2012 ERCOT Loss of Load Study

STUDY RESULTS

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San Francisco, California

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Disclaimer

This report presents the results of extensive simulations performed by ECCO using its advanced reliability assessment tool (ProMaxLT™) and actual system and reliability data provided by ERCOT. The simulation results are based on assumptions outlined in the report and should be evaluated within the framework of these assumptions.

Executive Summary

The ERCOT 2012 Target Reserve Margin Study (TRM) is an analysis to quantify the impact of system variability on desired reserve levels and reliability. This analysis determines the appropriateness, given changes to the ERCOT system, of the target reserve margin level used to evaluate resource adequacy. System volatilities such as generator outages and deratings, load forecast uncertainties, and the intermittent nature of wind were studied. Reliability indices such as Loss of Load Events (LOLEV), Loss of Load Hours (LOLH) and Expected Unserved Energy (EUE) for various levels of reserve margins were obtained.

Generator full and partial outages were modeled sequentially using random draws from two exponential distributions. The Mean Time to Failure (MTTF) and Mean Time to Repair (MTTR) for each generator was used to build independent sequences of generator full and partial availabilities. For each scenario, the Monte-Carlo simulation was iterated sufficiently to achieve convergence of the reliability metrics.

Load forecast uncertainties due to weather were studied by using fifteen different load scenarios, based upon loads from 1997 through 2011. Each of these scenarios was assigned a probability of occurrence. All load scenarios were developed using Moody's base economic forecast.

Due to the inherent variability of wind powered generation on the ERCOT System, the availability of wind power generation needed to be treated differently than the availability of conventional generators in reserve margin calculations. The *Effective Load Carrying Capability* (ELCC) indicates the percentage of the total nameplate capacity of wind that can be counted towards the calculation of the reserve margin. The ELCC for two regions (West and Coastal) were evaluated by comparing the relative reliability of the installed or planned wind generation to the reliability of the planned 2014 and 2016 fleets on an annual basis. Wind profiles were developed by AWS Truepower for this study. These hourly wind profiles were developed for each wind farm for the same fifteen years as for the load profiles.

The Effective Load Carrying Capacity (ELCC) for the wind generators are as follows:

- ELCC of Wind Generators
  - Coastal Region: 32.9%
  - West Region: 14.2%
- Installed Wind Capacity
  - Coastal Region: 1,915 MW (16% of total wind capacity)
  - West Region: 10,340 MW (84% of total wind capacity)

The West ELCC of 14.2% is slightly higher than the previous 2010 ELCC estimate of 12.2%. The Coastal ELCC of 32.9% is significantly higher, due to the increased coastal winds that occur in summer afternoon. Both ELCC values are consistent with the wind capacity factors seen during the peak afternoon load hours in August.

The ERCOT target reserve margin, based on a 0.1 Loss of Load Events metric that is equivalent to the "one day in ten years" metric that has traditionally been used in the industry, was found to be 16.1% for

2014, and 15.3% in 2016. The main reason for this difference is the non-uniform scaling of load curves between 2014 and 2016. Specifically, the TRM is based on the peak load from the nominal 2006 load curve, which increases by 7.94% between 2014 and 2016. Many loss-of-load events take place with the 2011 Load Profile, which only has a 6.93% peak load increase in 2016.

The TRM computed in 2010 was 13.75%, and the recent Brattle Report estimated a TRM closer to 15%, due to the extreme loads of 2011. The TRM results in this study have increased due to three factors:

- Extreme load conditions seen in 2011;
- Higher ELCC numbers increase the effective amount of wind capacity; and
- Increase in the generator Effective Forced Outage Rate demand (EFORd) rate from 4.45% to 5.47%, which reflects a marginally less reliable conventional generator fleet.

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1 INTRODUCTION

The objective of the Loss of Load (LOL) Study is to determine the annual Loss of Load Probability (LOLP) and related reliability metrics in accordance with North American Electric Reliability Corporation (NERC) requirements. This study has been carried out for the years 2014 and 2016.

This report includes:

A. Target Reserve Margins for 2014 and 2016
B. Effective Load Carrying Capability (ELCC) of wind generation in two different zones (West and Coastal).
C. The following loss-of-load statistics:
    i. Loss of Load Events (LOLEV)
    ii. Loss of Load Hours (LOLH)
    iii. Expected Unserved Energy (EUE)
    iv. Expected Unserved Energy as a percentage of Net Energy for Load (normalized EUE)
    v. Loss of Load Probability (LOLP)

The *ERCOT LOL Study* evaluates the impact of system volatility on the relationship between generation reserve levels and system reliability. A power system is volatile from a resource adequacy perspective due to several primary causes: the forced outage and de-rating of generating facilities; the load forecast uncertainty related to weather; and, the intermittent nature of renewable energy sources. At the same time a power system needs to maintain an adequate level of reliability. To cope with system volatility while maintaining adequate reliability, an appropriate level of generation reserves needs to be maintained in the planning timeframe.

Historically, reserve levels have been quantified in terms of a reserve margin. The reserve margin has been defined as the *difference between nameplate installed capacity and annual peak load (of the median load profile) as a percentage of the annual peak load*. The reserve margin is compared with the target reserve margin to determine if the system, in aggregate, has sufficient generation capacity over the course of a year. The scope of this study is to assess what the appropriate (target) reserve margin level is for the ERCOT system for years 2014 and 2016.

The ERCOT system has a considerable amount of wind power resources. Due to the variation of their availability, these resources were treated differently than conventional generators in reserve margin calculations. The concept of *Effective Load Carrying Capability* (ELCC) for renewable energy sources (RES) was introduced in past studies. ELCC indicates the percentage of the total nameplate capacity of these resources that can be counted towards the calculation of the reserve margin and forms the basis for the level of RES that currently counts towards planning reserves in ERCOT. Estimating a value of the ELCC in two zones is a part of this study, and the associated ELCC methodology is thus discussed in the *ERCOT LOLP study Assumptions and Methodology* document.

This report contains all the detailed results related to the ERCOT LOL study.

2 RESULTS AND CONCLUSION

LOLEV, which is a probability-based average, is calculated as follows,

$$LOLEV = \sum_{i=1}^{15} Probability_i \times LOLEV_i$$

The summation of the product of each load scenario probability and LOLEV for the scenario gives the study-wide LOLEV. In the above formula, i varies from 1 to 15 reflecting the fifteen annual load scenarios.

The reserve margin is calculated by,

$$Reserve\ Margin = \frac{Resources\text{- }Median\ Scenario\ Peak\ Load}{Median\ Scenario\ Peak\ Load}$$

where,

$$Resources = (NonWind\_Capacity + ELCC_{Coast} \times WindCapacity_{Coast} + ELCC_{West} \times WindCapacity_{West})$$

Variations in reserve margin are obtained by adjusting the non-wind generation capacity, as previously discussed in the *ERCOT LOLP study Assumptions and Methodology* document. The following reliability indices were estimated for various reserve margin levels.

- The annual Loss of Load Events (LOLEV).
- The annual Loss of Load Hours (LOLH).
- The annual Expected Unserved Energy (EUE).

2.1 ELCC for Wind Generation

The ELCC was computed using the methodology described in the *ERCOT LOLP study Assumptions and Methodology* document. The results for all 15 load profiles, two wind regions (Coastal, West), and two study years (2014, 2016) are summarized in the following table.

Table 1. Raw ELCCs for all Load Profiles, Wind Regions and Study Years

Load Profile	Coastal ELCC		West ELCC	
	2014	2016	2014	2016
1997	26.1%	48.2%	9.0%	12.2%
1998	50.8%	66.5%	22.5%	18.7%
1999	12.0%	29.5%	15.0%	10.6%
2000	17.2%	21.3%	8.2%	8.9%
2001	66.7%	63.3%	13.7%	9.0%
2002	18.0%	19.0%	35.0%	16.6%
2003	39.7%	34.0%	12.3%	14.1%
2004	40.3%	73.7%	15.9%	24.7%
2005	43.9%	35.7%	3.5%	5.8%
2006	50.2%	32.2%	32.9%	22.9%
2007	7.1%	1.8%	14.9%	4.8%
2008	24.1%	43.3%	25.3%	33.6%
2009	46.7%	18.0%	18.4%	14.7%
2010	19.0%	11.8%	4.1%	4.8%
2011	23.5%	31.4%	8.6%	12.2%

Since the ELCC largely depends on the wind for a few hours in the late-afternoon hours of August, the individual ELCC values vary substantially. The 2014 and 2016 numbers are slightly different because the wind profiles do not change between the simulations, but the load profiles between 2014 and 2016 are shifted 3 days (e.g. 8/2/2014 is an off-peak Saturday, while 8/2/2016 is an on-peak Tuesday). This shifting of days increases the diversity of the ELCC results.

For the Coastal and West Wind Regions, all the individual ELCCs are averaged after excluding the top and bottom 10% values[1]. The result is the following:

- **Coastal ELCC: 32.9%**
- **West ELCC: 14.2%**

Based on these ELCC values, the effective wind capacity contribution for each region can be computed:

- **Effective Coastal Wind Capacity: 1,915MW x 32.9% = 630 MW**
- **Effective West Wind Capacity: 10,340MW x 14.2% = 1,469 MW**

The West ELCC of 14.2% is slightly higher than the previous 2010 ELCC estimate of 12.2%. The Coastal ELCC of 32.9% is significantly higher, due to the increased coastal winds that occur in summer afternoon. Both ELCC values are consistent with the wind capacity factors (refer to *2.10. Wind Capacity Factor*) seen during the peak afternoon load hours in August.

[1] Note that ignoring the top/bottom 10% does not have a large impact on the results. Specifically, if all the raw ELCC values are included, the average Coastal ELCC becomes 33.8%, and the average West ELCC becomes 15.1%. Additionally, the median values are 31.8% for the Coastal ELCC, and 13.9% for the West ELCC.

2.2 Target Reliability Margin (TRM)

The Target Reliability Margin (TRM) indicates the amount of installed generation capacity that is needed to achieve the target reliability of 0.1 loss-of-load events/year. The generation capacity includes both conventional generation and wind generation derated with the ELCC values computed above.

2.2.1 TRM for 2014

Based on the weighted 2014 LOLEV vs. Generation Capacity curve[2], the amount of conventional generation capacity required to attain 0.1 LOLEV/year is 84,928 MW. Including the effective wind capacity yields a target generation capacity of 87,027 MW.

The peak load for the nominal load profile (2006) is 74,928 MW, resulting in a 2014 TRM of **16.1%** ((87,027 / 74,928) – 1)**.**

2.2.2 TRM for 2016

Based on the weighted 2016 LOLEV vs. Generation Capacity curve, the amount of conventional generation required to attain 0.1 LOLEV/year is 91,164 MW. Including the effective wind capacity yields a target generation capacity of 93,262 MW. The peak load for the nominal load profile (2006) is 80,879 MW, resulting in a 2016 TRM of **15.3%**. ((93,262 / 80,879) – 1)

2.2.3 Comparing the TRM for 2014 and 2016

The difference between the TRM for 2014 (16.1%) and 2016 (15.3%) is mainly attributable to the difference in the non-uniform scaling of load profiles between 2014 and 2016 as described in more detail below. This information may be found in the *ERCOT LOLP study Assumptions and Methodology* document, Table 1.

The TRM is based on the peak load from the nominal 2006 load curve, which increases by 7.94% between 2014 and 2016. Many loss-of-load events take place with the 2011 Load Profile, which only has a 6.93% peak load increase in 2016. If the TRM is adjusted to use a 6.93% load increase, then the 2016 TRM increases to 16.4%.

2.2.4 Discussion of TRM Results

The 2014 TRM of 16.1% is an increase over previous results, but it is strongly influenced by the higher ELCC numbers. If one uses the 12.2% ELCC from the 2010 ERCOT LOLP study, the 2014 TRM drops to 15.3%.

The impact of the 2011 high-load scenario also impacts this result, which was not part of the 2010 study. The Brattle Group report estimated that the TRM would increase to a value above 15% based on the

[2] TRM estimation is sensitive to the probability weighting scheme applied to the 15 annual hourly load profiles. The study results presented in this report assume a 1.0% weighting for the 2011 load profile. Weightings for other years (1997 to 2010) are documented on slide 24 of a presentation by the ERCOT Generation Adequacy Task Force (GATF), available for download at: http://www.ercot.com/content/meetings/gatf/keydocs/2013/0118/Loss_of_Load_Study_2013_GATF.ppt

2011 loads. Without the 2011 load profile year, the 2014 TRM drops to 13.0% (which includes the previous ELCC of 12.2%). This illustrates the strong impact of the record heat and loads of 2011.

Finally, the generator capacity-weighted EFORd outage rate for these studies is 5.47% compared to the 2010 ERCOT LOLP study EFORd of 4.45%. The 1.02 percentage point increase in the outage rate results in a corresponding increase in the TRM because the generation fleet experiences more outages. This pushes the TRM up to approximately 14.0%.

The current TRM results are consistent with the 2010 TRM of 13.75% after discounting the impact of these three factors.

2.3 Loss of Load Event (LOLEV) Results

In this section, LOLEV results are presented for 2014 and 2016. The LOLEV indicate the expected number of loss-of-load events that will occur in a given timeframe. The LOLEV results tables provide the following for each study year:

- Average Monthly LOLEV
- Average Annual LOLEV
    - Median Load Profile and Weighted Load Profile
- Standard Deviation for Annual LOLEV
    - Median Load Profile and Weighted Load Profile
- Annual Average LOLEV for various capacity deficiency levels

2.3.1 Average Monthly LOLEV

The next two tables show the average Monthly LOLEV Results for 2014 and 2016. Note that August is the peak month for loss-of-load events.

Table 2. 2014 Average Monthly LOLEV Results (Weighted Load Profile)

	Reserve Margin ->	4.8%	7.5%	10.2%	13.0%	15.6%	18.3%	21.0%	23.6%	26.3%	29.0%
	Gen Capacity (MW) ->	76,400	78,471	80,507	82,535	84,535	86,535	88,535	90,535	92,535	94,535
Month	January	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	February	0.010	0.010	0.010	0.006	0.002	0.000	0.000	0.000	0.000	0.000
	March	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	April	0.005	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	May	0.653	0.311	0.091	0.017	0.003	0.000	0.000	0.000	0.000	0.000
	June	0.465	0.044	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	July	2.810	0.854	0.127	0.009	0.001	0.000	0.000	0.000	0.000	0.000
	August	8.104	3.845	1.314	0.366	0.115	0.029	0.005	0.000	0.000	0.000
	September	0.020	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	October	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	November	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	December	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Total (Annual)	**12.068**	**5.066**	**1.542**	**0.398**	**0.121**	**0.029**	**0.005**	**0.000**	**0.000**	**0.000**

Table 3. 2016 Average Monthly LOLEV Results (Weighted Load Profile)

	Reserve Margin ->	5.8%	8.4%	11.0%	13.5%	16.0%	18.5%	21.0%	23.4%	25.3%	28.4%
	Gen Cap (MW) ->	82,660	84,732	86,809	88,810	90,810	92,810	94,810	96,810	98,332	100,770
Month	January	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	February	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	March	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	April	0.022	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	May	0.466	0.111	0.006	0.001	0.000	0.000	0.000	0.000	0.000	0.000
	June	0.236	0.022	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	July	1.611	0.467	0.098	0.011	0.000	0.000	0.000	0.000	0.000	0.000
	August	7.068	3.090	1.077	0.407	0.123	0.028	0.005	0.001	0.000	0.000
	September	0.029	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	October	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	November	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	December	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Total (Annual)	**9.433**	**3.694**	**1.182**	**0.418**	**0.123**	**0.028**	**0.005**	**0.001**	**0.000**	**0.000**

2.3.2 Average Annual LOLEV

The next two tables shows the average annual LOLEV results for the median load profile (2006), and for the weighted combination of all fifteen load profiles.

Table 4. 2014 Annual LOLEV Results (Weighted Load Profile & Median Load Profile)

Reserve Margin ->	4.8%	7.5%	10.2%	13.0%	15.6%	18.3%	21.0%	23.6%	26.3%	29.0%
Gen Capacity (MW) ->	76,400	78,471	80,507	82,535	84,535	86,535	88,535	90,535	92,535	94,535
Weighted Load Profile	12.068	5.066	1.542	0.398	0.121	0.029	0.005	0.000	0.000	0.000
Median Load Profile	11.025	4.458	0.893	0.108	0.013	0.000	0.000	0.000	0.000	0.000

Table 5. 2016 Annual LOLEV Results (Weighted Load Profile & Median Load Profile)

Reserve Margin ->	5.8%	8.4%	11.0%	13.5%	16.0%	18.5%	21.0%	23.4%	25.3%	28.4%
Gen Capacity (MW) ->	82,660	84,732	86,809	88,810	90,810	92,810	94,810	96,810	98,332	100,770
Weighted Load Profile	9.433	3.694	1.182	0.418	0.123	0.028	0.005	0.001	0.000	0.000
Median Load Profile	9.283	3.410	0.608	0.070	0.003	0.000	0.000	0.000	0.000	0.000

The next two figures plot the average LOLEV from the previous two tables. The first chart shows the results when using the weighted combination of all fifteen load profiles, while the second chart shows the results for only the median load profile (2006).

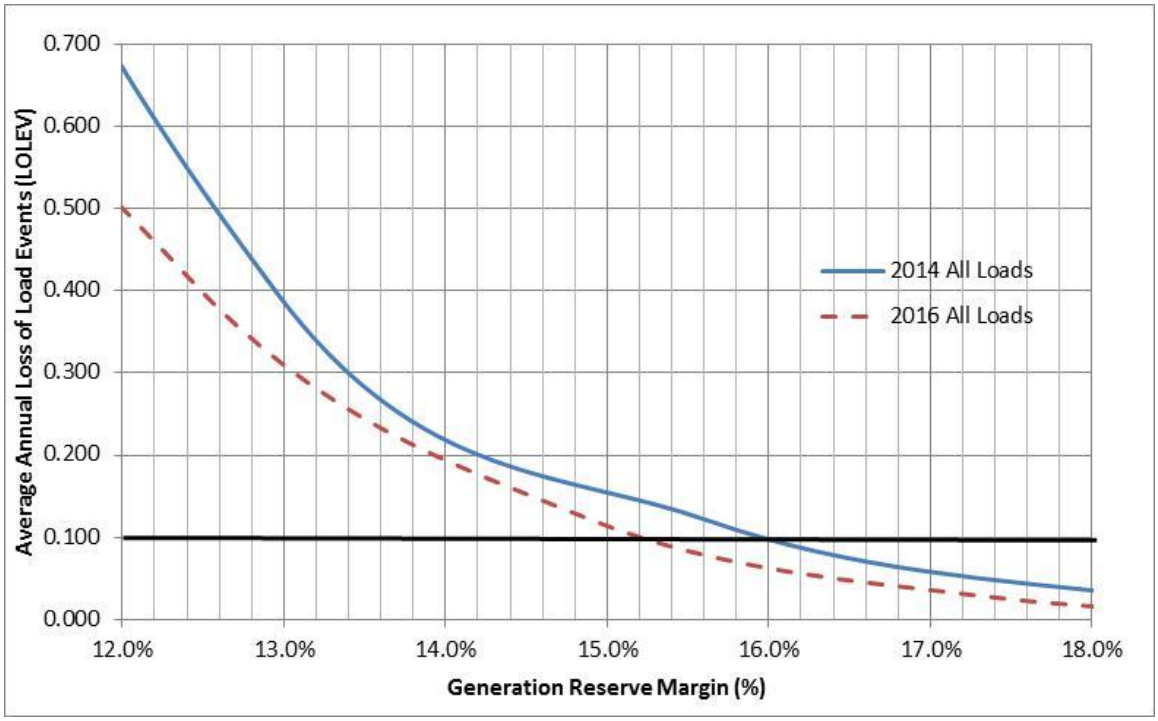

***Figure 1**. 2014 and 2016 Annual LOLEV vs. Reserve Margin (Weighted Load Profile)*

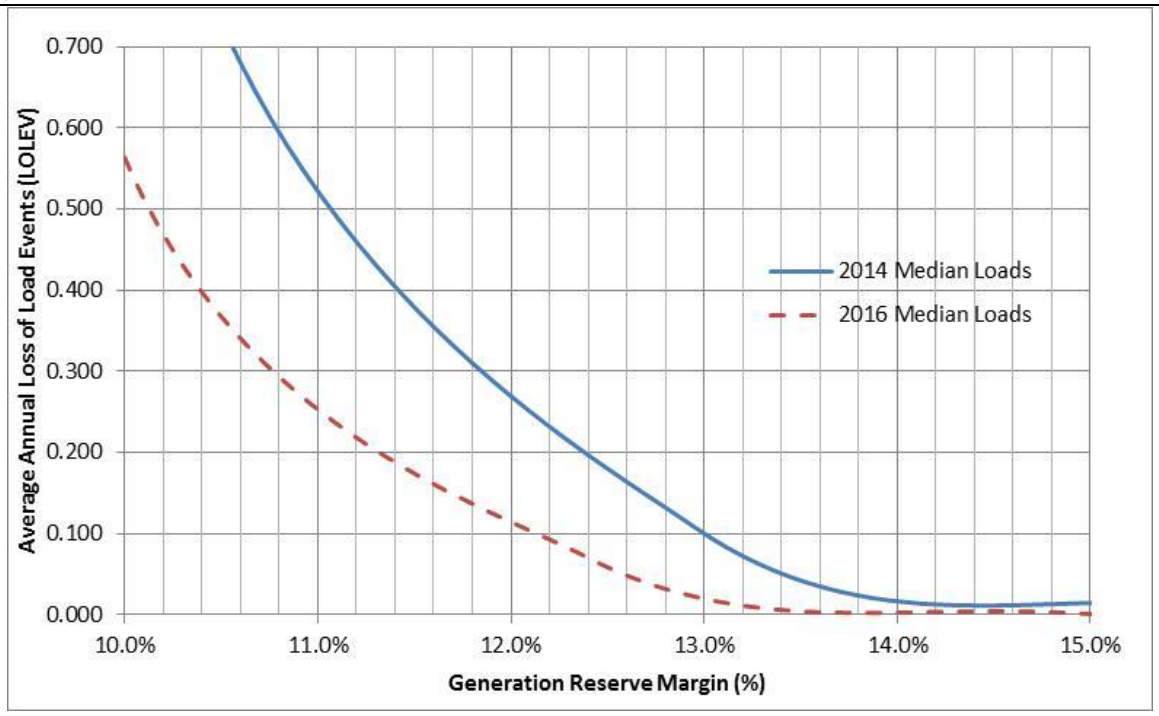

***Figure 2**. 2014 and 2016 Annual LOLEV vs. Reserve Margin (Median Load Profile)*

As described in section 2.2.3, the difference between the 2014 and 2016 curves can largely be attributed to the non-uniform scaling of load profiles.

2.3.3 Annual LOLEV Standard Deviations

The following two tables and accompanying charts show the standard deviations of the LOLEV results. This information is useful to gauge the variability of the results.

Table 6. 2014 LOLEV Standard Deviations (Weighted Load Profile & Median Load Profile)

Reserve Margin ->	4.8%	7.5%	10.2%	13.0%	15.6%	18.3%	21.0%	23.6%	26.3%	29.0%
Gen Capacity (MW) ->	76,400	78,471	80,507	82,535	84,535	86,535	88,535	90,535	92,535	94,535
Weighted Load Profile	2.531	1.281	0.502	0.166	0.058	0.013	0.005	0.001	0.000	0.000
Median Load Profile	2.155	0.981	0.316	0.101	0.032	0.000	0.000	0.000	0.000	0.000

Table 7. 2016 LOLEV Standard Deviations (Weighted Load Profile & Median Load Profile)

Reserve Margin ->	5.8%	8.4%	11.0%	13.5%	16.0%	18.5%	21.0%	23.4%	25.3%	28.4%
Gen Capacity (MW) ->	82,660	84,732	86,809	88,810	90,810	92,810	94,810	96,810	98,332	100,770
Weighted Load Profile	2.161	1.029	0.409	0.161	0.051	0.015	0.005	0.001	0.000	0.000
Median Load Profile	2.046	0.940	0.286	0.084	0.014	0.000	0.000	0.000	0.000	0.000

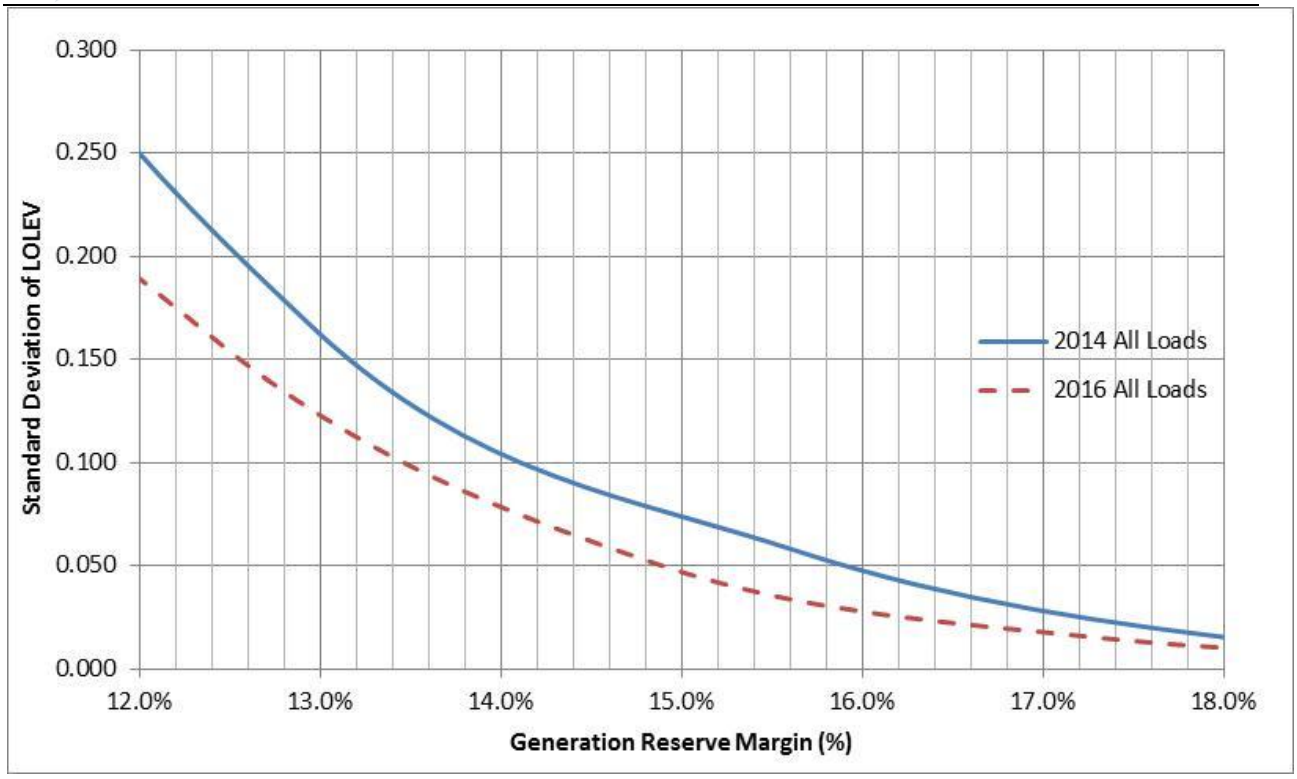

***Figure 3**. 2014 and 2016 LOLEV Standard Deviations (Weighted Load Profile)*

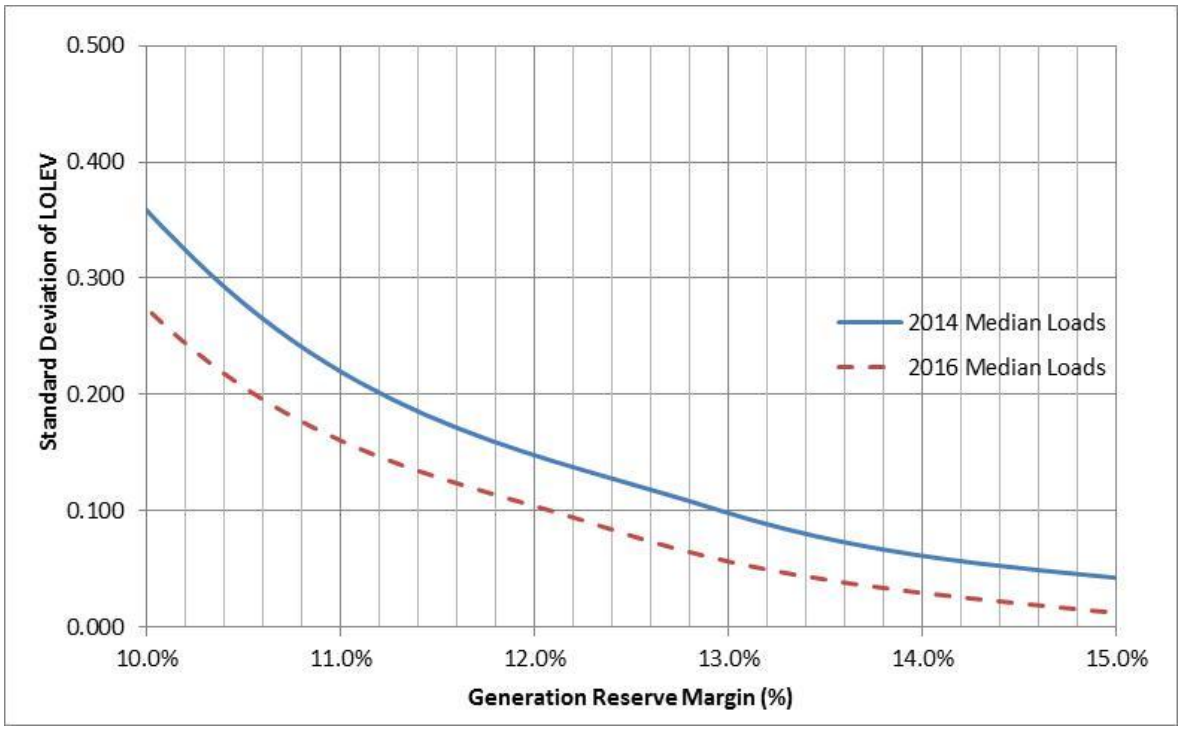

***Figure 4**. 2014 and 2016 LOLEV Standard Deviations (Median Load Profile)*

2.3.4 Annual LOLEV for Capacity Deficiency Levels

The following tables break down the LOLEV results according to the level of "capacity deficiency", which is the difference between the Net Load (Load – Wind Gen) minus the available generation capacity. During a loss-of-load event, the "capacity deficiency" is positive, indicating that there is insufficient generation to meet the Net Load.

Table 8. 2014 Annual LOLEV Results by Deficit Level (Weighted Load Profile)

Gen Capacity	Reserve Margin	Annual LOLEV for Various Capacity Deficiency Levels (MW)							
		Any MW	<2700 MW	<2200 MW	<1700 MW	<1200 MW	<700 MW	<200 MW	<0 MW
76,400	4.8%	12.068	11.991	11.777	11.102	9.588	6.707	2.199	0.000
78,471	7.5%	5.066	5.031	4.971	4.788	4.278	3.090	1.066	0.000
80,507	10.2%	1.542	1.524	1.500	1.445	1.290	0.946	0.336	0.000
82,535	13.0%	0.398	0.395	0.388	0.371	0.322	0.231	0.079	0.000
84,535	15.6%	0.121	0.120	0.119	0.115	0.104	0.075	0.028	0.000
86,535	18.3%	0.029	0.029	0.029	0.029	0.027	0.021	0.008	0.000
88,535	21.0%	0.005	0.005	0.005	0.005	0.005	0.004	0.002	0.000
90,535	23.6%	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
92,535	26.3%	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
94,535	29.0%	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 9. 2016 Annual LOLEV Results by Deficit Level (Weighted Load Profile)

Gen Capacity	Reserve Margin	Annual LOLEV for Various Capacity Deficiency Levels (MW)							
		Any MW	<2700 MW	<2200 MW	<1700 MW	<1200 MW	<700 MW	<200 MW	<0 MW
82,660	5.8%	9.433	9.373	9.174	8.659	7.479	5.249	1.752	0.000
84,732	8.4%	3.694	3.636	3.554	3.372	2.939	2.123	0.741	0.000
86,809	11.0%	1.182	1.157	1.130	1.072	0.930	0.673	0.236	0.000
88,810	13.5%	0.418	0.414	0.408	0.390	0.346	0.256	0.087	0.000
90,810	16.0%	0.123	0.123	0.122	0.119	0.106	0.080	0.030	0.000
92,810	18.5%	0.028	0.028	0.028	0.027	0.025	0.020	0.009	0.000
94,810	21.0%	0.005	0.005	0.005	0.005	0.005	0.004	0.001	0.000
96,810	23.4%	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000
98,332	25.3%	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
100,770	28.4%	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

2.4 Loss of Load Hour (LOLH) Results

In this section, the Loss of Load Hour (LOLH) results are presented for 2014 and 2016. The LOLH indicates how many loss-of-load hours are expected to occur in a given timeframe. The LOLH results tables provide the following for each study year:

- Average Monthly LOLH
- Average Annual LOLH
    - Median Load Profile and Weighted Load Profile

- Annual Average LOLH for various capacity deficiency levels

2.4.1 Average Monthly LOLH

The next two tables show the average Monthly LOLH Results for 2014 and 2016. The key point to notice in both tables is that August is the peak month for loss-of-load hours. When the reserve margin is in the 15% – 18% range, notice that August contributes almost the entire LOLH total.

Table 10. 2014 Average Monthly LOLH Results (Weighted Load Profile)

	Reserve Margin ->	4.8%	7.5%	10.2%	13.0%	15.6%	18.3%	21.0%	23.6%	26.3%	29.0%
	Gen Capacity ->	76,400	78,471	80,507	82,535	84,535	86,535	88,535	90,535	92,535	94,535
Month	January	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	February	0.04	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
	March	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	April	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	May	1.94	0.77	0.17	0.03	0.00	0.00	0.00	0.00	0.00	0.00
	June	0.93	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	July	7.30	1.70	0.19	0.01	0.00	0.00	0.00	0.00	0.00	0.00
	August	26.54	10.58	3.29	0.92	0.27	0.06	0.01	0.00	0.00	0.00
	September	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	October	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	November	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	December	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total (Annual)	**36.79**	**13.15**	**3.67**	**0.97**	**0.28**	**0.06**	**0.01**	**0.00**	**0.00**	**0.00**

Table 11. 2016 Average Monthly LOLH Results (Weighted Load Profiles)

	Reserve Margin ->	5.8%	8.4%	11.0%	13.5%	16.0%	18.5%	21.0%	23.4%	25.3%	28.4%
	Gen Capacity ->	82,660	84,732	86,809	88,810	90,810	92,810	94,810	96,810	98,332	100,770
Month	January	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	February	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	March	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	April	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	May	0.86	0.16	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	June	0.44	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	July	3.83	0.96	0.15	0.01	0.00	0.00	0.00	0.00	0.00	0.00
	August	21.59	8.41	2.86	0.99	0.26	0.05	0.01	0.00	0.00	0.00
	September	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	October	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	November	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	December	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total (Annual)	**26.80**	**9.58**	**3.02**	**1.00**	**0.26**	**0.05**	**0.01**	**0.00**	**0.00**	**0.00**

2.4.2 Average Annual LOLH

The next table shows the average annual LOLH results for the median load profile (2006), and for the weighted combination of all fifteen load profiles. Results are presented for both 2014 and 2016.

Table 12. 2014 Annual LOLH Results (Weighted Load Profile & Median Load Profile)

Reserve Margin ->	4.8%	7.5%	10.2%	13.0%	15.6%	18.3%	21.0%	23.6%	26.3%	29.0%
Gen Capacity ->	76,400	78,471	80,507	82,535	84,535	86,535	88,535	90,535	92,535	94,535
Weighted Load Profile	36.79	13.15	3.67	0.97	0.28	0.06	0.01	0.00	0.00	0.00
Median Load Profile	33.32	10.45	1.77	0.19	0.02	0.00	0.00	0.00	0.00	0.00

Table 13. 2016 Annual LOLH Results (Weighted Load Profile & Median Load Profile)

Reserve Margin ->	5.8%	8.4%	11.0%	13.5%	16.0%	18.5%	21.0%	23.4%	25.3%	28.4%
Gen Capacity ->	82,660	84,732	86,809	88,810	90,810	92,810	94,810	96,810	98,332	100,770
Weighted Load Profile	26.80	9.58	3.02	1.00	0.26	0.05	0.01	0.00	0.00	0.00
Median Load Profile	25.29	7.54	1.11	0.11	0.01	0.00	0.00	0.00	0.00	0.00

The next two figures plot the average LOLH from the previous two tables. The first chart shows the results when using the weighted combination of all fifteen load profiles, while the second chart shows the results for only the median load profile (2006).

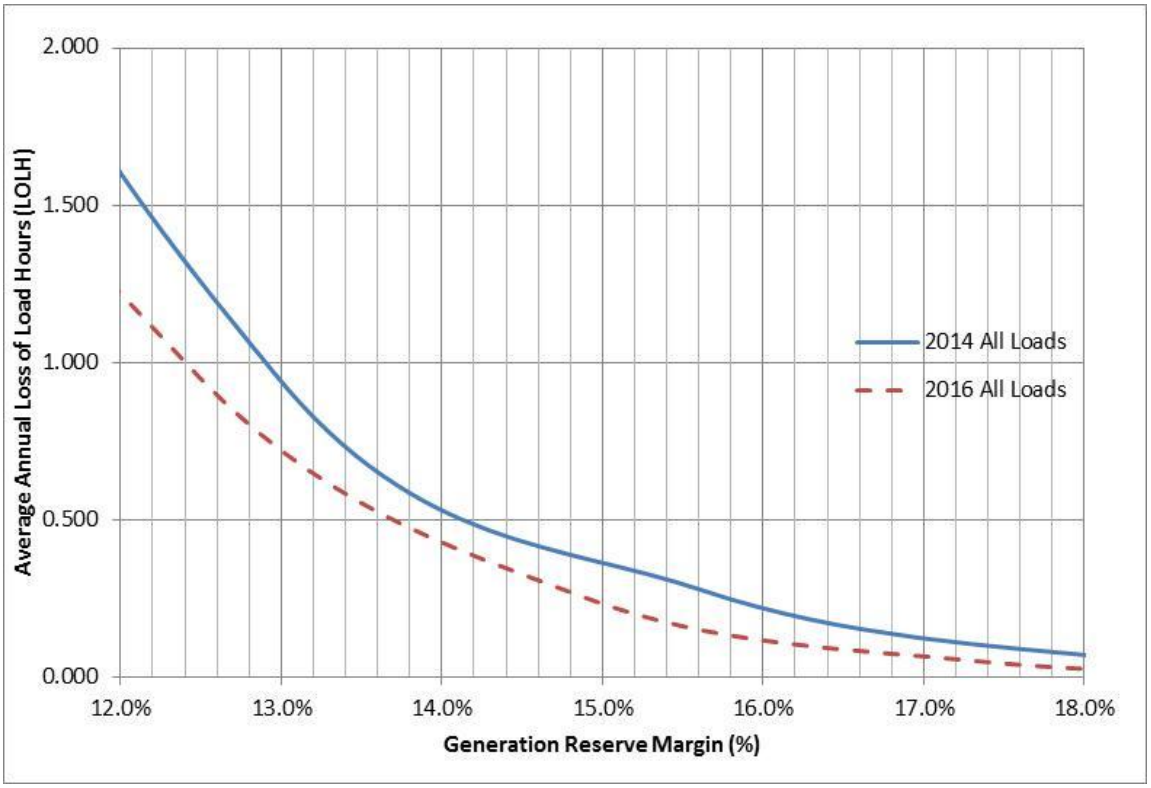

***Figure 5**. 2014 and 2016 Annual LOLH vs. Reserve Margin (Weighted Load Profile)*

With the 2014 TRM = 16.0% in the above chart, the corresponding 2014 LOLH is 0.242 hours/year.

With the 2016 TRM = 16.0% in the above chart, the corresponding 2016 LOLH is 0.151 hours/year.

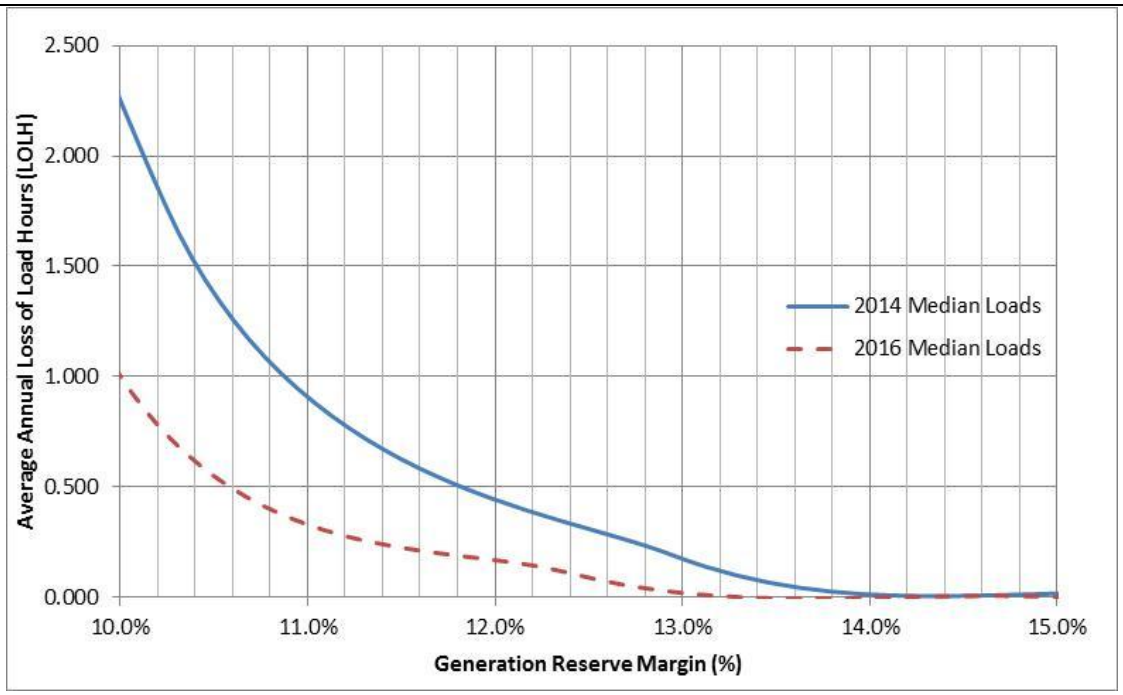

***Figure 6**. 2014 and 2016 Annual LOLH vs. Reserve Margin (Median Load Profile)*

As described in 2.2.3, the difference between the 2014 and 2016 curves can largely be attributed to the non-uniform scaling of load profiles.

2.4.3 Annual LOLH for Capacity Deficiency Levels

The following tables break down the LOLH results according to the level of "capacity deficiency", which is the difference between the Net Load (Load – Wind Gen) minus the available generation capacity. During a loss-of-load event, the "capacity deficiency" is positive, indicating that there is insufficient generation to meet the Net Load.

Table 14. 2014 Annual LOLH Results by Deficit Level (Weighted Load Profile)

Gen Capacity	Reserve Margin	Annual LOLH for Various Capacity Deficiency Levels (MW)							
		Any MW	<2700 MW	<2200 MW	<1700 MW	<1200 MW	<700 MW	<200 MW	<0 MW
76,400	4.8%	36.794	29.357	26.358	22.318	17.184	10.954	3.403	0.000
78,471	7.5%	13.147	11.235	10.348	9.106	7.327	4.858	1.575	0.000
80,507	10.2%	3.670	3.144	2.929	2.611	2.167	1.492	0.509	0.000
82,535	13.0%	0.969	0.834	0.766	0.673	0.548	0.367	0.119	0.000
84,535	15.6%	0.276	0.254	0.238	0.213	0.176	0.119	0.041	0.000
86,535	18.3%	0.057	0.055	0.052	0.048	0.041	0.029	0.011	0.000
88,535	21.0%	0.008	0.008	0.008	0.008	0.007	0.005	0.002	0.000
90,535	23.6%	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
92,535	26.3%	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
94,535	29.0%	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 15. 2016 Annual LOLH Results by Deficit Level (Weighted Load Profile)

Gen Capacity	Reserve Margin	Annual LOLH for Various Capacity Deficiency Levels (MW)							
		Any MW	<2700 MW	<2200 MW	<1700 MW	<1200 MW	<700 MW	<200 MW	<0 MW
82,660	5.8%	26.800	21.063	19.016	16.292	12.749	8.258	2.623	0.000
84,732	8.4%	9.581	7.743	7.107	6.228	4.989	3.332	1.105	0.000
86,809	11.0%	3.025	2.480	2.251	1.947	1.553	1.042	0.336	0.000
88,810	13.5%	1.002	0.884	0.820	0.724	0.585	0.396	0.130	0.000
90,810	16.0%	0.256	0.237	0.224	0.203	0.167	0.117	0.039	0.000
92,810	18.5%	0.050	0.048	0.045	0.042	0.035	0.026	0.011	0.000
94,810	21.0%	0.008	0.008	0.007	0.007	0.006	0.005	0.001	0.000
96,810	23.4%	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000
98,332	25.3%	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
100,770	28.4%	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

2.5 Load Outage Duration Results

In this section, the Load Outage Duration results are presented for 2014 and 2016. The Outage Duration indicates the average length of a loss-of-load event within a given timeframe. This value can be computed by dividing the LOLH by the LOLEV. The load outage duration results tables provide the following for each study year:

- Average Monthly Load Outage Duration
- Average Annual Load Outage Duration
    - Median Load Profile, and Weighted Load Profile

2.5.1 Average Monthly Load Outage Duration

The next two tables show the average Monthly Load Outage Durations for 2014 and 2016. In both tables, August is the peak month for load outage durations. As the number of events (LOLEV) decrease, there is a corresponding decrease in the length/severity of the events.

Note that outages outside of August (and July to some extent) are relatively rare, and typically are the result of planned maintenance, high loads, and excessive forced outages in that particular Monte-Carlo iteration. So even though outage durations are shown for several other months, they contribute almost nothing to the total (annual) average, because they occur so infrequently.

Table 16. 2014 Average Monthly Outage Duration (Hours/Event), (Weighted Load Profile)

	Reserve Margin ->	4.8%	7.5%	10.2%	13.0%	15.6%	18.3%	21.0%	23.6%	26.3%	29.0%
	Gen Capacity (MW) ->	76,400	78,471	80,507	82,535	84,535	86,535	88,535	90,535	92,535	94,535
Month	January										
	February	3.957	3.040	1.979	1.390	1.108	1.000				
	March										
	April	1.392	1.038								
	May	2.972	2.461	1.862	1.556	1.500					
	June	2.001	1.615	1.444	1.000						
	July	2.598	1.991	1.491	1.445	1.019					
	August	3.275	2.751	2.505	2.515	2.340	1.930	1.477	1.200		
	September	1.556	1.254	1.000							
	October										
	November										
	December	1.000									
	Total (Annual)	**3.049**	**2.595**	**2.380**	**2.432**	**2.287**	**1.925**	**1.477**	**1.200**		

Table 17. 2016 Average Monthly Outage Duration (Hours/Event), (Weighted Load Profile)

	Reserve Margin ->	5.8%	8.4%	11.0%	13.5%	16.0%	18.5%	21.0%	23.4%	25.3%	28.4%
	Gen Cap (MW) ->	82,660	84,732	86,809	88,810	90,810	92,810	94,810	96,810	98,332	100,770
Month	January										
	February	1.000									
	March										
	April	1.116	1.000								
	May	1.844	1.471	1.239	1.000						
	June	1.882	1.706	1.200							
	July	2.376	2.055	1.552	1.180	1.222	1.000				
	August	3.055	2.724	2.659	2.431	2.075	1.790	1.535	1.304	1.000	
	September	1.790	1.535								
	October										
	November										
	December										
	Total (Annual)	**2.841**	**2.594**	**2.559**	**2.396**	**2.074**	**1.789**	**1.535**	**1.304**	**1.000**	

2.5.2 Average Annual Load Outage Duration

The next table shows the average annual load outage durations for the median load profile (2006), and for the weighted combination of all fifteen load profiles. Results are presented for both 2014 and 2016.

Table 18. 2014 Annual Outage Duration (Hours/Event) (Weighted & Median Load Profiles)

Reserve Margin ->	4.8%	7.5%	10.2%	13.0%	15.6%	18.3%	21.0%	23.6%	26.3%	29.0%
Gen Capacity (MW) ->	76,400	78,471	80,507	82,535	84,535	86,535	88,535	90,535	92,535	94,535
Weighted Load Profile	3.049	2.595	2.380	2.432	2.287	1.925	1.477	1.200		
Median Load Profile	3.022	2.344	1.980	1.767	1.400					

Table 19. 2016 Annual Outage Duration (Hours/Event) (Weighted & Median Load Profiles)

Reserve Margin ->	5.8%	8.4%	11.0%	13.5%	16.0%	18.5%	21.0%	23.4%	25.3%	28.4%
Gen Capacity (MW) ->	82,660	84,732	86,809	88,810	90,810	92,810	94,810	96,810	98,332	100,770
Weighted Load Profile	2.841	2.594	2.559	2.396	2.074	1.789	1.535	1.304	1.000	
Median Load Profile	2.725	2.211	1.819	1.571						

The next two figures plot the average load outage durations for the weighted load profile, and the median load profile (2006).

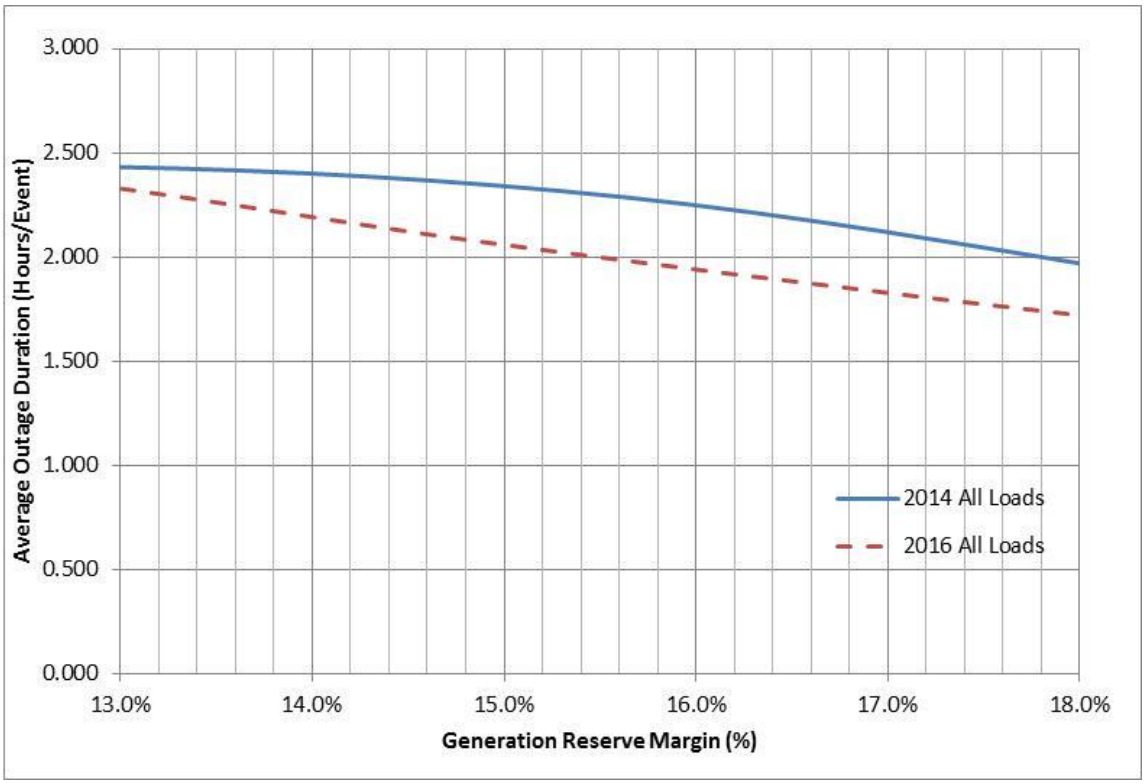

***Figure 7**. 2014 and 2016 Load Outage Duration vs. Reserve Margin (Weighted Load Profiles)*

2.6 Expected Unserved Energy (EUE) Results

In this section, the Expected Unserved Energy (EUE) results are presented for 2014 and 2016. The EUE indicates the expected load energy that will not be served, within in a given timeframe. The EUE results tables provide the following for each study year:

- Average Monthly EUE
- Average Annual EUE
    - Median Load Profile and Weighted Load Profile
- Standard Deviation for Annual EUE
    - Median Load Profile and Weighted Load Profile
- Annual Average EUE for various capacity deficiency levels

2.6.1 Average Monthly EUE

The next two tables show the average Monthly EUE Results for 2014 and 2016. In both tables, August is the peak month for unserved energy.

Table 20. 2014 Average Monthly EUE Results (Weighted Load Profile)

	Reserve Margin ->	4.8%	7.5%	10.2%	13.0%	15.6%	18.3%	21.0%	23.6%	26.3%	29.0%
	Gen Capacity (MW) ->	76,400	78,471	80,507	82,535	84,535	86,535	88,535	90,535	92,535	94,535
Month	January	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	February	135.5	76.1	29.8	8.5	1.3	0.1	0.0	0.0	0.0	0.0
	March	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	April	4.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	May	2,948.9	909.1	136.1	15.9	1.2	0.0	0.0	0.0	0.0	0.0
	June	702.8	34.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	July	9,085.9	1,504.6	135.3	10.3	0.5	0.0	0.0	0.0	0.0	0.0
	August	49,533.7	16,307.9	4,668.4	1,274.8	304.9	50.5	5.1	0.2	0.0	0.0
	September	23.6	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	October	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	November	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	December	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total (Annual)	**62,435.0**	**18,834.2**	**4,969.8**	**1,309.5**	**307.9**	**50.6**	**5.1**	**0.2**	**0.0**	**0.0**

Table 21. 2016 Average Monthly EUE Results (All Load Profiles)

	Reserve Margin ->	5.8%	8.4%	11.0%	13.5%	16.0%	18.5%	21.0%	23.4%	25.3%	28.4%
	Gen Capacity (MW) ->	82,660	84,732	86,809	88,810	90,810	92,810	94,810	96,810	98,332	100,770
Month	January	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	February	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	March	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	April	13.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	May	826.5	113.5	3.7	0.6	0.0	0.0	0.0	0.0	0.0	0.0
	June	324.2	21.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	July	4,856.1	951.8	112.7	6.4	0.2	0.0	0.0	0.0	0.0	0.0
	August	40,802.0	14,221.9	4,530.4	1,272.8	274.1	45.1	5.7	0.4	0.0	0.0
	September	38.2	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	October	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	November	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	December	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total (Annual)	**46,860.9**	**15,311.3**	**4,646.9**	**1,279.8**	**274.3**	**45.1**	**5.7**	**0.4**	**0.0**	**0.0**

2.6.2 Average Annual EUE

The next table shows the average annual EUE results for the median load profile (2006), and for the weighted combination of all fifteen load profiles.

Table 22. 2014 Annual EUE Results (Weighted Load Profile & Median Load Profile)

Reserve Margin ->	4.8%	7.5%	10.2%	13.0%	15.6%	18.3%	21.0%	23.6%	26.3%	29.0%
Gen Capacity ->	76,400	78,471	80,507	82,535	84,535	86,535	88,535	90,535	92,535	94,535
Weighted Load Profile	62,435.0	18,834.2	4,969.8	1,309.5	307.9	50.6	5.1	0.2	0.0	0.0
Median Load Profile	47,873.8	10,739.6	1,333.7	118.3	5.8	0.0	0.0	0.0	0.0	0.0

Table 23. 2016 Annual EUE Results (Weighted Load Profile & Median Load Profile)

Reserve Margin ->	5.8%	8.4%	11.0%	13.5%	16.0%	18.5%	21.0%	23.4%	25.3%	28.4%
Gen Capacity ->	82,660	84,732	86,809	88,810	90,810	92,810	94,810	96,810	98,332	100,770
Weighted Load Profile	46,860.9	15,311.3	4,646.9	1,279.8	274.3	45.1	5.7	0.4	0.0	0.0
Median Load Profile	35,308.5	7,360.3	828.5	59.0	1.2	0.0	0.0	0.0	0.0	0.0

The next two figures plot the average annual EUE from the previous two tables. The first chart shows the results when using the weighted combination of all fifteen load profiles, while the second chart shows the results for only the median load profile (2006).

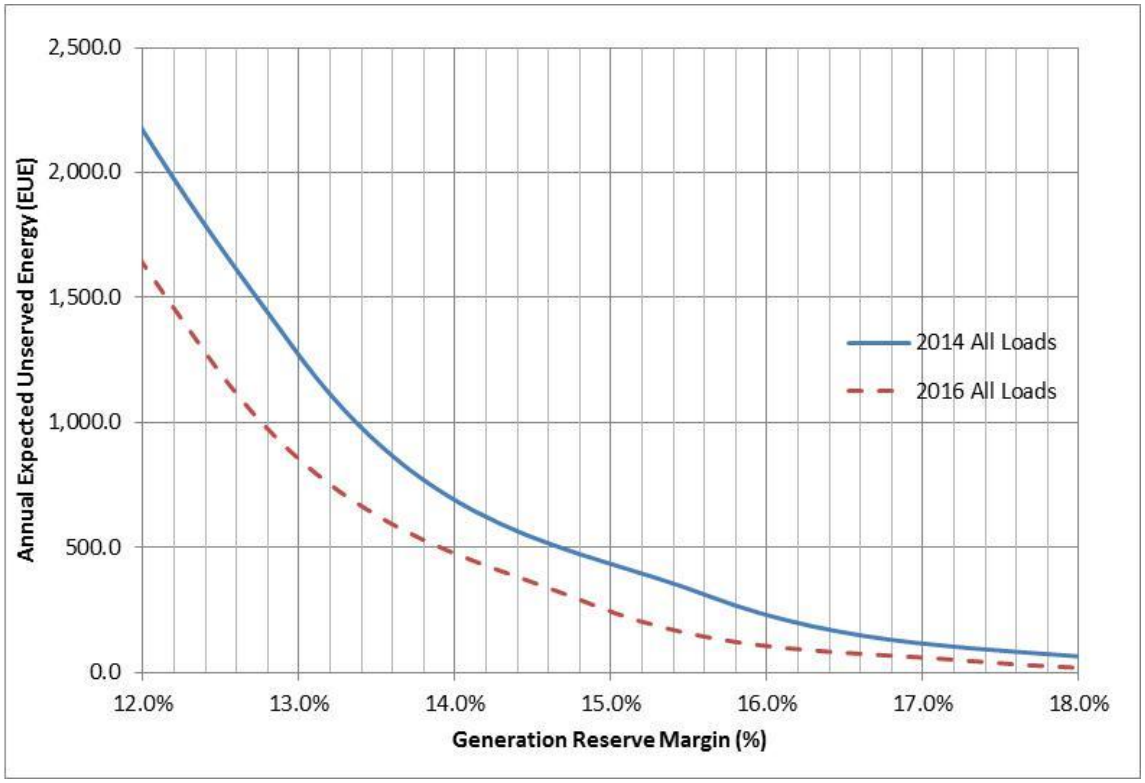

***Figure 8**. 2014 and 2016 Annual EUE vs. Reserve Margin (Weighted Load Profile)*

With the 2014 TRM = 16.0% in the above chart, the corresponding 2014 EUE is 266.7 MWh/year.

With the 2016 TRM = 16.0% in the above chart, the corresponding 2016 EUE is 164.3 MWh/year.

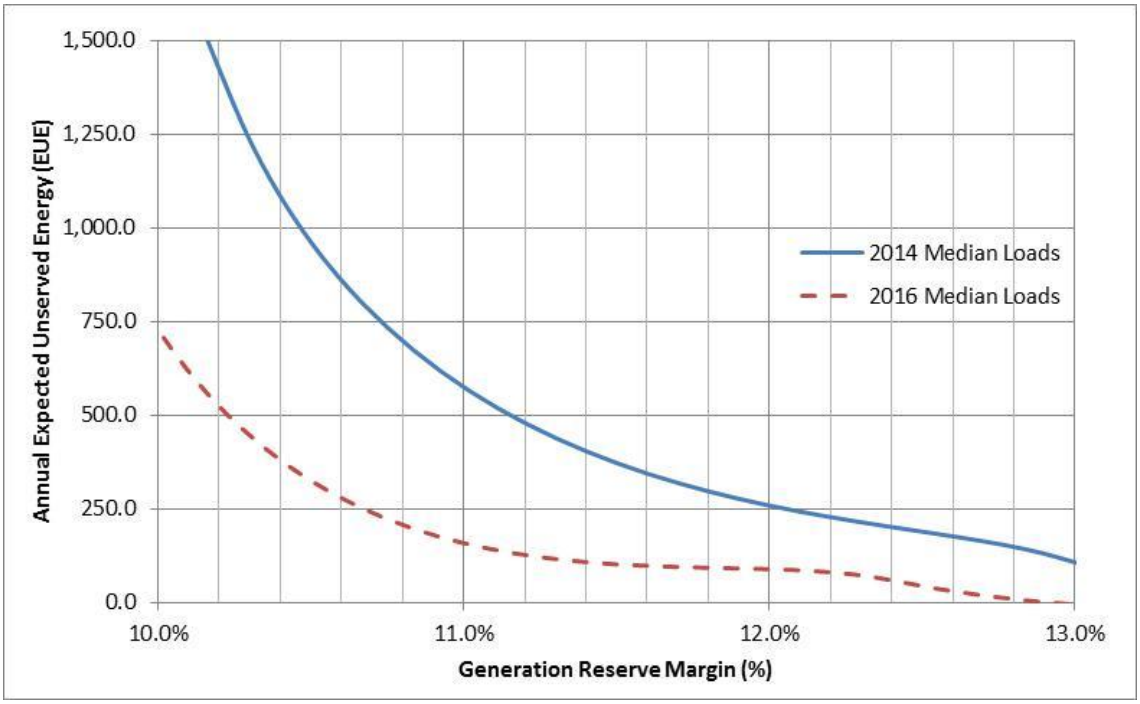

***Figure 9**. 2014 and 2016 Annual EUE vs. Reserve Margin (Median Load Profile)*

As described in 2.2.3, the difference between the 2014 and 2016 curves can mainly be attributed to the non-uniform scaling of load profiles.

2.6.3 Annual EUE Standard Deviations

The following two tables (and two charts) show the standard deviations of the EUE results. This information is useful to gauge the variability of the results.

Table 24. 2014 EUE Standard Deviations (Weighted Load Profile & Median Load Profile)

Reserve Margin	4.8%	7.5%	10.2%	13.0%	15.6%	18.3%	21.0%	23.6%	26.3%	29.0%
Gen Cap (MW)	76,400	78,471	80,507	82,535	84,535	86,535	88,535	90,535	92,535	94,535
Weighted Load Profile	15,721	5,566	1,751	526	133	29	4	0	0	0
Median Load Profile	10,664	3,088	798	187	19	0.0	0	0	0	0

Table 25. 2016 EUE Standard Deviations (Weighted Load Profile & Median Load Profile)

Reserve Margin	5.8%	8.4%	11.0%	13.5%	16.0%	18.5%	21.0%	23.4%	25.3%	28.4%
Gen Cap (MW)	82,660	84,732	86,809	88,810	90,810	92,810	94,810	96,810	98,332	100,770
Weighted Load Profile	12,743	4,688	1,562	471	123	32	6	1	0	0
Median Load Profile	9,889	2,701	589	104	7	0	0	0	0	0

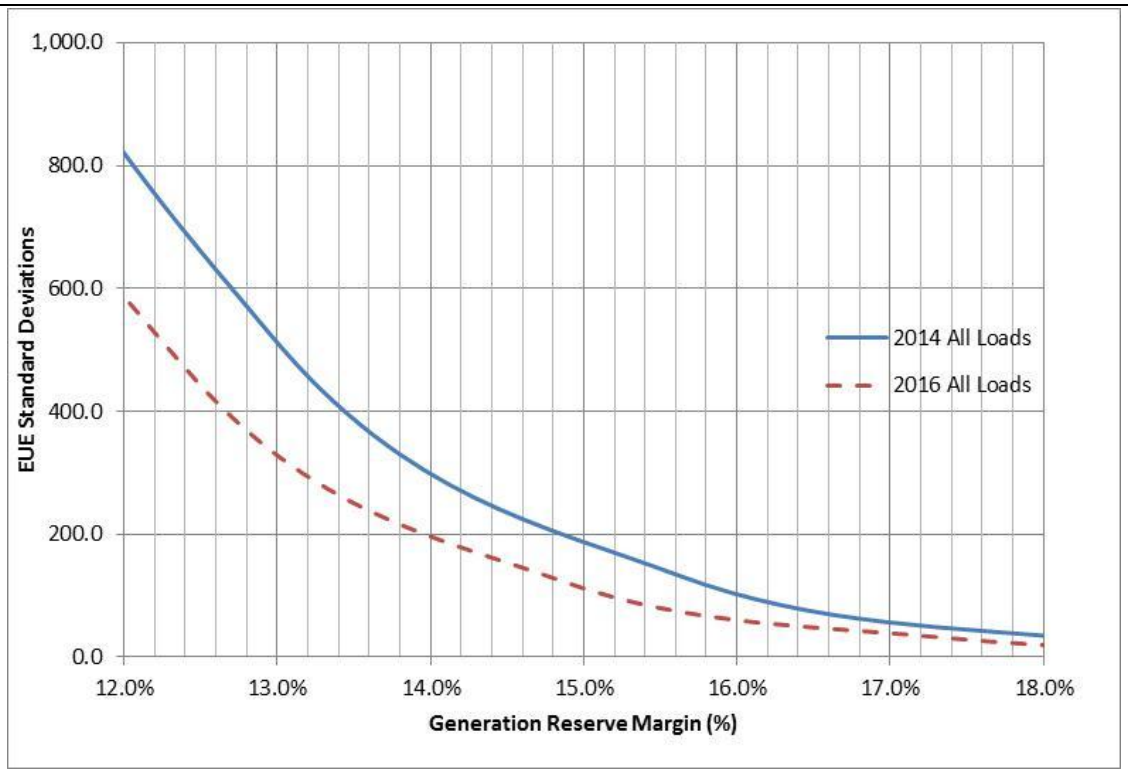

***Figure 10**. 2014 and 2016 EUE Standard Deviations (Weighted Load Profile)*

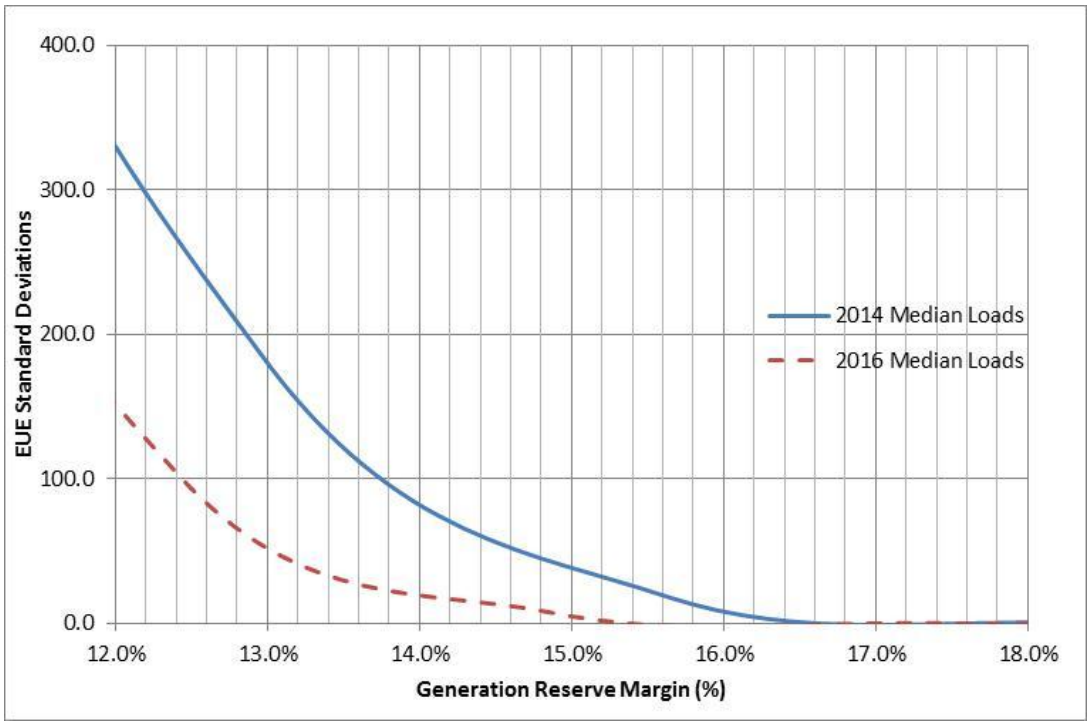

***Figure 11**. 2014 and 2016 EUE Standard Deviations (Median Load Profile)*

2.6.4 Annual EUE for Capacity Deficiency Levels

The following tables break down the EUE results according to the level of "capacity deficiency", which is the difference between the Net Load (Load – Wind Gen) minus the available generation capacity. During a loss-of-load event, the "capacity deficiency" is positive, indicating that there is insufficient generation to meet the Net Load.

Table 26. 2014 Annual EUE Results by Deficit Level (Weighted Load Profile)

Gen Capacity (MW)	Reserve Margin	Annual EUE for Various Capacity Deficiency Levels (MW)							
		All MW	<2700 MW	<2200 MW	<1700 MW	<1200 MW	<700 MW	<200 MW	<0 MW
76,400	4.8%	62,435.0	32,093.9	24,775.3	16,935.7	9,540.0	3,670.1	335.8	0.0
78,471	7.5%	18,834.2	11,015.6	8,854.5	6,454.2	3,901.1	1,585.8	154.4	0.0
80,507	10.2%	4,969.8	2,875.2	2,352.3	1,738.9	1,104.5	477.1	50.7	0.0
82,535	13.0%	1,309.5	812.6	646.9	466.5	287.7	118.4	11.5	0.0
84,535	15.6%	307.9	230.8	193.5	144.1	90.9	37.7	3.9	0.0
86,535	18.3%	50.6	44.3	38.9	29.6	20.0	8.9	1.1	0.0
88,535	21.0%	5.1	5.0	4.4	4.1	2.9	1.4	0.2	0.0
90,535	23.6%	0.2	0.2	0.2	0.2	0.2	0.1	0.0	0.0
92,535	26.3%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
94,535	29.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 27. 2016 Annual EUE Results by Deficit Level (Weighted Load Profile)

Gen Capacity (MW)	Reserve Margin	Annual EUE for Various Capacity Deficiency Levels (MW)							
		All MW	<2700 MW	<2200 MW	<1700 MW	<1200 MW	<700 MW	<200 MW	<0 MW
82,660	5.8%	46,860.9	22,362.5	17,368.7	12,084.1	6,976.9	2,753.5	257.6	0.0
84,732	8.4%	15,311.3	7,676.3	6,125.2	4,424.1	2,646.2	1,091.3	109.5	0.0
86,809	11.0%	4,646.9	2,537.1	1,980.2	1,390.1	823.0	339.8	33.0	0.0
88,810	13.5%	1,279.8	849.2	693.1	507.5	308.0	130.9	12.4	0.0
90,810	16.0%	274.3	208.1	176.8	135.2	83.9	38.0	4.1	0.0
92,810	18.5%	45.1	38.3	32.1	25.5	16.4	7.5	1.1	0.0
94,810	21.0%	5.7	5.3	4.9	3.9	2.9	1.6	0.1	0.0
96,810	23.4%	0.4	0.4	0.4	0.4	0.3	0.1	0.0	0.0
98,332	25.3%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
100,770	28.4%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

2.7 Normalized Expected Unserved Energy (EUE) Results

The Normalized EUE results are similar to the EUE results, except that they are scaled according to the size of the systems under study. This is helpful when comparing reliability between systems of different sizes.

Table 28. 2014 Normalized EUE Results (Weighted Load Profile & Median Load Profile)

Reserve Margin ->	4.8%	7.5%	10.2%	13.0%	15.6%	18.3%	21.0%	23.6%	26.3%	29.0%
Gen Capacity ->	76,400	78,471	80,507	82,535	84,535	86,535	88,535	90,535	92,535	94,535
Weighted Load Profile	166.97	50.37	13.29	3.50	0.82	0.14	0.01	0.00	0.00	0.00
Median Load Profile	128.03	28.72	3.57	0.32	0.02	0.00	0.00	0.00	0.00	0.00

Table 29. 2016 Normalized EUE Results (Weighted Load Profile & Median Load Profile)

Reserve Margin ->	4.8%	7.5%	10.2%	13.0%	15.6%	18.3%	21.0%	23.6%	26.3%	29.0%
Gen Capacity ->	76,400	78,471	80,507	82,535	84,535	86,535	88,535	90,535	92,535	94,535
Weighted Load Profile	117.18	38.29	11.62	3.20	0.69	0.11	0.01	0.00	0.00	0.00
Median Load Profile	88.30	18.41	2.07	0.15	0.00	0.00	0.00	0.00	0.00	0.00

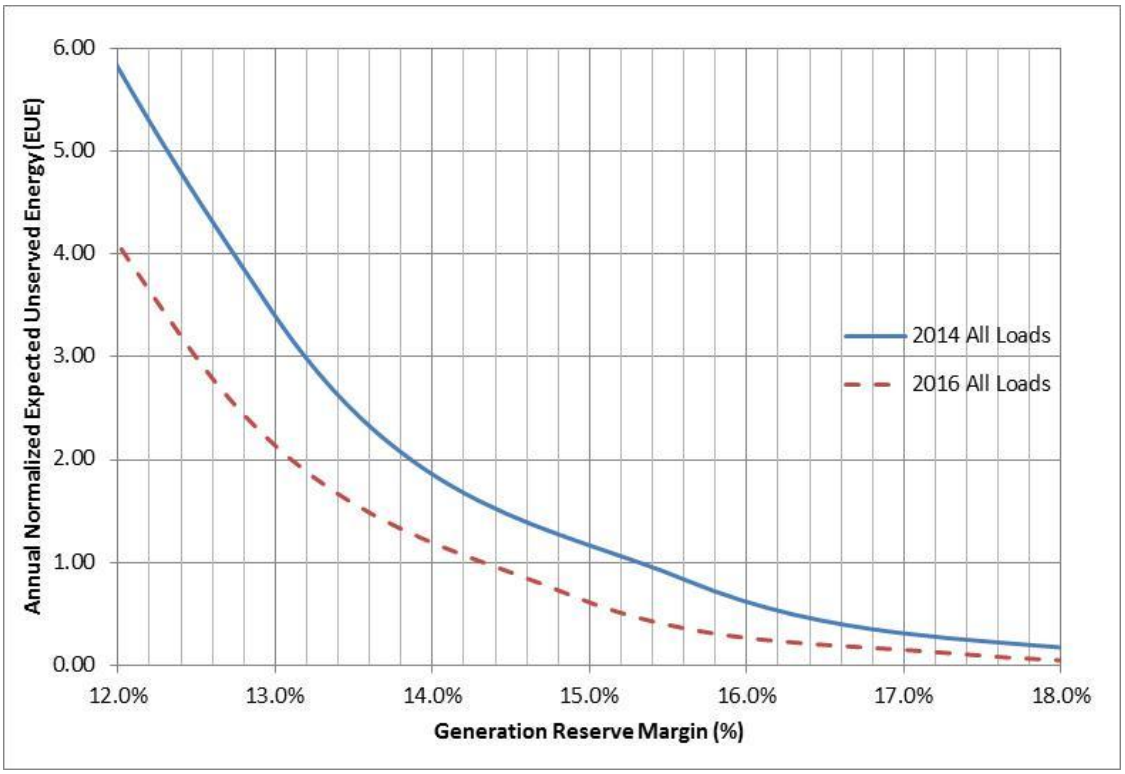

***Figure 12**. 2014 and 2016 Normalized EUE vs. Reserve Margin (Weighted Load Profiles)*

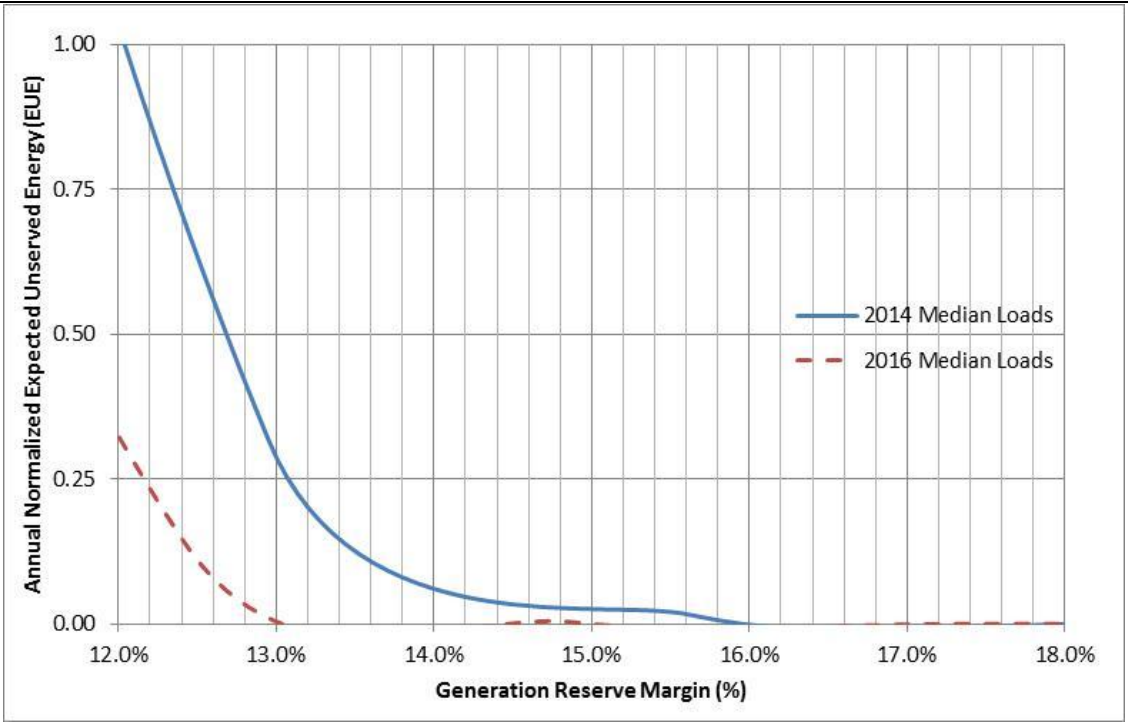

***Figure 13**. 2014 and 2016 Normalized EUE vs. Reserve Margin (Median Load Profile)*

2.8 Loss of Load Probability (LOLP) Results

In this section, the Loss of Load Probability (LOLP) results are presented for 2014 and 2016. The LOLP indicate the probability that a loss-of-load event will occur within a particular hour. On an annual basis, this is equivalent to the LOLH divided by the number of hours in a year (typically 8,760). Results are reported on an average annual basis for the Median and Weighted Load Profiles.

2.8.1 Average Annual LOLP

The next table shows the average annual LOLP results for the median load profile (2006), and for the weighted combination of all fifteen load profiles.

Table 30. 2014 Annual LOLP Results (Weighted Load Profile & Median Load Profile)

Reserve Margin	4.8%	7.5%	10.2%	13.0%	15.6%	18.3%	21.0%	23.6%	26.3%	29.0%
Gen Cap (MW)	76,400	78,471	80,507	82,535	84,535	86,535	88,535	90,535	92,535	94,535
Weighted Load Profile	0.420%	0.150%	0.042%	0.011%	0.003%	0.001%	0.000%	0.000%	0.000%	0.000%
Median Load Profile	0.380%	0.119%	0.020%	0.002%	0.000%	0.0000%	0.000%	0.000%	0.000%	0.000%

Table 31. 2016 Annual LOLP Results (Weighted Load Profile & Median Load Profile)

Reserve Margin	5.8%	8.4%	11.0%	13.5%	16.0%	18.5%	21.0%	23.4%	25.3%	28.4%
Gen Cap (MW)	82,660	84,732	86,809	88,810	90,810	92,810	94,810	96,810	98,332	100,770
Weighted Load Profile	0.306%	0.109%	0.035%	0.011%	0.003%	0.001%	0.000%	0.000%	0.000%	0.000%
Median Load Profile	0.289%	0.086%	0.013%	0.001%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%

The next two figures plot the average LOLP from the previous two tables. The first chart shows the results when using the weighted combination of all fifteen load profiles, while the second chart shows the results for only the median load profile (2006). Note that this chart uses a lower reserve margin range.

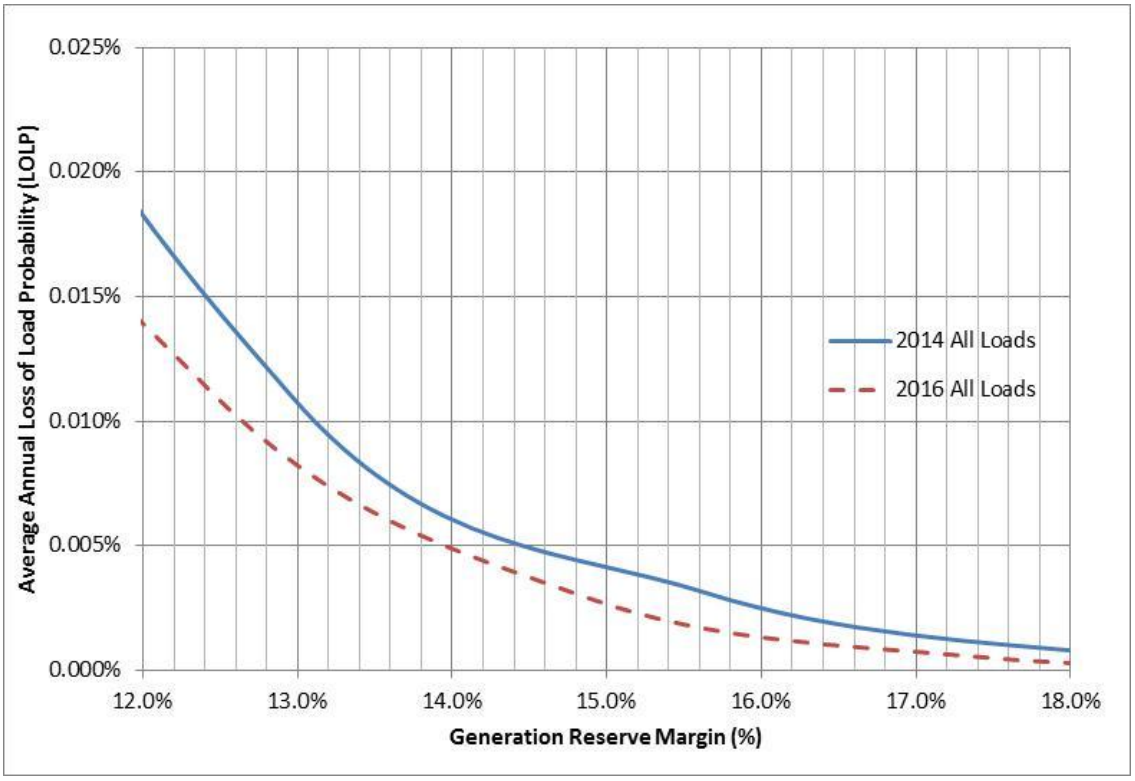

***Figure 14**. 2014 and 2016 Annual LOLP vs. Reserve Margin (Weighted Load Profile)*

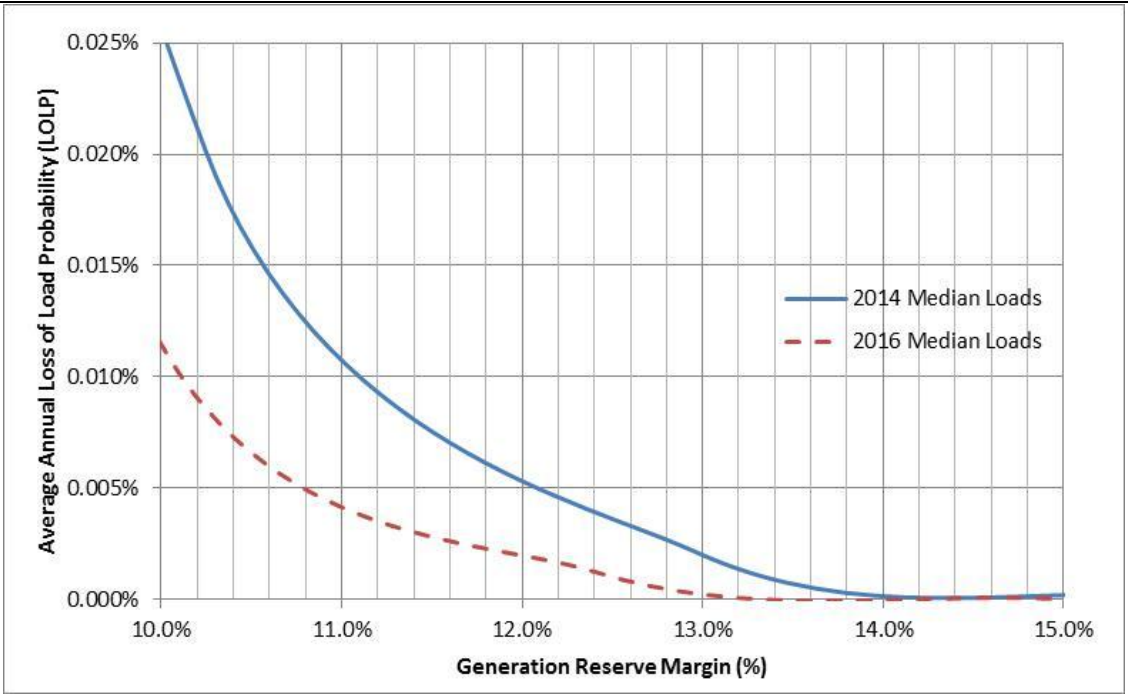

***Figure 15**. 2014 and 2016 Annual LOLH vs. Reserve Margin (Median Load Profile)*

2.9 Simulation Convergence

The following convergence criterion was used for this study:

- The Standard deviation of LOLEV/sqrt(n) is within a "small percentage" of the mean value of LOLEV, where n is the number of iterations. In this study, we used 1% as the minimally acceptable value for the "small percentage".

The following chart plots STDEV(LOLEV)/(SQRT(Iter)*MEAN(LOLEV)), as function of iterations:

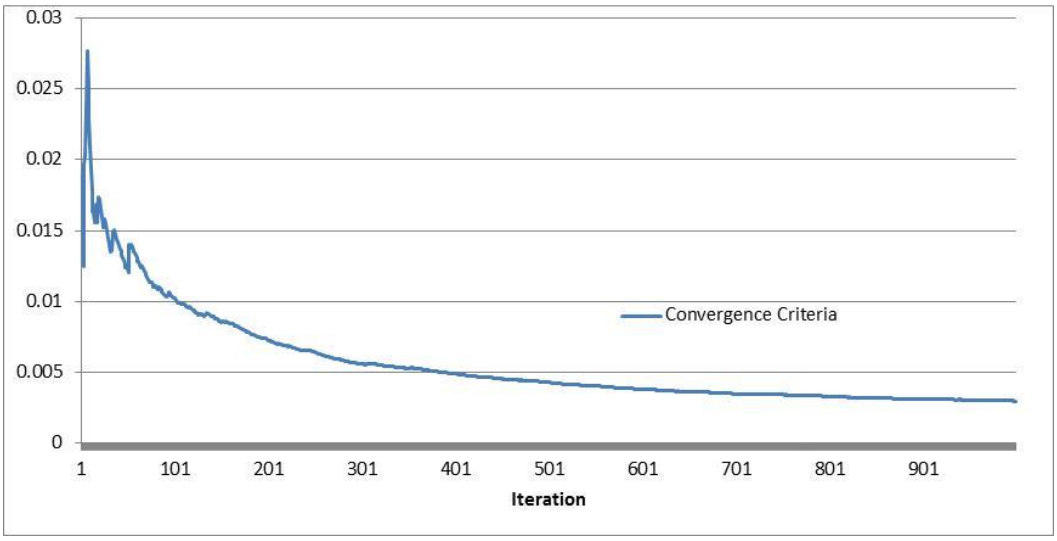

***Figure 16**. Convergence Criteria vs. Iteration Count (2014 Case)*

After 400 iterations, this criterion drops to 0.5%, and further drops to 0.3% after 1000 iterations.

The next chart shows how the overall LOLEV and EUE errors (as compared to the final values) reduce as more iterations are performed.

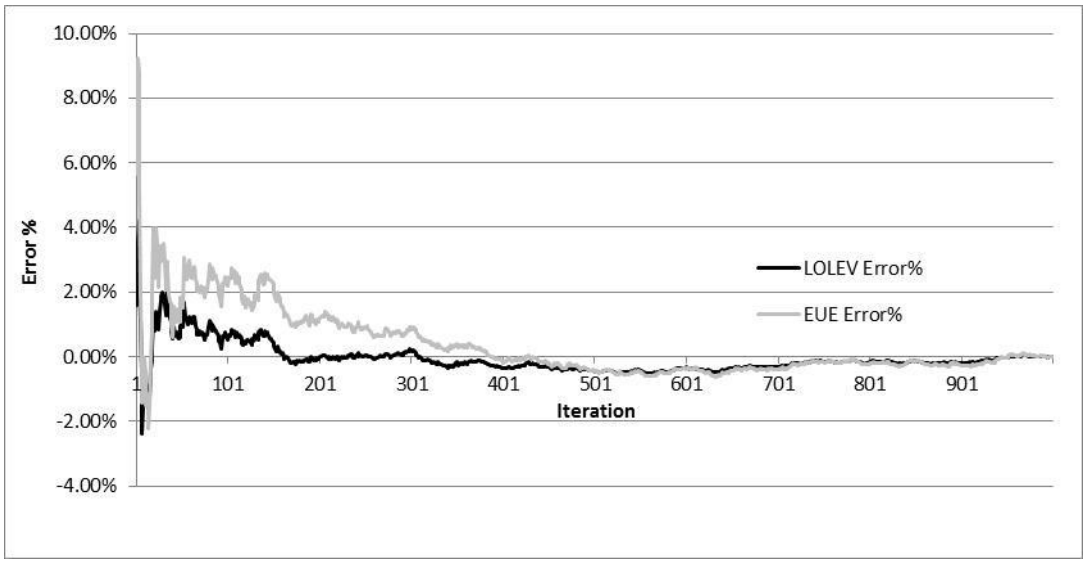

***Figure 17**. LOLEV and EUE Errors vs. Iteration Count (2014 Case)*

For this simulation, the LOLEV and EUE are within 1% of the final result after about 300 iterations.

Based on these results, we could reasonably stop the iterations at 400, and still be within 1% of the final result.

2.10 Wind Capacity Factor

The wind capacity factor is defined as the total energy produced by wind generators divided by the total possible energy production (based on the nameplate capacities). While wind capacity factors are deterministic values, as opposed to probabilistic values like the ELCC, they nevertheless are helpful in gauging the reasonability of the ELCC results.

ERCOT provided synchronized hourly wind data for the same fifteen years as the study load profiles: 1997 through 2011. The following two tables show the average hourly wind generation for the Coastal and West Regions on a beginning-of-hour basis.

Table 32. Average Wind Generation (MW) in Coastal Region

Hour	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
0	409	321	258	222	395	405	346	348	421	352	249	377	336	285	292	334
1	355	282	234	152	339	286	262	279	369	319	181	286	269	232	259	274
2	297	253	208	110	293	256	218	263	324	261	155	230	245	193	234	236
3	251	215	203	113	284	283	202	252	311	207	150	211	237	189	220	222
4	224	202	217	114	303	307	216	269	282	197	162	199	196	185	210	219
5	220	187	227	90	321	295	206	267	249	197	154	206	173	190	186	211
6	220	202	205	95	303	285	204	242	235	208	150	213	171	191	166	206

Hour	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
7	257	170	177	67	260	300	206	267	218	240	145	244	225	197	191	211
8	309	163	168	53	249	330	212	318	213	292	150	291	306	222	229	234
9	379	207	191	112	349	402	272	314	290	363	230	353	331	239	239	285
10	452	216	223	167	406	414	299	380	347	404	277	376	325	227	254	318
11	456	318	248	249	417	493	336	416	431	514	282	414	340	233	277	361
12	568	552	386	451	528	492	353	501	544	623	345	475	426	255	332	455
13	735	689	577	655	619	533	414	541	635	726	405	560	503	296	425	554
14	862	718	717	712	700	655	499	614	706	792	536	660	651	402	559	652
15	943	797	706	702	788	718	548	697	823	854	542	735	742	479	677	717
16	929	781	668	665	885	781	615	770	812	845	543	823	748	472	708	736
17	877	735	578	632	919	822	662	800	850	809	517	847	820	497	699	738
18	854	688	533	587	966	855	670	809	846	814	557	872	857	558	713	745
19	803	627	504	497	859	807	668	731	823	757	517	793	786	545	672	693
20	748	584	482	438	769	737	665	657	790	689	492	727	729	550	645	647
21	661	541	446	412	693	593	515	529	649	537	415	696	571	501	556	554
22	576	463	361	320	540	508	434	455	539	434	324	515	455	405	486	454
23	491	373	285	263	455	461	344	393	467	381	294	433	383	350	390	384
Total	**536**	**428**	**367**	**328**	**527**	**501**	**390**	**463**	**507**	**492**	**324**	**481**	**451**	**329**	**401**	**435**

Table 33. Average Wind Generation (MW) in Western Region

Hour	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
0	3654	3516	3867	5110	3734	4828	3605	3840	3099	4213	4289	3090	4958	4307	5340	4097
1	3751	3299	3981	4828	3615	4618	3558	3725	3000	4177	4134	2838	4688	4142	5073	3962
2	3669	2964	3743	4590	3253	4123	3186	3383	2700	4075	3863	2584	4509	3986	4734	3691
3	3542	2892	3702	4542	2999	3883	2910	3139	2533	3811	3445	2567	4320	3844	4524	3510
4	3433	2822	3547	4267	2728	3354	2718	2899	2333	3444	2967	2314	4050	3718	4328	3262
5	3347	2494	3202	3895	2436	3068	2535	2687	2250	3177	2696	2051	3930	3428	3989	3012
6	2904	2182	2631	3333	2082	2829	2313	2458	2168	2899	2397	1740	3687	2981	3487	2673
7	2603	1500	1779	2452	1578	2502	1803	2134	1741	2464	2214	1209	3160	2351	2559	2137
8	2452	1090	1260	1827	1336	2406	1523	2037	1542	2241	2185	964	2870	1927	1877	1836
9	2286	958	1015	1448	1358	2411	1362	1869	1345	1981	2345	877	2427	1564	1637	1659
10	2215	947	909	1531	1292	2161	1347	1882	1368	1727	2184	983	2504	1684	1548	1619
11	1874	915	796	1340	1296	2046	1205	1888	1347	1713	2206	1169	2560	1703	1512	1571
12	1531	995	781	1283	1386	2055	1316	1746	1271	1653	2381	1361	2153	1643	1312	1524
13	1452	1204	887	1364	1381	1933	1537	1754	1385	1727	2426	1442	1919	1483	1173	1538
14	1611	1311	999	1544	1433	1854	1592	1816	1493	1777	2724	1495	1830	1405	1192	1605
15	1668	1536	1274	1868	1567	1880	1758	2026	1457	1960	3036	1742	1927	1390	1336	1762
16	1751	1626	1462	2152	1609	1904	1944	2214	1463	2034	2947	1800	1886	1411	1522	1848
17	1900	1718	1705	2485	1844	2197	2097	2645	1608	2181	3170	1957	2134	1577	1719	2062
18	2381	1921	2203	3172	2225	2827	2366	3151	1990	2657	3763	2299	2774	1975	2166	2525
19	2457	2120	2431	3670	2504	3449	2711	3256	2204	2836	4046	2355	3380	2596	2832	2857
20	2756	2559	2857	4226	2977	4233	3333	3471	2713	3220	4331	2651	4099	3442	3725	3373
21	3324	2987	3447	4695	3346	4369	3499	3478	2904	3688	4345	2832	4562	3893	4276	3710

Hour	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
22	3518	2671	3702	4856	3379	4213	3386	3523	2775	3910	3912	2725	4704	3834	4490	3706
23	3655	3046	3702	5007	3595	4452	3407	3723	2858	4050	4033	3019	5041	3915	4945	3897
Total	2656	2053	2328	3145	2290	3067	2375	2698	2064	2817	3168	2003	3336	2675	2971	2643

From these two tables, the overall wind capacity factors can be computed:

- Coastal Region Capacity Factor: 435/1,915 = 22.7%
- West Region Capacity Factor: 2,643/10,340 = 25.6%

Thus, the average capacity factor in the West Region is 2.9% higher than the Coastal Region when considering all hours of the fifteen study years.

The following chart illustrates the average hourly wind production in the two wind regions using all 15 years of wind data.

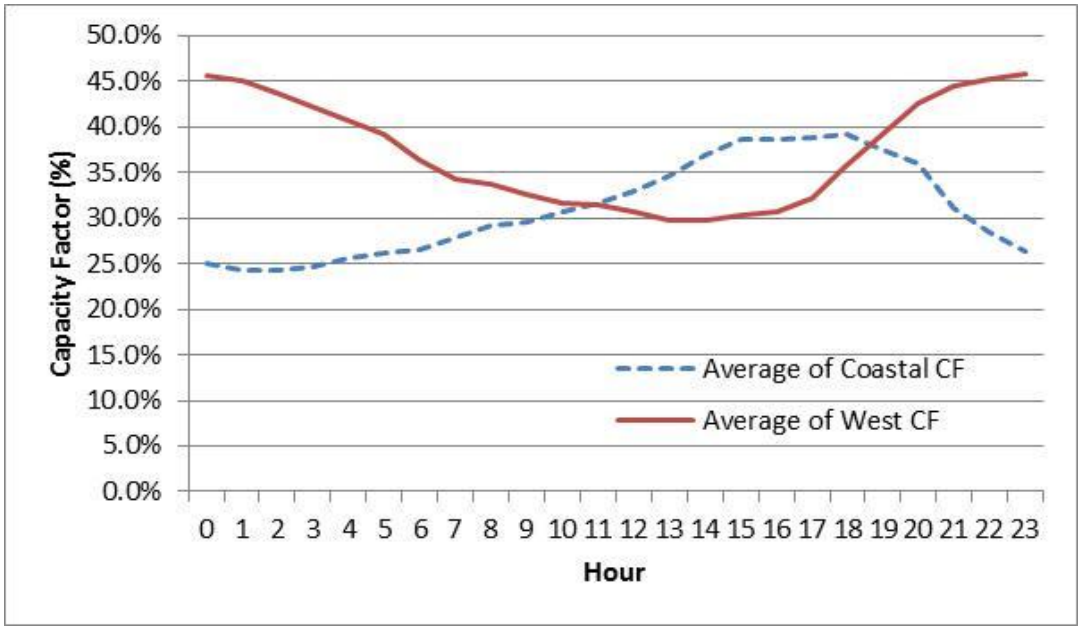

***Figure 18**. Average Hourly Capacity Factor for Wind Generation (All Months)*

This chart illustrates that the Coastal Region Wind typically has a peak output during late afternoon hours, while the Western Region Wind typically has a peak output near midnight.

For reliability studies, however, it is important to focus on the peak load hours, since it is during these hours when the generation/load surplus (Differential) is the smallest, meaning lowest margin of reserve capacity. The following chart shows the average wind production for the month of August. This shows that the coastal wind (on average) is much higher than the west wind during the afternoon hours of August.

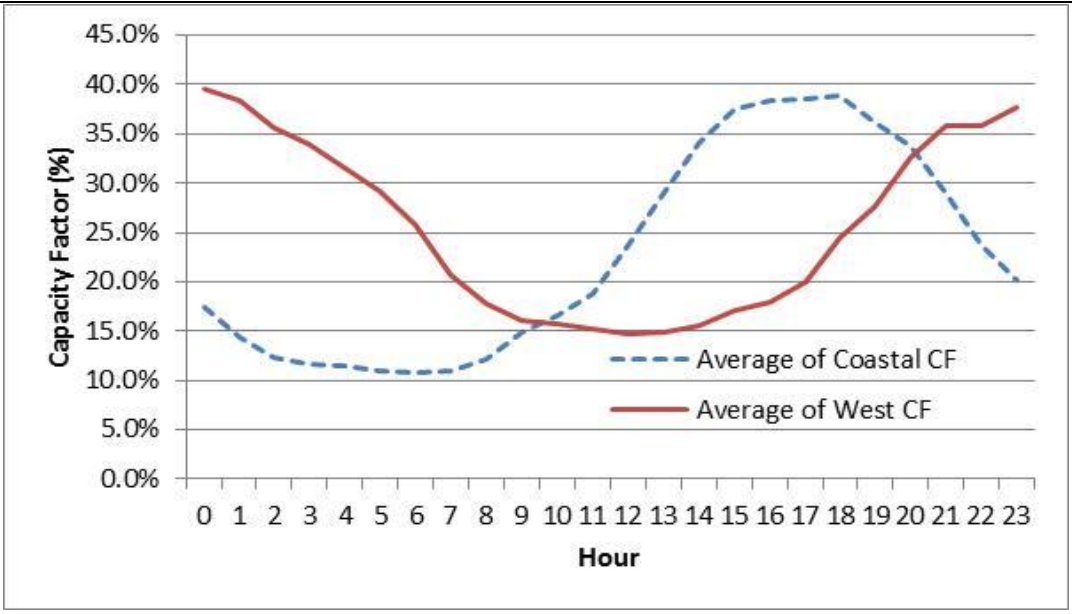

***Figure 19**. Average Hourly Capacity Factor for Wind Generation (August only)*

The capacity factors, for the late-afternoon hours (15-18) of August, are as follows:

- Coastal Region Capacity Factor (peak August hours): 38.1%
- West Region Capacity Factor (peak August hours): 18.3%

The wind capacity factor drops in the West (from 25.6% to 18.3%) when considering just the peak load hours, but rises in the Coastal region (from 22.7% to 38.1%). These results are consistent with a higher ELCC for the Coastal Region wind generation.

3 References

[1] *2010 ERCOT Target Reserve Margin Study*, November 1, 2010. Available at ERCOT website: www.ercot.com.

[2] *NERC G&T RPM Task Force Final Report on Methodology and Metrics*, December 8, 2010. (http://www.nerc.com/docs/pc/gtrpmtf/GTRPMTF_Meth_&_Metrics_Report_final_w._PC_approvals,_revisions_12.08.10.pdf).

[3] *ERCOT Investment Incentives and Resource Adequacy*, The Brattle Group, June 1, 2012. Available at ERCOT website: www.ercot.com.