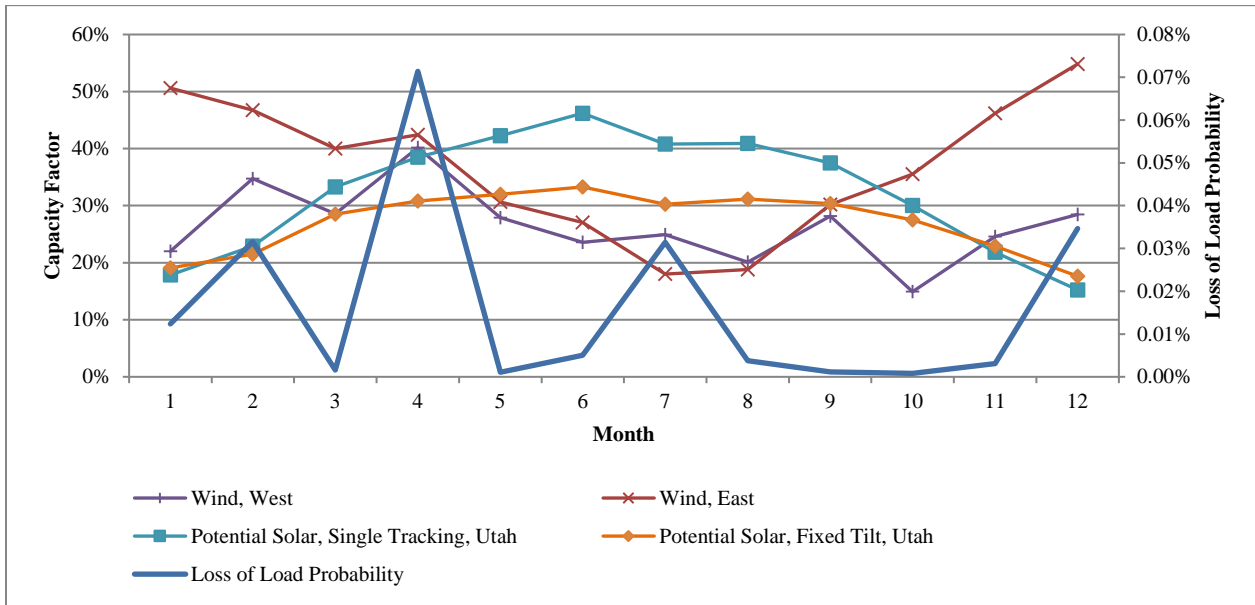


Figure 2 presents the relationship between monthly capacity factors among wind and solar resources (primary y-axis) and average monthly LOLP from the PaR simulation (secondary y-axis) in PacifiCorp’s CF Method analysis. As noted above, the average monthly LOLP is most prominent in April (spring maintenance period), summer (July peak loads), and winter (when loads are high).

Figure 2 - Monthly Resource Capacity Factors as Compared to LOLP



Figures 3 through 5 present the hourly distribution of capacity factors among wind and solar resources (primary y-axis) as compared to the hourly distribution of LOLP (secondary y-axis) for a typical day in the months of April, July, and December, respectively. Among a typical day in April, LOLP events peak during morning and evening ramp periods when generating units are

transitioning between on-peak and off-peak operation. Among a typical day in July, LOLP events peak during higher load hours and during the evening ramp. In December, LOLP events peak during higher load evening hours.

Figure 3 - Hourly Resource Capacity Factors as Compared to LOLP for an Average Day in April

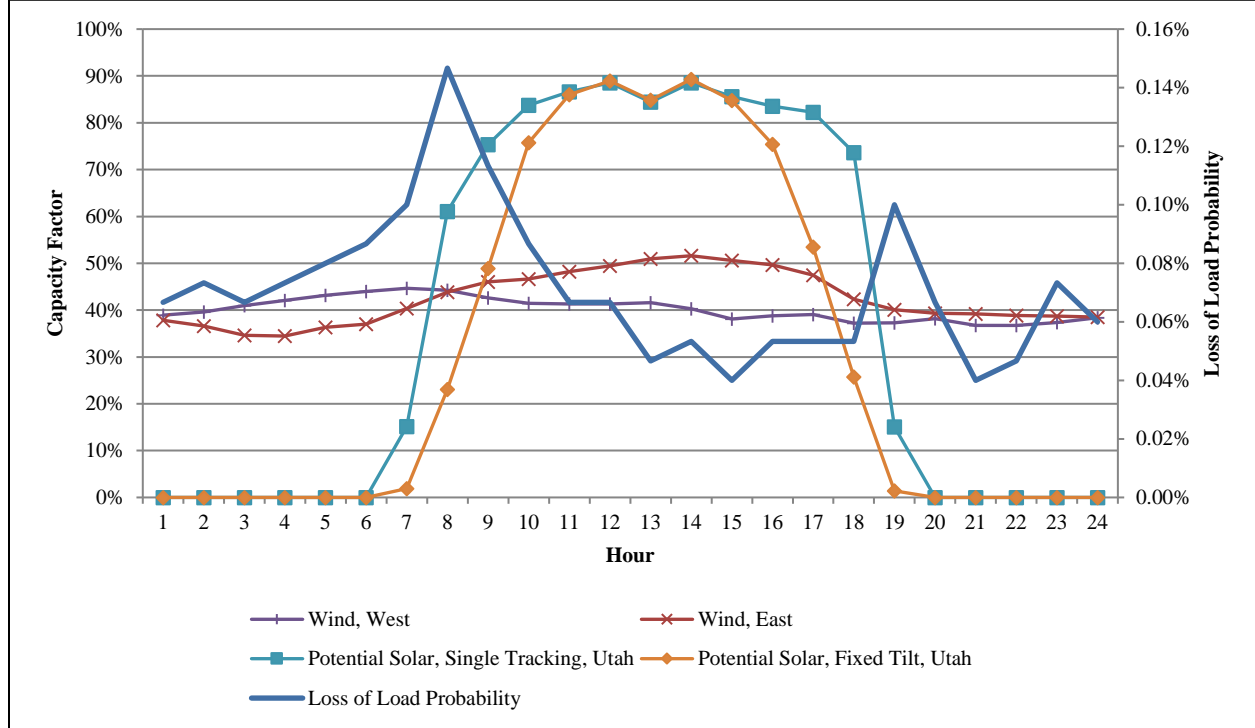


Figure 4 – Hourly Resource Capacity Factors as Compared to LOLP for an Average Day in July

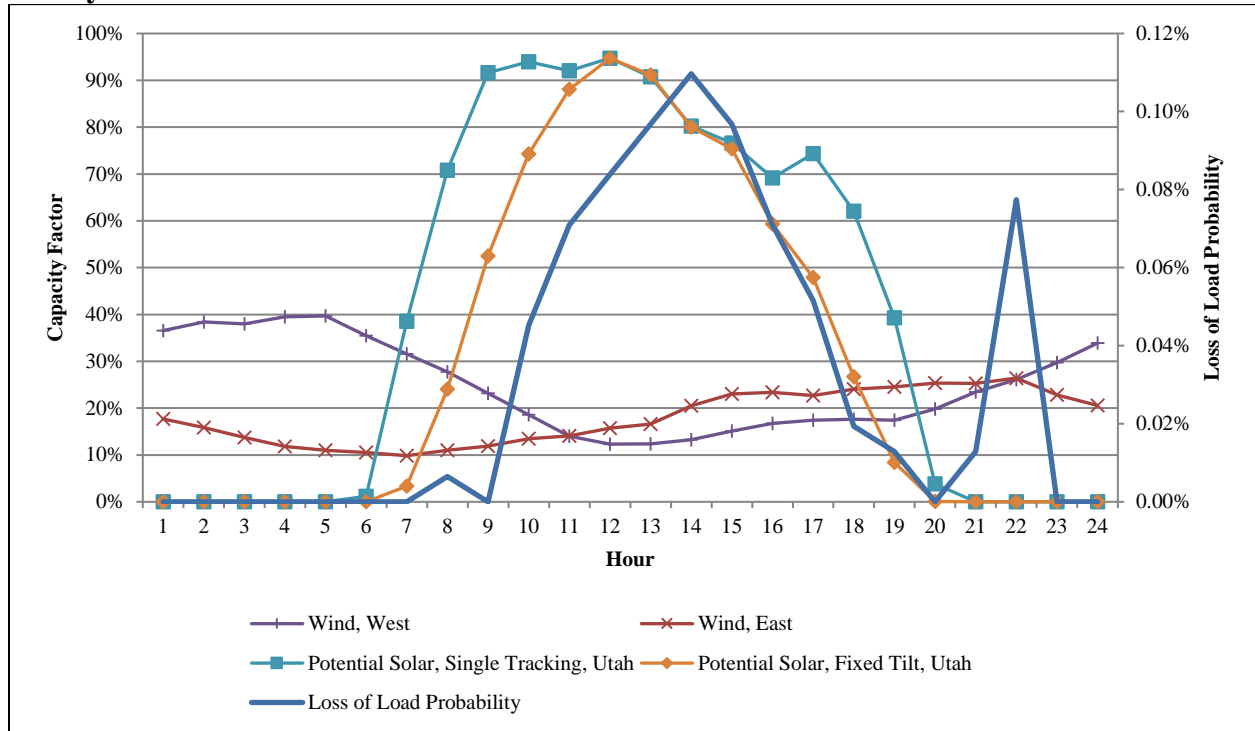
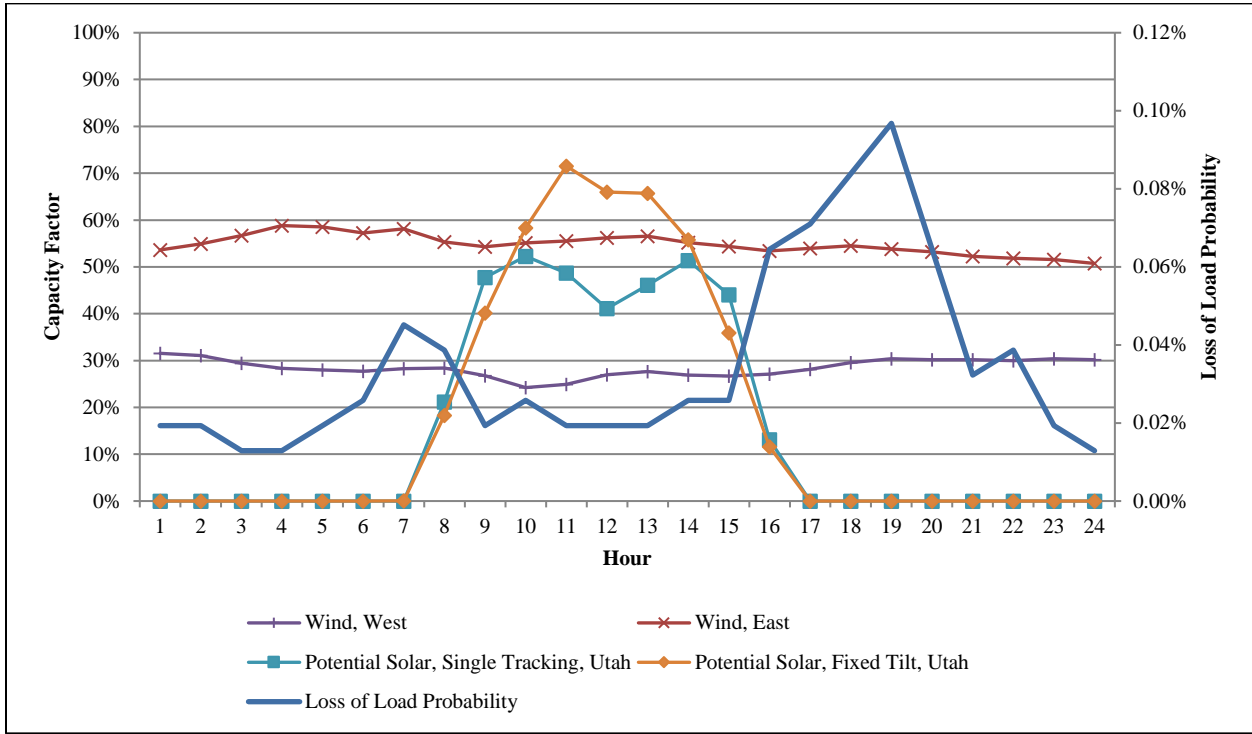


Figure 5 – Hourly Resource Capacity Factors as Compared to LOLP for an Average Day in December



Conclusion

PacifiCorp conducts its resource planning by ensuring there is sufficient capacity on its system to meet its net load obligation at the time of system coincident peak inclusive of a planning reserve margin. The peak capacity contribution of wind and solar resources, represented as a percentage of resource capacity, is the weighted average capacity factor of these resources at the time when the load cannot be met with available resources. The peak capacity contribution values developed using the CF Method are based on a LOLP study that aligns with PacifiCorp’s 13% planning reserve margin, and therefore, the values represent the expected contribution that wind and solar resources make toward achieving PacifiCorp’s target resource planning criteria.