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ANALYSIS OF WESTERN KANSAS WIND POWER CHARACTERISTICS DURING 2003 KANSAS CITY HEAT WAVES

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The Issue

Electric Utility companies serving Kansas communities have been reluctant to commit to the purchase or installation of a significant amount of wind power in the state. Though KCP&L is investing in one 100.5 MW wind farm near Spearville, they are also proceeding to build a 850 MW coal- fired power plant by 2010 near Weston, Mo., Westar has announced plans for a large coal plant by 2013. Sunflower Electric, with partners, has announced plans for three 650 MW coal-fired boilers near Holcomb, Kansas, and the Bureau of Public Utilities of Kansas City, Kansas has announced plans to build a 250 MW or larger coal plant by 2012 next to their Nearman power station.

Both KCP&L and Westar have indicated that wind power is too unreliable for their needs. That is, wind generation may not be sufficient when they need power the most such as during summer heat waves in their service areas. For example, Westar indicated this concern in their slide presentation to the Senate Utilities Committee in the Kansas legislative committee on February 1, 2005[1]. They showed a slide comparing the power generated by the Blue Canyon Wind Farm in Oklahoma during August 2, 2004 compared to their load that day. In proceedings of the Kansas Corporation Commission KCP&L has noted that only 5 to 10 % of wind power output will be accredited by the WPP, the regional transmission authority, as "dispatchable" for meeting peak demand.[2]

The wind industry responds that temporary declines in wind generation can be reasonably well predicted in advance and compensated for by other sources on the grid, such as gas-fired "spinning reserve" or by purchased power. In other states and countries where a significant amount of wind power is in operation, studies have shown that wind turbine output can be readily incorporated into the grid with careful coordination of generation assets. The Utility Wind Integration Group recently issued a summary of such studies that concluded that there are no fundamental technical barriers to wind power penetration of up to 20% of system peak demand.[3]

Also there is some indication that turbines of recent design are larger and more efficient in extracting power from wind energy potential common in western Kansas. Finally, by installing turbines in widely dispersed wind farms, a decline in power production at one location can be buffered by generation from another wind farm where the wind speeds are not diminished.

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Objective of Analysis

This study will assess these concerns by analyzing tall tower wind data that has recently become available from a wind speed monitoring program in Kansas. More specifically this study will describe the quality of wind resources in central and western Kansas during July and August of 2003 when the Kansas City metro area experienced a number of periods of very hot weather sometimes described as heat waves. In effect, this study will address the concerns of the Kansas electric utility companies *under a worst case scenario*.

Study Design

From an economic standpoint electric utilities need electric power the most during hot summer days when electricity demand, primarily from air conditioning, exceeds their "base load" capacity which are their coal and nuclear plants that run all the time except for unplanned outages for repairs. Excessive loads are called intermediate and peak loads that are generally met with natural gas-fired power generators. During periods of high natural gas prices, like the present, installing and operating intermediate and peak load power generation capacity can be 2 - 4 times more expensive than base load.[1]

Study Period. The summer of 2003 was the hottest in recent years. Kansas City Power & Light experienced all time peaks of one hour electricity demand between 3 & 4 pm on August 18 and then on August 21 of 2003.[4] Accordingly periods in July and August of 2003 were selected that encompassed extended periods of hot weather as a suitable test for utilities' concerns about availability of wind power. The criteria for these periods is three or more continuous days in Kansas City when the cooling degree days were 18 or higher, with the exception that July 5 & 19 exhibited 17 cooling degree days and were included as part of extended hot periods.

Days with 18 cooling degree days or higher had a maximum temperature of 95 degrees F, or higher 82 percent of the time during the study period. In August it was 92 percent of the time. A cooling degree day is the difference between the average daily temperature and 65 degrees F. It is used by the utility companies as a measure of their air conditioning demand potential which is the major element in summer power load. The selection criteria yielded the following four periods of interest for a total of 30 hot days:

July 3 - 9
July 14-20
July 25-27
August 16-28.

The heat profile during the study intervals is described in more detail in Tables 1 & 2 in the Appendix.

Daily Intervals. According to Westar, power demand enters the intermediate load phase about 10 am on a typical summer day and lasts until midnight. During the peak day case intermediate load may begin as early as 8 am and last until 1 am the next morning.[1] This time interval may vary from one utility company to the next depending on the mix of their types of generating capacity and the margin of excess capacity they hold. It will also vary by the cooling degree days experienced for the particular day. For this study 11 am to 11 pm was selected to represent the interval when intermediate load would reach a significant level.[5]

Loads peaked in Kansas City on two mid-August days in 2003 between 3 & 4 PM according to KCP&L. However Westar indicates that their summer day peak occurs about 5 PM. The difference may reflect the shorter days in August. So a 2 to 6 pm interval was selected to represent load at or near the peak electricity demand faced by local utilities on hot summer days.[5]

Sites Studied. Data from six Kansas sites was available. Average wind speeds for all days and hours in July and August, 2003 at 80 meters height are shown below.

Meters/sec

Site (county)	**July 03**	**Aug 03**
Kearny	9.53	8.53
Ellsworth	9.43	7.56
Logan	9.03	7.84
Ness	8.74	7.57
Jewell	8.25	7.16
Sumner	7.81	6.28

Ness County, in western Kansas, has relatively high winds but was not selected because data was missing for almost the entire Aug. 16 - 28 study interval. Sumner County, in south central Kansas, was excluded because it has significantly lower winds and would not likely be selected by a wind developer. Data for Jewell County, near the Nebraska border in central Kansas, was processed on a preliminary basis because it was thought that the site might exhibit higher air density characteristics and better turbine output during the study intervals, but this factor was not great enough to merit further examination.

This study focuses on Kearny, Ellsworth and Logan Counties both because these represent sites most likely to be selected by wind power developers and because they are also significantly spaced apart within Kansas for the purpose of assessing geographical buffering effects. The Logan County site is about 130 miles west of the Ellsworth County site and about 80 miles north of the Kearny County site. The Kearny County site is about 165 miles southwest of the Ellsworth County site.

The sites selected for the KCC's Tall Tower Wind Project do not necessarily represent the best sites in Kansas. They were, in part, selected because existing communication towers were available on which to mount instruments. They represent a limited geographical coverage. Also wind quality depends significantly on terrain characteristics.

Performance Criteria. Wind industry participants and Kansas utility industry engineers generally agree that, at good sites in Kansas, new wind farms will operate at a year around average capacity factor at or near 40%.[1,6] The economic analysis performed by purchasers or owners of wind power will generally take into account this capacity factor when comparing costs to alternative generating modes such as coal fired power plants typically assigned an 80% capacity factor. The standard used for this study is how the capacity factor experienced during the study period compares to the average of 40%.

Data Sources

Wind Data**.** Wind data was obtained on a DVD from the Kansas Corporation Commission. This data was collected under an extensive program sponsored by the Department of Energy and the Kansas Corporation Commission and performed by Joe King of Coriolos Co. of Lawrence, Kansas. The name of the project is Kansas Tall Tower Wind Resource Data 2003/2004/ 2005.

With rare exceptions wind speed increases with elevation at sites with level terrain. The object of the Tall Tower program was to measure wind speeds at elevations of 50, 80 and 110 meters above ground level which correspond with common “hub heights” of wind turbines that are currently available from turbine manufacturers or expected to be available in the near future.

Instruments were mounted on existing communication towers at six locations maintained by the Kansas Department of Transportation. See last page of the appendix for a map showing the locations. Wind speed was measured by both a primary and back-up anemometer along with wind direction.. Wind data was recorded in ten-minute intervals along with a maximum, minimum and standard deviation for the interval. This is a standard method utilized by the wind industry. Also measured was temperature and barometric pressure at or near ground level. This is important because power output at a particular wind speed is function of air density, and air density is a function of temperature and barometric pressure at the site.

Kansas City Heat Characteristics**.** The Source was *Local Climatological Data* for Kansas City Intl Airport in Kansas City, Mo., July 2003 and August 2003, published by the National Climatic Data Center of the National Oceanic and Atmospheric Administration (NOAA).

Turbine performance. The General Electric Model 1.5sl/sle, which has a maximum capacity of 1.5 megawatts (1500 kilowatts, kw), was modeled for power output. According to the American Wind Energy Association, the GE 1.5 MW unit is the most common design being installed in the Midwest and plains states at this time. General Electric Energy kindly provided on a confidential basis the calculated power curve for this model and suggested that we assume a turbine hub height of 80 meters. The curve was based on a rotor diameter of 77 meters.

Processing the Data

Wind speed. Wind speed values were produced by two instruments on the tower. At any one time one of the instruments might be in the “wind shadow” of the tower structure, or down wind where the tower structure would reduce wind velocity slightly. Mr. King recommended that the higher or “upwind” value be used which he listed separately in the data base. He cautioned, however, that while the highest value could be assumed to be the upwind value, the difference might be somewhat obscured by calibration differences in the two anemometers. The average of the values recorded by both instruments was also calculated and the differences were determined to be minimal. So only upwind values were used.

Turbine output. Assigning turbine power outputs to wind speeds required several steps. Turbine power curves are normalized to standard air density at sea level. Below the turbine's rated power, output declines with declining air density Air density at site conditions must be corrected by the equation below:[8]

site air density in kg/m^3 = 1.225 (288.15)/T)(B/1013.3)

where B is the barometric pressure in millibar and
T = 273.15^O C + site temperature

Barometric pressure is an important consideration in wind farm siting in the plains states. For example the elevation of Kearny County is 3634 feet above sea level. Site temperature is not normally a consideration because power potential is evaluated in total output over the year when average temperatures are near standard conditions of 15^O C. However, in the present study, it is an important consideration because we are evaluating turbine performance during heat waves when maximum temperatures are in the range of 35 to 41^O C.

Temperature and Barometric pressure were averaged and air density calculated for each 12 hour or 4 hour study interval. See table 3 for a summary of air density values for the study sites. The barometer at the Logan County tower was not operative during the study period so the average value from July and August of 2005 at that site, 911.9 millabar, was used instead.

The standard deviation around this average was only 3.58 so, assuming the barometric pressure during July and August of 2005 is representative of the same period in 2003, there is a 95% chance that the true average value will fall within a range from 905 to 919 millibar, for a potential error of only + or - 0.8%, which is much too small to affect the results. Barometric pressure is closely related to land elevation which doesn't change. Weather patterns in July and August also don't change much in Kansas from year to year.

GE's calculated power curve provided a table of output values for air densities down to 1.02 kg/m^3. The air density for each 12 and 4 hour daily interval was calculated. Four curves ranging from 1.02 to 1.08 kg/m^3 were plotted to encompass conditions at the sites analyzed. In most cases (72%), output values were assigned from the curves for each ten minute wind speed interval. However when ten minute wind speeds were stable over a narrow range, these were averaged as a group and assigned output values from the curves.

The GE 1.5 MW turbine "cuts out" when wind speeds fall below 3.5 meters per second for a minute or more. For shorter periods the unit has the capability to ride through the calm period. Once stopped the turbine may not start up again until winds pick up to 4 to 4.5 m/s.[7] Likewise, this turbine cuts out when wind speeds exceed 20 m/s average for 10 minutes. One meter per second (m/s) equals 2.24 miles per hour (mph).

When a ten minute interval showed a minimum speed of 3 meter/seconds or less, particularly for consecutive intervals, the range and standard deviation were analyzed to determine if the turbine would likely cut out. Dr. Kyle Wetzel, a turbine designer and consultant in Lawrence, Kansas kindly assisted in making these determinations. If the turbine was likely to cut out, then that 10 minute interval was set to zero before calculating the average. Likewise this was done in *over speed* situations. In only sixteen ten-minute intervals over all study intervals and sites was the average wind speed over 20 m/s for 10 minutes, indicating a cut out.

Wind Speed Elevation. Table 4 compares average wind speeds at an 80 meter hub height with 110 meters for all three sites and the two time intervals. During the hottest part of the day there's only a small gain in wind speed at 110 meters hub height. The difference becomes more important for the 11 am to 11 pm interval. At the average speeds shown about 11% more power would be generated across all the sites, which would be a significant contribution to the grid for the intermediate load phase. In view of GE's recommendation to focus on the 80 meter height and the large amount of time involved, a full analysis for wind speeds at 110 meter height was not attempted.

Results

Overall Average Turbine output. The overall average during the study period is summarized below:

Summary of Turbine Output during the Study Period (Average kw)

Site interval	Kearny Co	Logan Co	Ellsworth Co.	Average of 2 west Ks	Average of all 3	Best of three
11 am -11pm	993	939	882	966	938	1111
2 pm - 6 pm	916	936	802	926	885	1100

Summary of Turbine Output during the Study Period (% of 1500 kw capacity)

Site interval	Kearny Co	Logan Co	Ellsworth Co.	Average of 2 west Ks	Average of all 3	Best of three
11 am - 11pm	66.2	62.6	58.8	64.4	62.5	74.1
2 pm - 6 pm	61.1	62.4	53.4	61.7	59.0	73.3

The typical annual capacity factor for good sites in Kansas is 40%. Thus these results indicate that during the 2003 heat waves in Kansas City the wind, on average, blew quite strongly in central and western Kansas. Wind farms, had they been in existence at the sites studied, would have produced power at well above the annual average and would have contributed quite strongly to meeting intermediate and peak loads, thereby displacing the need for expensive natural gas-fueled capacity, or purchased power.

Range of of Turbine Outputs. Results of the analysis for each day in the study period are shown in Table 5 for the 11 am - 11 pm intermediate load interval and in Table 6 for the 2 to 6 pm peak load interval. Data from those tables is summarized below in terms of frequency of days in which the capacity factor fell within the range shown.

Frequency of Turbine Capacity Factors for 11am - 11 pm interval (Number of days)

% of capacity	Kearny Co.	Logan Co.	Ellsworth Co	Avg. of west ks	Avg of alll 3	Best of 3
>80	10	12	10	11	10	15
70-80	6	2	3	3	2	5
60-70	2	4	2	4	5	2
50-60	4	1	3	4	3	2
40-50	2	3	2	1	2	2
30-40	4	2	2	3	5	3
20-30	0	4	6	2	2	1
<20	2	2	2	1	1	0
Total	30	30	30	30	30	30

Frequency of Turbine Capacity Factors for 2 pm to 6 pm interval (Number of days)

% of capacity	Kearny Co.	Logan Co.	Ellsworth Co	Avg of west Ks.	Avg of all 3	Best of 3
>80	13	12	10	10	10	16
70-80	3	3	1	3	1	4
60-70	1	3	3	3	4	2
50-60	2	1	3	5	4	1
40-50	1	2	0	1	2	1
30-40	4	3	2	2	2	3
20-30	1	2	4	1	3	2
<20	5	4	7	5	4	1
Total	30	30	30	30	30	30

During the 11 am to 11 pm intermediate load interval, turbines would have generated above average power output 80, 73 and 67 percent of the time at the Kearny, Logan and Ellsworth County sites respectively. During only 2 days out of 30 was the capacity factor less than 20% at the three sites. During the peak load interval, turbines would have generated above average output on 67, 70 and 57% of the time at the Kearny, Logan and Ellsworth County sites respectively, but there were a few more days of low output.

Site buffering. Buffering effects were significant. A utility company who wants to own or control several wind farms would probably look at the combination of outputs from the study sites as indicative of reliability. Under this scenario on only 1 of 30 days would turbines have produced at less than 20 % of capacity for intermediate loads and 4 in 30 days for peak loads. These values are generally lower than for any one site indicating an increase in reliability as a whole. Under the peak load scenario above average output would have occurred on 70% of hot days.

A wind power user who wants to buy from the grid might also look at the “best” of the three site outputs as indicative of buffering effects that might be available since the grid could interconnect many more wind farms spaced further apart. In this case, during the intermediate load interval, at least one site was producing at greater than average output 87% of the time and never below 20%. During the peak load interval the corresponding value was 80% and only on one day was the capacity factor less than 20%.

***Peak Days*.** KCP&L experienced all time peak loads, successively, on Aug.18, 2003 and then Aug. 21, 2003. On August 18 turbine output during the intermediate load interval averaged 57% of capacity at the three sites and over 70% at two of the three sites. It was about the same for the peak load interval. On August 21 intermediate load output was just below average at 38% of capacity for the three sites together and output during the peak load interval was 29%. The two west Kansas sites would have operated at 45 and 33% respectively. Best-of- three values were 48 and 45% respectively.

***Meteorological and diurnal patterns*.** Table 7 compares average wind speed during the 11 am - 11 pm study interval in July and August of 2003 with the corresponding 24 hour average wind speed on those hot days and with the average for all days in each of those two months. Both the 11 am - 11 pm interval average and the 24 hour average for the hot days exceeded the monthly averages for all sites, in most cases quite substantially.

Discussion

Wind turbines in central and western Kansas appear to be particularly suited to providing fairly reliable support for intermediate loads. The reason is that wind speeds pick up strongly in mid-afternoon on most days and blow strongly well into the evening. The worst day in this study period was July 20 when the combined sites would have delivered at 16% of capacity. On only 3 days would average output have been below 30% of capacity. On the few days of low output utilities could use their natural gas fired capacity or purchase power off the grid as they normally do.

The total amount of natural gas fuel that would be displaced by wind power during the intermediate load phase would far exceed that displaced during a peak phase. On some hot days the need for gas-fired peaking turbines is not reached. However, when it is, the price per kilowatt of peaking power on the open market would likely be higher than if such power were purchased to serve intermediate load.

Wind turbines at the two western Kansas sites would have made a significant contribution to the grid on KCP&L's all time peak load day on August 21, 2003. During the August 18 peak, wind turbines at Ellsworth in central Kansas and at Kearny County in western Kansas would have operated at well above average output. In no case during the study period were all three sites off line at the same time.

As shown on Table 7, 24 hour average wind speeds on hot days were significantly above the monthly averages for July and August. This suggests that the meteorological patterns that bring heat waves to the KC region also stimulate the winds in western Kansas. If further research confirms that this is more generally true for our region, then this could be an important result. That is, there may be a natural factor that causes wind turbines to compensate for intermediate and peak loads. A future study might assess this possibility by comparing wind speeds and meteorological patterns in July and August of 2004, one of the coolest summers in many years, with July and August of 2003, one of the hottest. In most cases, the winds during the 11 am to 11 pm study interval was even stronger than the 24 hour average for hot days and much stronger than the monthly average for all days..

Conclusions

This study assessed the contribution that 1.5 MW wind turbines in central and western Kansas would have made to the grid during the Kansas City heat waves of July and August, 2003. This can be considered a worst case scenario for assessing utility companies' concerns about the output performance of wind turbines in Kansas.

As a whole turbine output at all three sites would have been well above average during the 30 hot days in July and August of 2003. On a substantial majority of hot days the wind was blowing very strongly in Western Kansas, and power output at these sites would have made an important contribution toward satisfying high load levels in the Kansas City service area. This was only modestly less so at the central Kansas site. Wind power appears to be particularly suited for matching intermediate loads from 11 am to 11 pm.

There was a significant compensating effect among the three sites studied which are fairly well dispersed within Kansas. On only one day out of 30 hot days was the combined turbine output of the three sites below 20 percent of capacity during the intermediate load interval. On only four days was combined output less than 20% of capacity during the peak load interval. On no day were all three sites essentially off line at the same time.

Wind turbines would have made a very strong contribution to the grid on one of KCP&L's two all time peak load days in August, 2003. On the other, output would have been slightly below average during the intermediate load interval and moderately below average during the peak load interval.

Wind speeds in central and western Kansas were significantly greater than average on hot days suggesting that the meteorological patterns that bring heat waves to Kansas City also stimulate the winds that would drive turbines in western Kansas. However further research is necessary to confirm this finding.

Had wind farms been in place at the study sites in the hot summer of 2003, they could have displaced a large amount of natural gas or purchased power that was used to satisfy intermediate and peak loads.

References

1. John Olsen, Westar, "Long Term Power Supply," presented to the Kansas Legislature Utilities Committee, Feb. 1, 2005. See wind power capacity factor, page 11. The capacity factor is the actual power output of a wind farm as a percentage of the power output possible if the wind farm operated at maximum rated capacity all the time.
2. KCP&L, Response to Comments Received at Public Hearing, Docket No: 04-KCPE-1025-GIE, July, 2005.
3. Utility Wind Integration Group, www.uwig.org/IntegrationStateoftheArt.htm
4. KCP&L press release, August 22, 2003.
5. The data set for 11 am - 11 pm intermediate interval consists of 72 ea 10 minute average wind velocity measurements time stamped from 11:10 to 23:00. The data set for the 2 pm to 6 pm

peak load interval is 24 ea 10 minute avg. measurements time stamped from 14:10 to 18:00.
6. John Grimwade, Direct Testimony on behalf of KCP&L under Docket No: 04-KCPE-1025-GIE, May 10, 2005. See base case: 38% capacity factor. In later testimony under KCC Docket 06-KCPE-838-RTS, Jan.30, 2006, Mr. Grimwade stated that the capacity factor at the Spearville, Ks. site selected for their 100.5 MW wind farm would have a higher capacity than originally estimated though this figure was withheld as confidential.
7. Personal Communication. April 21, 2006 with Kyle Wetzel, Phd, Wetzel Engineering, Lawrence, Kansas.
8. T. Burton, D. Sharpe, E. Bussanyi, "Wind Turbine Performance," Wind Energy Handbook, Wiley & Sons, Ltd, page 195.

Appendix

Table 1 Kansas City Heat Profile, July of 2003

day	3	4	5	6	7	8	9	14	15	16	17	18	19	20	25	26	27
max ^{o}F	95	94	93	91	94	94	94	99	96	98	99	99	92	99	96	102	98
cooling degrees days	18	20	17	18	20	21	18	20	19	19	23	23	17	21	19	23	22

Table 2 Kansas City Heat Profile, August of 2003

day	16	17	18	19	20	21	22	23	24	25	26	27	28
max ^{o}F	101	104	105	104	103	106	98	96	100	104	103	95	94
cooling degree days	22	24	25	23	23	28	21	19	18	24	24	20	18

Table 3. Calculation of air density at Kansas tower sites, July & Aug. '03 study periods

Site	Average Temperature Degrees C	Average Temperature Degrees F	Tower elevation at ground level	Barametric Pressure millibars	Average Air Density Kg/m^3
Kearny Co.					
11 am - 11 pm	33.7	92.7	951 meters	909.5	1.032
2 pm- 6 pm	37.6	99.7		909.2	1.019
Logan Co					
11 am - 11 pm	34.7	94.5	918 meters	911.9	1.032
2 pm- 6 pm	38.0	100.4		911.9	1.021
Ellsworth County					
11am - 11 pm	35.2	95.4	550 meters	950.2	1.074
2 pm- 6 pm	38.2	100.8		949.6	1.063

Table 4. Avg Wind Speed (m/s) at 80 & 110 meters hub height

Site (Co.)	11 am - 11 pm		2 pm - 6 pm		July, 2003		August, 2003	
	80 M	110 M	80 M	110 M	80 M	110 M	80 M	110 M
Kearny	10.35	10.87	9.46	9.68	9.53	10.23	8.53	9.18
Logan	9.96	10.41	9.94	10.12	9.03	9.62	7.84	8.42
Ellsworth	9.37	9.84	8.92	9.11	9.43	10.06	7.56	8.12

Table 5. Turbine Performance Summary:
11 am to 11 pm interval. Percent of rated capacity.

Day	Kearny Co.	Logan Co.	Ellsworth Co	Avg of west Ks	Avg of all 3	Best of all 3
July 3	85.2	56.5	69.4	70.9	70.4	85.2
4	98.7	95.3	93.2	97.0	95.8	98.7
5	78.6	82.0	89.1	80.3	83.2	89.1
6	96.4	76.4	97.0	86.4	89.9	97.0
7	99.5	85.4	92.1	92.4	92.3	99.5
8	94.0	82.1	95.0	88.0	90.4	95.0
9	71.7	68.0	57.6	69.8	65.8	71.7
July 14	42.5	67.5	44.0	55.0	51.4	67.5
15	55.1	82.0	65.5	68.5	67.5	82.0
16	96.9	86.3	90.6	91.6	91.2	96.9
17	92.1	91.0	91.1	91.5	91.4	92.1
18	51.4	27.4	22.0	39.4	33.6	51.4
19	14.9	37.1	19.8	26.0	23.9	37.1
20	9.7	23.3	16.2	16.5	16.4	23.3
July 25	91.7	88.5	97.8	90.1	92.6	97.8

26	67.7	83.8	70.5	75.7	74.0	83.8
27	31.2	47.5	31.7	39.3	36.8	47.5
August 16	97.1	97.2	59.4	97.1	84.6	97.2
17	96.9	96.8	83.7	96.9	92.5	96.9
18*	75.5	25.1	71.5	50.3	57.4	75.5
19	78.1	38.7	84.6	58.4	67.1	84.6
20	31.8	4.2	73.3	18.0	36.4	73.3
21*	41.5	47.5	23.9	44.5	37.6	47.5
22	53.2	69.3	20.6	61.2	47.7	69.3
23	74.9	87.9	26.5	81.4	63.1	87.9
24	64.2	78.5	25.7	71.4	56.1	78.5
25	52.9	49.7	44.4	51.3	49.0	52.9
26	30.1	15.9	22.6	23.0	22.9	30.1
27	75.5	61.2	54.6	68.4	63.8	75.5
28	36.5	26.5	30.1	31.5	31.0	36.5

* all time KCP&L peak load days

Table 6 . Turbine Performance Summary:
2 pm to 6 pm interval. Percent of rated capacity.

Day	Kearny Co.	Logan Co.	Ellsworth Co.	Avg of West Ks	Avg of all 3	Best of 3
July 3	96.5	60.1	77.4	78.2	78.0	96.5
4	99.7	99.3	90.9	99.5	96.6	99.7
5	91.6	98.6	90.0	95.1	93.4	98.6
6	96.8	98.5	98.8	97.7	98.0	98.8
7	99.6	95.1	93.5	97.4	96.1	99.6
8	92.8	90.5	98.5	91.7	94.0	98.5

9	65.5	69.5	63.1	67.5	66.0	69.5
July 14	32.3	78.3	19.3	55.3	43.3	78.3
15	52.2	83.3	56.9	67.7	64.1	83.3
16	98.0	96.3	88.9	97.2	94.4	98.0
17	87.0	93.4	95.7	90.2	92.0	95.7
18	33.2	3.8	0	18.5	12.3	33.2
19	2.3	32.1	13.8	17.2	16.1	32.1
20	0.7	13.8	0.5	7.2	5.0	13.8
July 25	86.7	89.1	98.1	87.9	91.3	98.1
26	41.7	74.0	55.8	57.9	57.2	74.0
27	18.1	29.3	29.5	23.7	25.6	29.5
August 16	97.1	99.3	62.9	98.2	86.5	99.3
17	94.5	98.9	84.8	96.7	92.7	98.9
18*	82.3	24.9	62.7	53.6	56.6	82.3
19	77.2	30.3	82.7	53.7	63.4	82.7
20	7.9	0.4	59.2	4.1	22.5	59.2
21*	21.7	44.7	19.5	33.2	28.7	44.7
22	34.7	63.1	3.9	48.9	33.9	63.1
23	70.7	86.1	28.9	78.4	61.9	86.1
24	50.7	71.7	5.9	61.2	42.8	71.7
25	31.4	35.0	33.9	33.2	33.4	35.0
26	12.3	11.3	21.9	11.8	15.2	21.9
27	82.1	58.5	29.0	70.3	56.5	82.1
28	75.3	43.1	37.2	59.2	51.9	75.3

* all time KCP&L peak load days

Table 7. 80 meter wind speeds, m/s: intermediate load interval vs hot days vs average for the month

Site (Co)	11 a - 11 p on hot days		24 hr avg. on hot days		All days	
	July	August	July	August	July	August
Kearny	10.74	9.85	10.60	9.48	9.53	8.53
Logan	10.74	8.95	10.03	8.41	9.03	7.84
Ellsworth	10.10	8.41	10.44	8.57	9.43	7.56

Location of Instrumented Towers