

MISO LRZ Annual Energy to Summer/Winter Peak Demand Conversion Factors

Introduction

Conversion factors will be used to translate annual electricity sales forecasts at the Midcontinent Independent System Operator's (MISO) local resource zone (LRZ) level to summer and winter non-coincident peak demands. These conversion factors are based on normal weather conditions at the time of peak demand and are determined from historical relationships between average hourly load for the year, summer/winter peak levels for the year, and weather conditions at the time of the peak demand.

The process used essentially involves three steps: (1) determine the relationship between the peak demand (normalized to the average demand level for the year) and temperature¹ using historical data, (2) estimate the "normal" weather conditions at the time the peak demand occurs, and (3) determine the relationship between peak demand and average demand under normal conditions.

Data Sources and Issues

Load data consisted primarily of hourly loads at the local balancing authority (LBA) for the period of 2010-2013 that were provided by MISO. These data points represented the MISO footprint at the time the data was collected. Since the MISO footprint has evolved over time, the entire dataset does not cover the current MISO footprint. This is particularly true for the MISO South region (LRZs 8 and 9), which was added in December 2013. Where possible, the MISO load data was supplemented with hourly load data obtained from Federal Energy Regulatory Commission (FERC) filings. Since not all utilities make these filings with FERC (they are generally limited to investor-owned utilities), the dataset is incomplete. A necessary assumption is that the partial data is representative of the missing data within a particular LRZ. Due to the availability of data for LRZs 8 and 9, hourly loads for 2009-2012 were used.

For 2005-2013 (2005-2012 for LRZs 8 and 9), the hour at which the LRZ experienced its summer peak was known, but not the actual load level for 2005-2009 (2005-2008 and 2013 for LRZs 8 and 9). The times of winter peaks were only known for the years when hourly loads were available.

Hourly weather data was obtained dating back to 1997. For most weather stations, there are a handful of missing observations in the course of a year. For most LRZs, data from a second or third weather station were collected to supplement the main station. As described later, the data from these stations were used either for informational purposes or as a replacement for the primary stations under specific unusual circumstances. The primary station was selected to be as centrally located within the loads of the particular LRZ (these may or may not correspond to the weather stations used in the development of the state annual energy models that were done previously). Table 1 lists the primary and secondary weather stations.

¹ While heat index was considered as a substitute for temperature for summer peaks, it was found to be less indicative of peak demand occurrences than ambient temperature was.

Table 1. Weather Stations

LRZ	Primary	Secondary
1	St. Paul, MN	Bismarck, ND; Fergus Falls, MN
2	Milwaukee, WI	Green Bay, WI; Marquette, MI
3	Des Moines, IA	Davenport, IA
4	Springfield, IL	Carbondale, IL
5	St. Louis, MO	
6	Indianapolis, IN	Evansville, IN; South Bend, IN
7	Lansing, MI	Grand Rapids, MI
8	Little Rock, AR	
9	Alexandria, LA	Houston, TX; Jackson, MS; New Orleans, LA

Relationship between Peak Demand and Temperature

For the four years (2010-2013 for LRZs 1 through 7 and 2009-2012 for LRZs 8 and 9) during which hourly loads were available, the ten highest load hours (with the corresponding temperature) were selected for the summer and winter. The ratio of average load to hourly load for each of these ten hours was calculated². Using the forty pairs of data points (four years times ten hours/year for load factor and temperature), a linear regression was performed to determine the mathematical relationship between load and temperature during periods of high loads. These calculations were performed for both winter and summer.

A few observations regarding the relationships are worth noting. The statistical fits for the summer are generally better in the northern LRZs and for the winter in the southern LRZs. Furthermore, the factors for northern LRZs are less sensitive to winter temperatures and the factors for southern LRZs are less sensitive to summer temperatures. The summer lines all have negative slopes, indicating that the load factor decreases as temperature increases (or alternatively, demand increases with temperature). The winter lines all have positive slopes, indicating that load factor increases (and demand decreases) with increasing temperature. These results are intuitive in that summer air conditioning load increases with temperature, while winter heating load decreases with temperature.

Table 2 provides the linear relationship for each LRZ. T indicates temperature and LF represents the ratio of average hourly demand for the year to summer or winter peak demand. Figures 1 through 9 provide the scatter plots for the data pairs, along with the estimated linear relationships.

² For the absolute peak demand hour for the year, this value represents the load factor for the LRZ. For those hours with less than peak demand, the calculation is identical. While these numbers do not strictly represent the LRZ's load factor, the terminology is used here for sake of explanation.

Table 2. Load Factor vs. Temperature Relationships

LRZ	Summer	Winter
1	$LF=0.9969-0.003841T$	$LF=0.7804+0.00004095T$
2	$LF=0.8692-0.003043T$	$LF=0.7846+0.0007954T$
3	$LF=0.7989-0.002023T$	$LF=0.7815+0.0004810T$
4	$LF=0.8957-0.003335T$	$LF=0.7521+0.002048T$
5	$LF=0.9862-0.004199T$	$LF=0.6615+0.004333T$
6	$LF=0.8355-0.002040T$	$LF=0.7407+0.002103T$
7	$LF=1.0940-0.005983T$	$LF=0.7867+0.001108T$
8	$LF=0.6532-0.0007886T$	$LF=0.5924+0.005740T$
9	$LF=0.5918-0.0002066T$	$LF=0.5140+0.008117T$

Figure 1. Load Factor vs. Temperature for LRZ 1

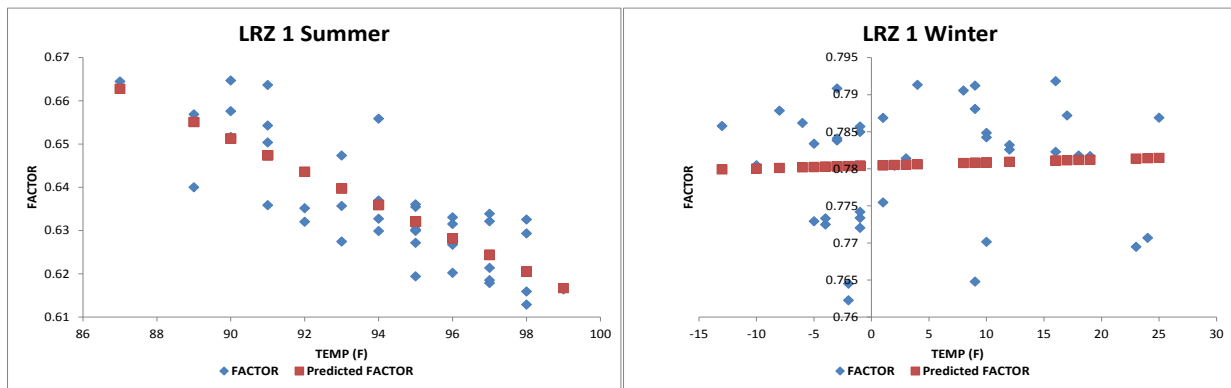


Figure 2. Load Factor vs. Temperature for LRZ 2

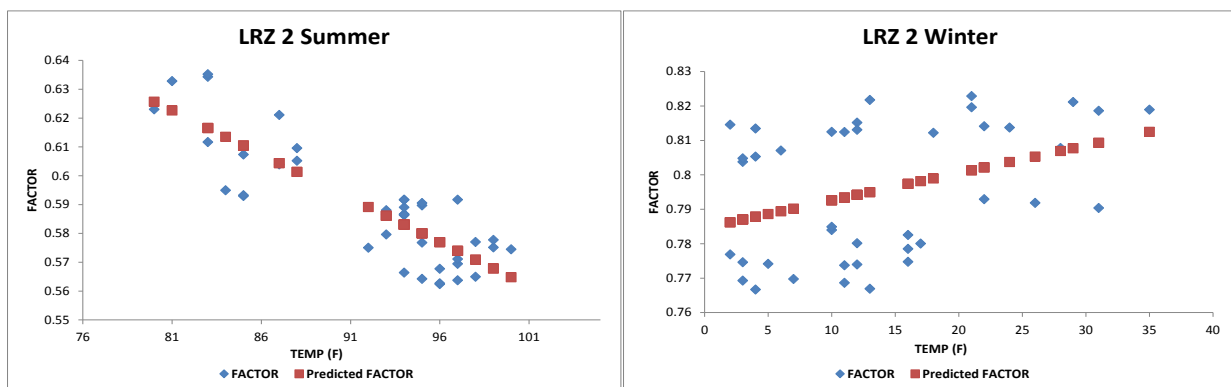


Figure 3. Load Factor vs. Temperature for LRZ 3

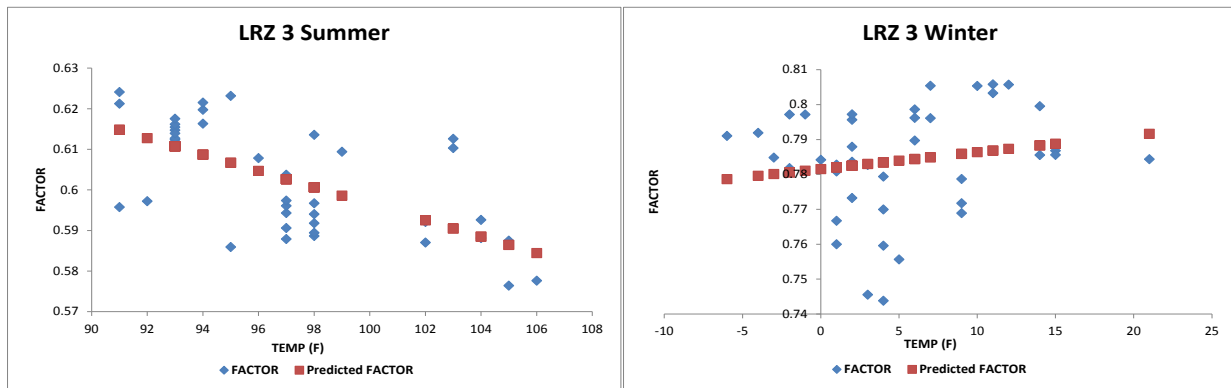


Figure 4. Load Factor vs. Temperature for LRZ 4

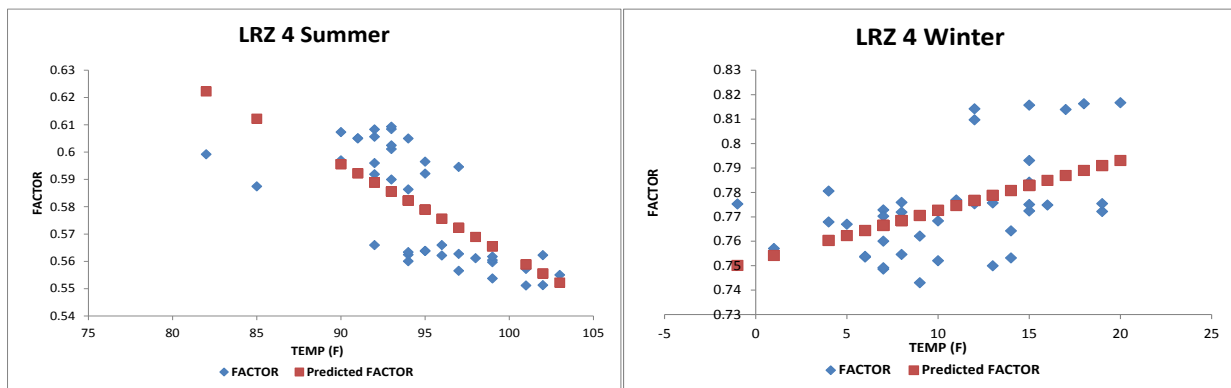


Figure 5. Load Factor vs. Temperature for LRZ 5

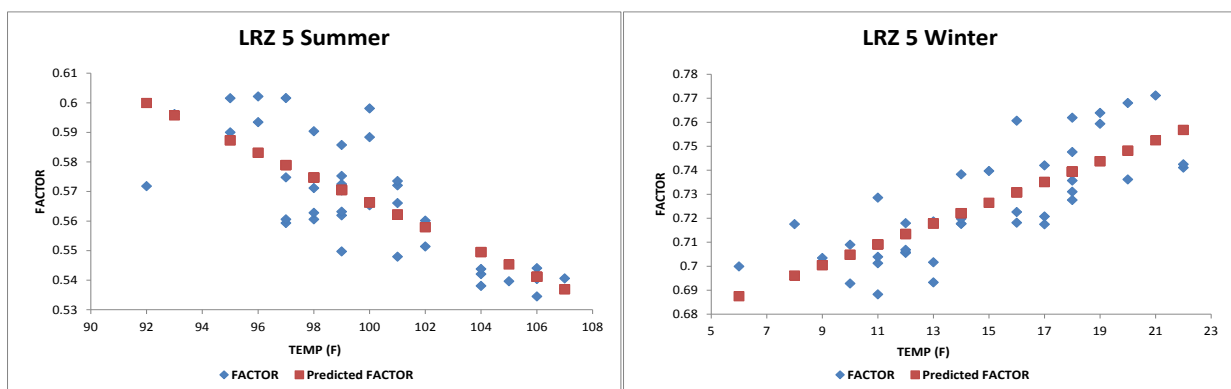


Figure 6. Load Factor vs. Temperature for LRZ 6

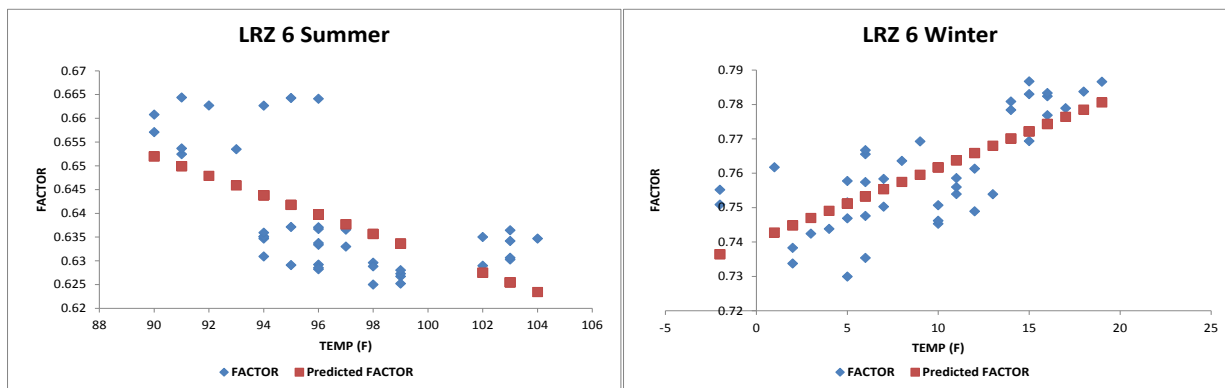


Figure 7. Load Factor vs. Temperature for LRZ 7

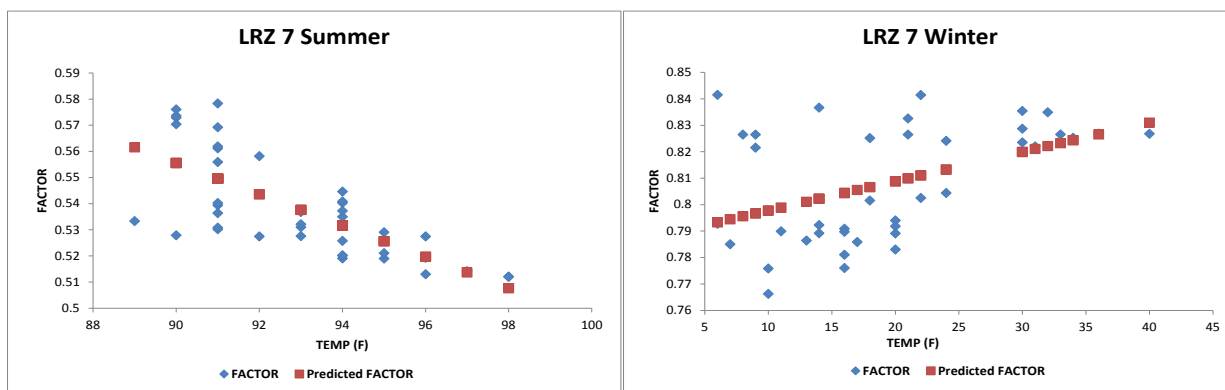


Figure 8. Load Factor vs. Temperature for LRZ 8

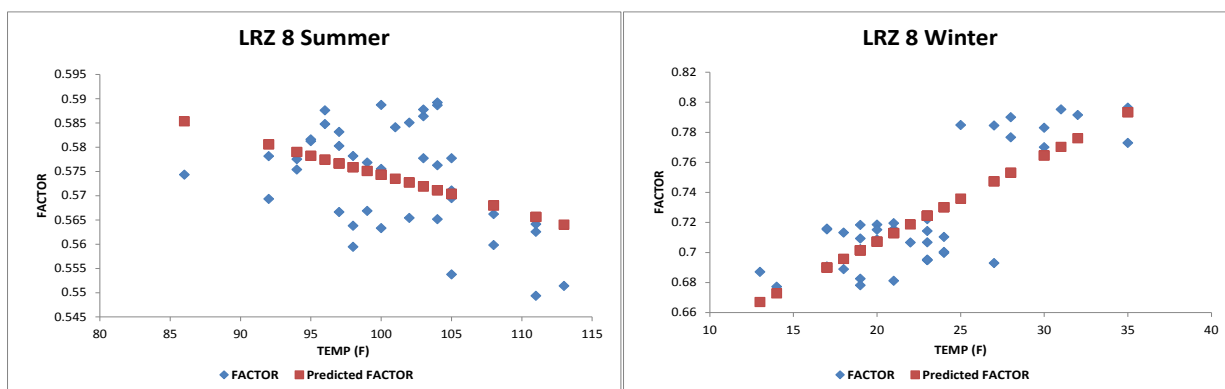
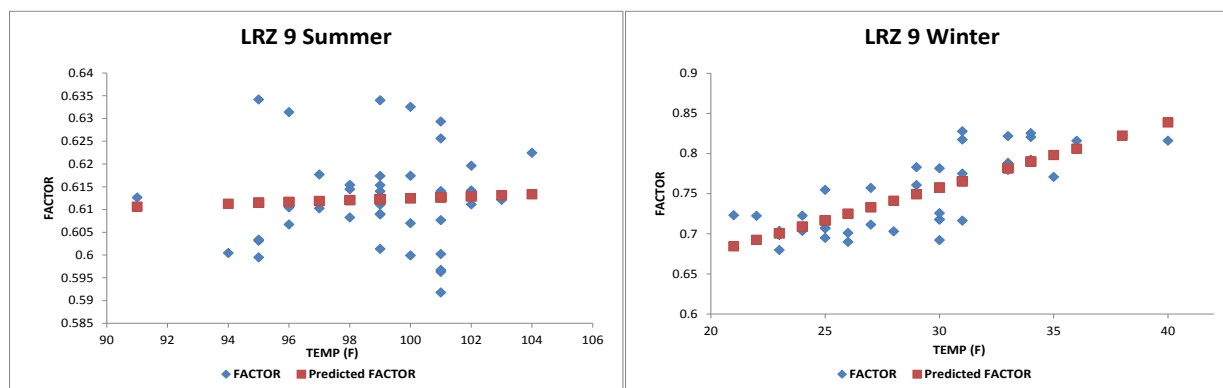


Figure 9. Load Factor vs. Temperature for LRZ 9



Estimating “Normal” Peak Demand Weather Conditions

For summer, nine years’ worth of information (eight for LRZs 8 and 9) was available regarding the hour and temperature that corresponded to actual LRZ peak demands. For winter, only four years’ worth of information was available. Due to concerns over the insufficiency of the data to accurately reflect typical peak demand weather conditions (especially for winter), weather data was incorporated going back to 1997. Since the actual hour that the peak demand occurred was not known and since peak demand does not always occur on the hottest (coldest) hour of the year for the summer (winter) peak, an estimation of what temperatures were typical was undertaken.

Extreme temperatures that occurred during times when demand does not historically peak were excluded from the analysis. These include weekends, holidays, and off-peak hours. The potential peak hours were determined using the ten highest load hours during the four years for which hourly loads were available (as described previously). While there is some variation across LRZs, peak hours generally occur in the morning and evening in the winter and the afternoon and evening in the summer. The elimination of off-peak hours was especially important for the winter analysis, since many of the coldest temperatures occurred in the middle of the night.

After eliminating off-peak times, the remaining hours were ranked according to hottest temperatures in summer (and lowest temperatures in winter). For years where the hourly loads were known, the actual temperature on peak was compared to the list of highest (lowest) temperatures. Thus, it was determined whether the summer peak occurred on the hottest hour, the second hottest hour, and so forth. A similar determination was performed for the winter peak. More often than not, the peak demand did not occur on the hour with the most extreme temperature and occasionally, the peak occurred on an hour which ranked outside of the top ten or twenty extreme hours.

Next the average of the ranked extreme temperatures was calculated for two separate time periods: 1997-2013 (which included all weather data) and 2005-2013 (the years for which the hour at which the peak demand occurred was known)³. This facilitated a comparison of the extremity of the temperatures over the smaller period to the larger period (which indicated whether the smaller period was generally warmer or colder than the larger period). The next step was to calculate the average of the actual temperatures at the time of peak for the years that these were known. Finally, this average was

³ For the winter analysis, the second period covered 2010-2013. For LRZs 8 and 9, the known periods ended at 2012.

adjusted if the 1997-2013 period was warmer or colder than the known period. Adjustment tended to be more significant in the winter since the known period was smaller and warmer (at least for extremes) than the total period. A couple examples are provided:

- In LRZ 5 (the St. Louis weather station), the average summer temperature on peak from 2005 to 2013 was 99.7 degrees. The average extreme temperature for the 1997-2013 period was 1 degree cooler. Therefore, a “normal” peak temperature of 98.7 degrees was assumed.
- In LRZ 2 (the Milwaukee weather station), the average winter temperature on peak from 2010 to 2013 was 5.5 degrees. Since the average extreme temperature for the 1997-2013 period was 0.5 degrees warmer, a “normal” peak temperature of 6.0 degrees was assumed.

A pair of outlier observations was encountered during the analysis. In LRZ 1, the temperature (MSP airport) at the time of the winter peak was 23 degrees, despite there being several significantly colder hours that year. Further analysis indicated that the temperatures at the secondary weather stations were not particularly cold (Bismarck and Fergus Falls both registered 18 degrees). Therefore, that data point was excluded from the analysis.

In LRZ 3, the temperature (Des Moines) at the hour of the 2009 summer peak was 72 degrees, but the temperature at the secondary station (Davenport) was 94 degrees and the temperature in Des Moines the hour prior to the peak was 95 degrees. Since it was apparent that a front was moving through the LRZ at the time of the peak (and since temperatures are recorded during the middle of an hour rather than on the hour), the Davenport temperature was used in the analysis as more indicative of the LRZ.

Table 3 lists the summer and winter temperatures used as normal peak temperatures for each LRZ.

Table 3. Summer and Winter Peak Normal Temperatures

LRZ	Summer	Winter
1	93.5	-4.0
2	89.1	6.0
3	93.2	5.9
4	93.9	7.6
5	98.7	11.6
6	91.6	2.6
7	91.3	15
8	99.0	20.2
9	96.8	27.1

Peak Demand Conversion Factors

The peak demand conversion factors were then determined by inserting the normal peak temperature to the mathematical relationships developed previously. The factors determined by the process

represent the ratio of annual average hourly load over summer (or winter) peak demand under normal weather. Since the desired conversion factor is actually the inverse of this ratio, these numbers were inverted to achieve the results in Table 4⁴. To find the peak demand, multiply the average hourly load for a given year of the forecast by the conversion factor. An example of that calculation follows.

Suppose the forecast annual energy for a given year in LRZ 1 is 100 million MWh. The average hourly load is found by dividing the annual energy by the number of hours in the year.

$$\frac{100,000,000 \text{ MWh}}{8,760 \text{ hr}} = 11,416 \text{ MW}$$

The summer and winter peak demands are found by multiplying the average hourly load by the appropriate conversion factor.

$$11,416 \text{ MW} * 1.568 = 17,900 \text{ MW (summer)}$$

$$11,416 \text{ MW} * 1.282 = 14,635 \text{ MW (winter)}$$

Table 4. Peak Demand Conversion Factors

LRZ	Summer	Winter
1	1.568	1.282
2	1.672	1.267
3	1.638	1.275
4	1.717	1.303
5	1.749	1.405
6	1.542	1.340
7	1.826	1.245
8	1.739	1.412
9	1.634	1.363

⁴ Please note that there may be slight variations from the numbers presented at the July workshop to correct some minor data and consistency issues.