Meteorol. Appl. 12, 319–328 (2005) doi:10.1017/S1350482705001891

Using dew points to estimate savings during a planned cooling shutdown

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In an effort to save money during the summer of 2003, Northern Illinois University (NIU) administrators instituted a four-day working week and stopped air conditioning buildings for the three-day weekends (Friday through Sunday). Shutting down the air conditioning systems caused a noticeable drop in electricity usage for that part of the campus that features in our study, with estimated total electricity savings of 1,268,492 kilowatt-hours or 17% of the average usage during that eight-week period. NIU's air conditioning systems, which relied on evaporative cooling to function, were sensitive to dew point levels. Greatest savings during the shutdown period occurred on days with higher dew points. An examination of the regional dew point climatology (1959–2003) indicated that the average summer daily dew point for 2003 was 14.9°C (58.8°F), which fell in the lowest 20% of the distribution. Based on the relationship between daily average dew points and electrical usage, a predictive model that could estimate electrical daily savings was created. This model suggests that electrical savings related to any future three-day shutdowns over summer could be much greater in more humid summers. Studies like this demonstrate the potential value of applying climatological information and of integrating this information into practical decision-making.

1. Introduction

As the result of severe state budget cuts in Illinois during 2003, public universities across the state were forced to find ways to dramatically cut spending. At Northern Illinois University (NIU) in DeKalb, administrators developed and implemented a plan to lengthen the working day and shorten the working week, creating a three-day weekend during the summer school semester from mid-June to mid-August. During the extended weekend, air conditioning systems on campus were completely shut down in unoccupied buildings. Prior to implementing this plan, the administration could not predict the dollar amount that would be conserved but hoped the savings would be significant. It was known though that NIU spent on average $10 million dollars per year on heating and cooling facilities (Changnon et al. 2000). It has been shown in the past that by assessing the vital role of climate, better decisions can be made in near real-time or months in advance in the area of utilities (Changnon et al. 1999).

The extent of savings from shutting down the air conditioning systems was dependent on several factors, including the dew point level. The majority of campus air conditioning systems used an evaporative cooling system to cool air in buildings. Since the process of evaporation was very important in these large systems, dew point had a much greater impact on the operation and efficiency of the air conditioning units (Kreutzmann 2002). As dew points increased, the efficiency of the system decreased due to the decreased ability to evaporate water (Sparks et al. 2002). When the average daily dew point exceeded 18°C (65°F) the equipment experienced a notable decrease in efficiency and increase in electrical usage.

Recent summer heat waves in northern Illinois (July 1995 and July 1999) have been associated with higher dew point levels (Kunkel et al. 1996; Palecki et al. 2001; Sparks et al. 2002; Changnon et al. 2003). These higher levels of atmospheric water vapour have impacted not only on air conditioning systems, but also created big demands for electricity and caused health-related problems. When NIU administrators considered budgeting for future summer-related cooling expenditures, they needed to understand the impacts of various dew point levels on savings.

The goal of this study was to examine this relationship between electrical usage from air conditioning on campus and the dew point in order to estimate the level of electricity savings NIU might expect during the summer period. From the daily operational standpoint, a decision tool based on the relationship between daily average dew point value and daily electricity usage could be used to estimate accumulated summer electricity savings related to air conditioning. With such tools, administrators would be better equipped to make sound decisions related to the operation of the systems and the budgets required to support them.

2. Data and analytical methods

2.1. Dew point climatology for northern Illinois

Daily averaged dew point data for Rockford, IL from 1959 to 2003 was obtained from the Midwest Regional Climate Center (MRCC). Rockford is located 70 km northwest of DeKalb and was chosen because it is the closest weather observing station with an historical record of hourly dew point observations. Various instruments were used over time and prior studies determined that data collected through these instruments were found to be homogeneous and therefore suitable for use as a single data set for this study (Sparks et al. 2002).

Temporal characteristics were determined using daily average dew point time series and cumulative frequency plots or ogives. These allowed for the analysis of range and variability of dew points in northern Illinois. For each year, a summer average dew point was determined by averaging the daily mean dew point for the days between 1 June and 31 August.

2.2. Daily comparisons of dew point and electricity usage

Daily electricity data obtained from the NIU Heating Plant were used to assess the impact dew point has on the cooling system. This project isolated two substations on the NIU electric network which accounted for approximately 40% of total electricity used on campus. The Carroll and Lucinda Avenue substations were selected primarily because nearly all of the buildings supplied by these substations were shut down for the extended three-day weekends during the summer of 2003.

Daily electricity usage data from these substation branches were available only for the summer months (1 June–31 August) of 2001, 2002 and 2003. The period 1–15 June in 2003 was not analysed or used in the daily analysis part of this study for two reasons: (1) electricity data for the period 13–15 June was not available and would cause a gap in the analysis, and (2) the transition to weekend shutdowns during early June required substantial reprogramming of the air conditioning system. By 15 June 2003, the heating plant manager indicated that most of the air condition system changes associated with the three-day shutdown had been completed. The shutdown period lasted eight weeks to the end of the summer school semester on 10 August 2003.

Regression analyses were used to assess the relationship between daily average dew point and electricity usage for each summer, both uniquely and together, with days of the week noted. The weekdays versus weekend days were critical in this study considering when the shutdown occurred on the NIU campus. Potential savings (in kilowatt-hours) were calculated on the weekend days, or NIU shutdown times during the 2003 summer. These were based on comparison of the 2001 and 2002 weekday data for Fridays and weekend day data for Saturdays and Sundays.

3. Results

3.1. Dew point climatology for northern Illinois

The findings of this study are illustrated best with dew point climatology. A time series of summer-averaged daily dew point values (Figure 1) shows an increase from approximately 15°C to 16°C (59°F to 61°F) during the 45-year period. These findings were similar to those described by Robinson (2000), who examined seasonal dew point trends across the United States, and Sparks et al. (2002), who examined the frequency of hours with dew points >24°C (75°F) in northeast Illinois. Average summer daily dew point values for the 45-year period ranged from approximately 13°C to 18.7°C (Figure 2). The 2003 value of 14.9°C (58.8°F) fell in the bottom 20th percentile of the data, which indicated that summer 2003 was 'dry' in terms of atmospheric moisture. Daily averaged dew points experienced during the 45 summers (4140 daily values) ranged from –3°C to 26°C (27°F to 79°F).

3.2. Relationship of dew point to electricity usage

The relationships between daily electricity data and daily average dew point were determined for the summers of 2001, 2002 and 2003. For each summer, the daily electricity usage values for the Carroll and Lucinda Avenue substations were represented in a time series individually and then combined. Mondays were used as the major labels on the x-axis to better illustrate the beginning of the work week in each summer.

Figure 3 shows the summer 2001 daily electricity data from each substation as well as the daily average dew points. One can note minor fluctuations through each seven-day week, with less energy used during the class-free weekends. These declines in electricity usage were related to the absence of students, staff and faculty on these days, and thus fewer essentials (computers, lights, etc.) being used. However, unlike 2003, the cooling systems remained operational during the 2001 and 2002 weekends.

A comparison of electricity values, when the two substations were combined, with the daily dew point values appeared to be well related during summer 2001

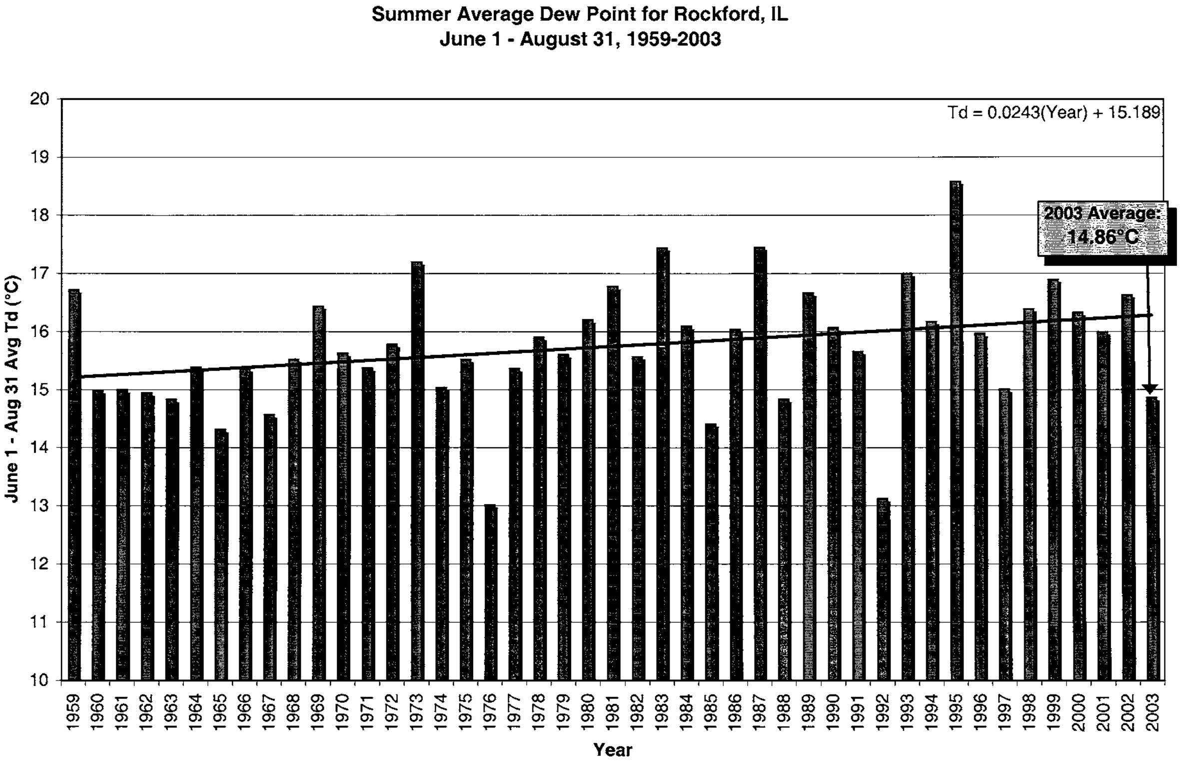

Figure 1. *Summer average daily dew points for Rockford, Illinois, 1 June–31 August, 1959–2003.*

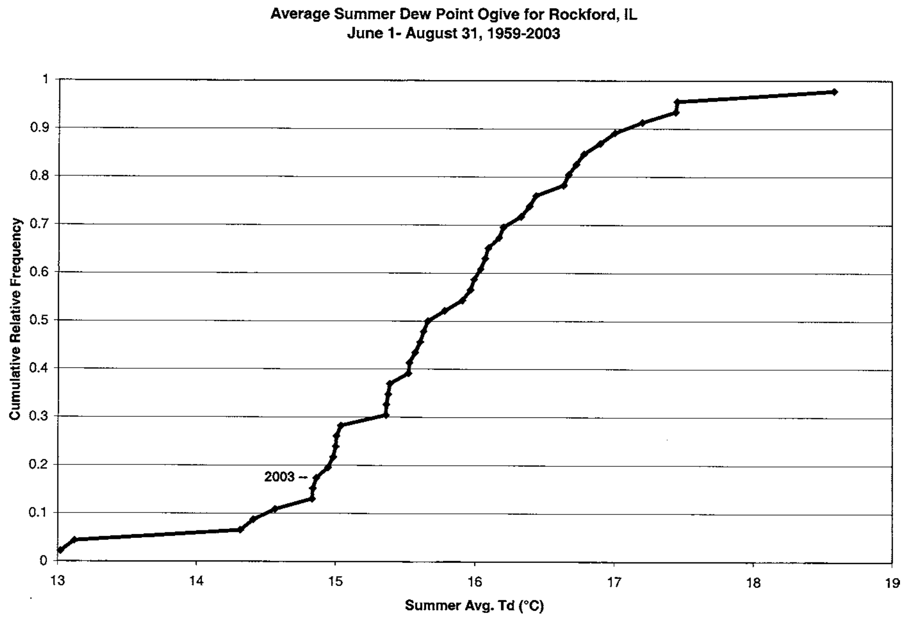

Figure 2. *Ogive of the average summer daily dew point for Rockford, Illinois, based on data for the period 1959–2003.*

(Figure 4). This relationship was highlighted by the regression analysis between daily average dew point and daily electricity usage in Figure 5. An R-value of +0.76 suggested a directly proportional relationship with nearly 58% of the electricity usage variance explained by dew points.

Data from 2002 revealed a similar relationship, though not as strong. The time series in Figure 6 depicts the problem of workload transfer between substations on 17 July 2002. Through the first half of that summer, one station was used to carry a greater electrical load. On 17 July 2002, the stations were altered to handle equal shares of needed electricity. Therefore, the individual outputs from each of the substations through the summer were not uniform. When the values from the two substations were combined a decrease in daily electricity values became evident after 16 July 2002 (Figure 7). Due to this shift, administrators of the heating plant suggested that only the relationship

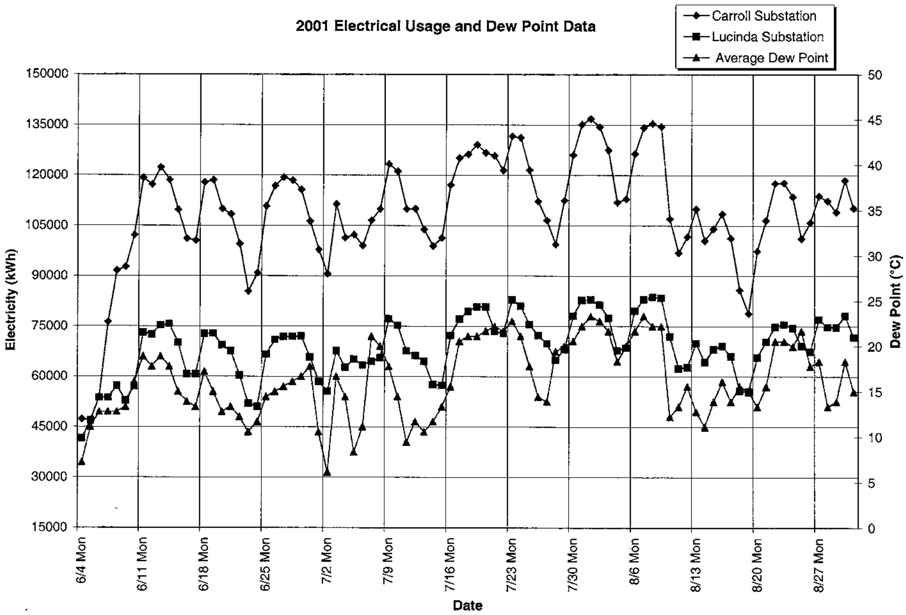

Figure 3. *Electricity usage data for two separate substations plotted (in kilowatt-hours) along with the daily average dew point during summer 2001. The vertical lines indicate Mondays.*

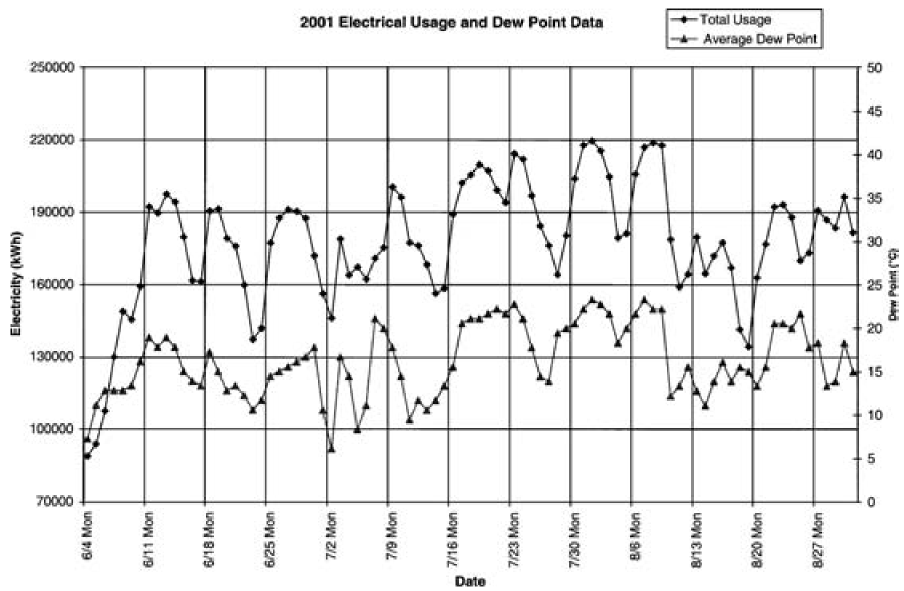

Figure 4. *As for Figure 3, but with electricity usage data for the two substations combined.*

between dew point and electricity usage for the period from 13 June to 16 July should be considered, which they viewed as providing reliable and consistent data (Kevin Howard, personal communication, 10 September 2003). The R-value for this period was +0.77 (Figure 8).

The plot of combined electricity usage data relative to the average daily dew point during the summer of 2003 (Figure 9) identified the transition period to four-day workweeks, the eight-week period (16 June–10 August) when three-day air conditioning shutdowns occurred on weekends, and the period when normal operations resumed. Falls in usage were evident from weekdays to weekend days, both when comparing days in this eight-week period to previous years or to the normal operation period in 2003. This difference during this eight-week period was approximately double the difference that occurred between weekdays and weekend days during the previous two summers (see Table 1).

The relationship between daily average dew point and daily electricity usage of the two substations for summer 2003 (1 June–31 August) is depicted in the scatter plot in Figure 10. Note the lower R-value (+0.56) compared to the correlations of the prior two summers. This result was expected given that the weekend dew point would no longer have an effect on the chilling system because it was shut down across much of the campus area.

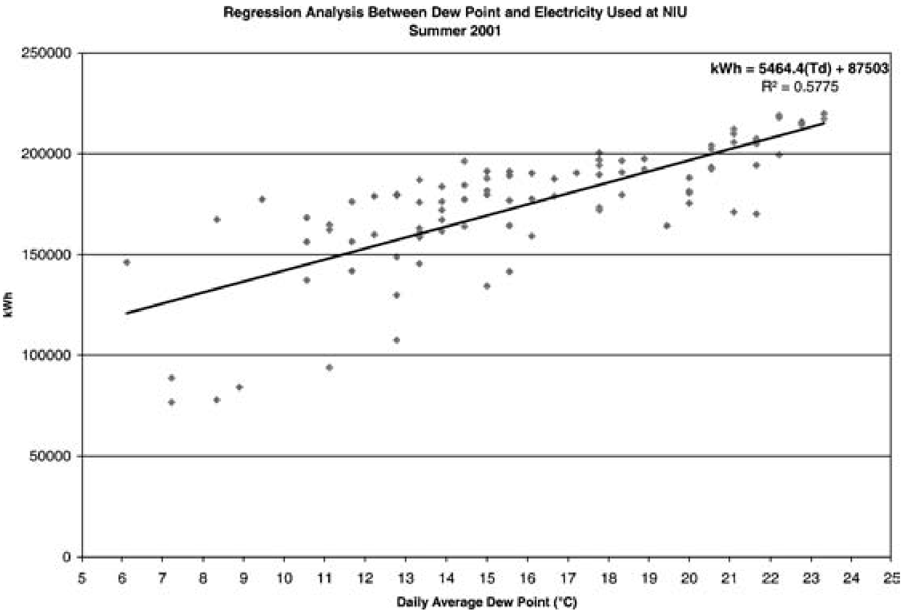

Figure 5. *The relationship of daily electricity usage data to daily average dew point values during summer 2001. Black line represents least squares 'best fit' line.*

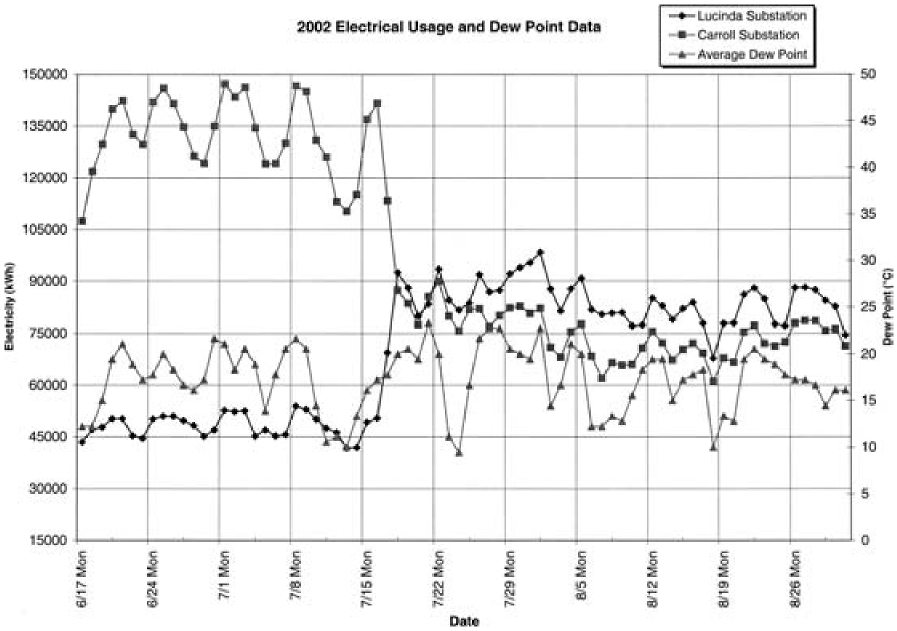

Figure 6. *Electricity usage data for two separate substations plotted (in kilowatt-hours) along with the daily average dew point in summer 2002. The vertical lines indicate Mondays.*

Table 1. *Weekday and weekend day electrical usage differences at NIU.*

Year (summer portion)	Difference between average weekday and weekend day electricity usage at NIU
2001 (1 Jun–31 Aug)	24,225 kWh
2002 (13 Jun–16 Jul)	18,541 kWh
2003 (16 Jun–10 Aug)	40,890 kWh[a]

Note: [a] In 2003, weekdays include Monday through Thursday, while weekends include Friday through Sunday.

To assess the efficiency of the 2003 shutdown, savings by days of the week were evaluated. An average base load was determined for weekdays and weekend days from the summers of 2001 and 2002, both of which had daily electricity data. By using daily average dew point as the independent variable, expected electricity usage of the combined Lucinda and Carroll substations was ascertained for the 2003 summer.

For weekends (Saturdays and Sundays), a regression analysis was completed for daily average dew point

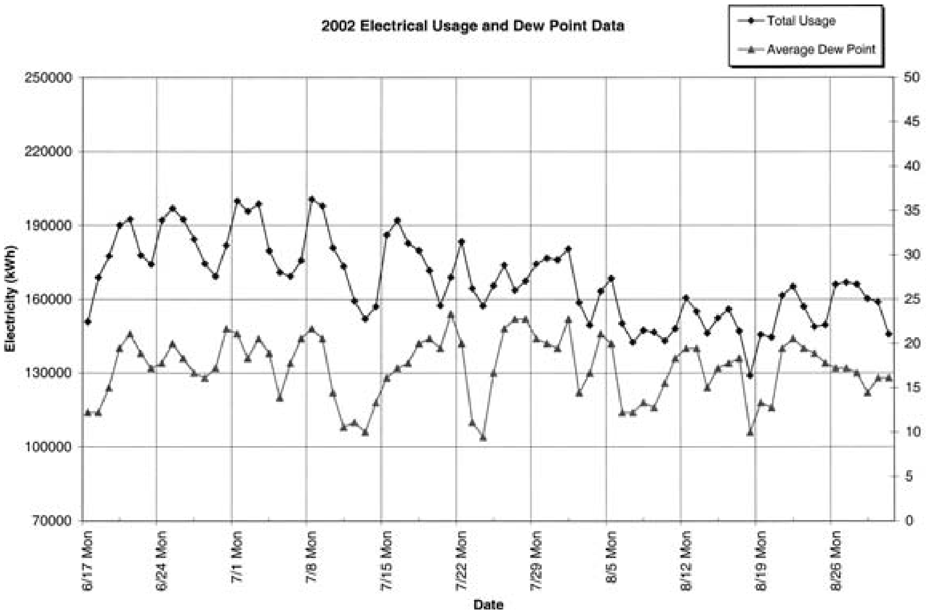

Figure 7. *As for Figure 6, but with electricity usage data for the two substations combined.*

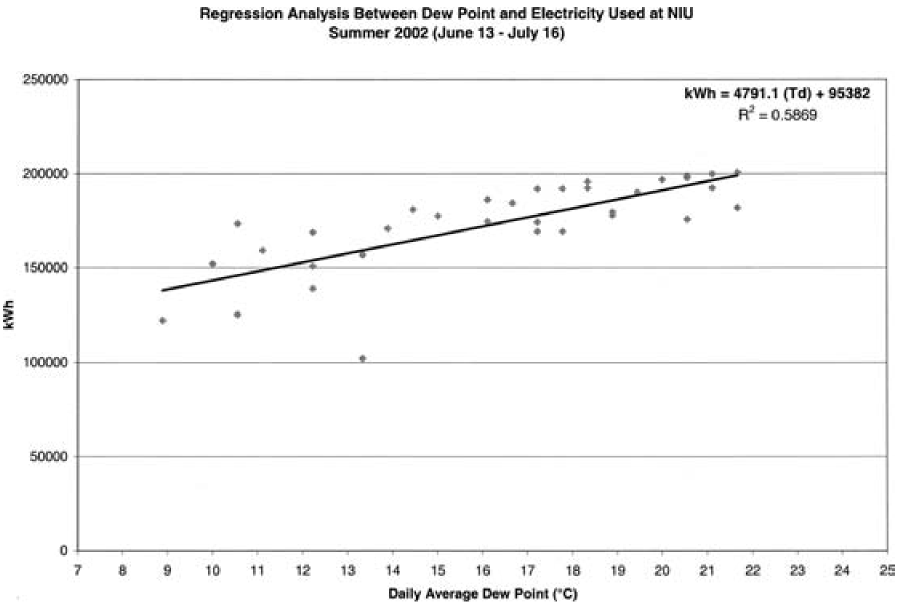

Figure 8. *The relationship of daily electricity usage data to daily average dew point values for the period 13 June–16 July 2002. Black line represents least squares 'best fit' line.*

and combined daily electricity usage from the two substations for the same eight-week period during the summers of 2001 and 2002 (Figure 11). Although basic electricity uses (lights, computers, etc.) were minimal during the weekends of the summers of 2001 and 2002, the campus air conditioning systems were in normal operation. The R-value between these two variables was +0.83 reflecting a strong positive relationship on weekends.

To estimate total weekend savings in 2003, the difference was calculated between the actual daily electricity usage and an estimate of what would have been used if the air conditioning systems were operating. This estimate of expected usage was determined using the 2001 and 2002 weekend least squares 'best fit' line equation (see Figure 11), and summed for the Saturdays and Sundays within the 16 June–10 August period. The distance between the 2003 actual electricity usage values (squares) and the least squares 'best fit' line (shown as diamonds) represents the estimate of daily savings in kilowatt-hours.

Combining the weekdays of 2001 and 2002, a correlation between daily average dew point and weekday electricity usage was determined to be +0.78 (Figure 12). As with the weekend days, a least squares 'best fit' line was determined based on the 2001 and 2002 weekday data and was applied to the observed 2003 dew points to estimate expected electrical usage on weekdays

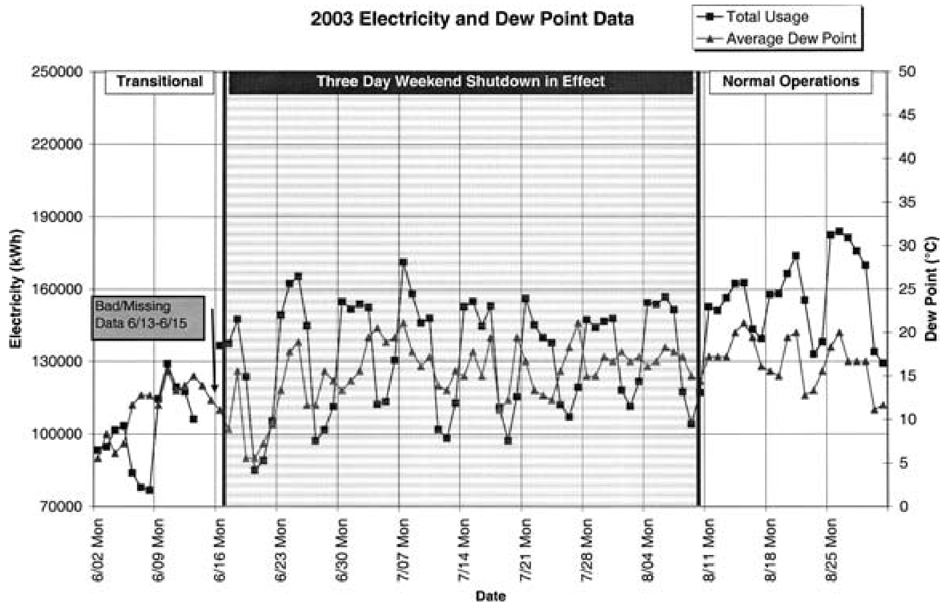

Figure 9. *Electricity usage data for the two substations combined, along with daily average dew point. Vertical lines indicate Mondays. The period in the middle of the graph (16 June–10 August) shows when NIU shut down their air conditioning systems on three-day weekends.*

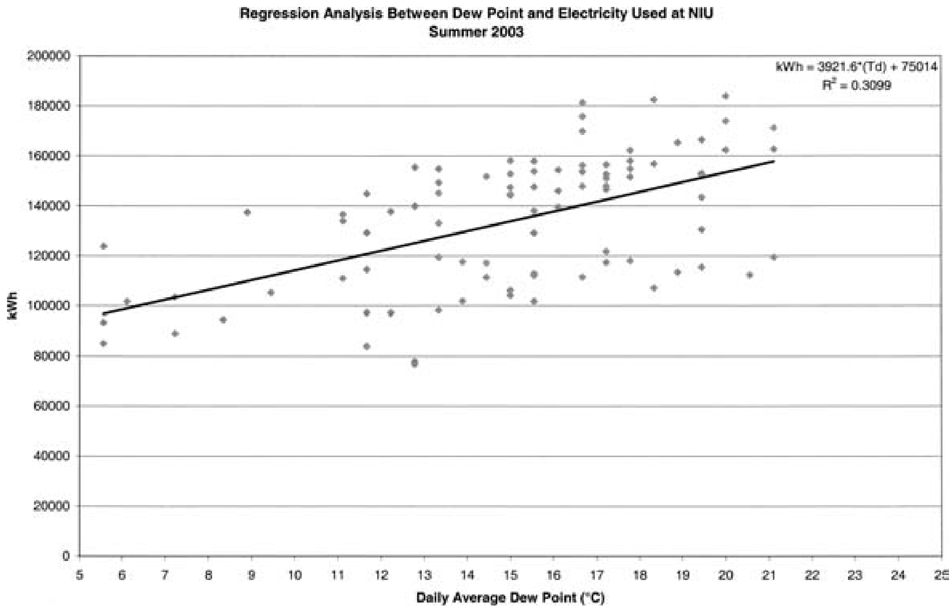

Figure 10. *The relationship of daily electricity usage data to daily average dew point values for summer 2003.*

(Monday–Friday). In Figure 12 the 16 June–10 August 2003 Fridays (triangles) are shown. With the air conditioning systems shut down and buildings closed on Fridays in 2003, the expected electricity usage for a given dew point was far less.

Estimates of total electricity usage savings during 2003 shutdown days (Friday–Sunday) were determined (Table 2). Results for the 2003 savings were also examined as average daily savings (Table 3). The greatest savings during the three-day shutdowns occurred on Fridays and was related to both the air conditioning shutdown and the lack of normal electricity usage for computers, lights, and other activities.

Table 2. *Estimated total weekend day savings during shutdowns of the NIU air conditioning systems, 16 June–10 August 2003.*

Day of the week	Total savings (kWh)
Fridays	506,914
Saturdays	401,024
Sundays	360,554
All Weekend Days	1,268,492

These findings allowed administrators at NIU to judge whether the three-day weekend shutdown was a significant money-saving opportunity in the summer of

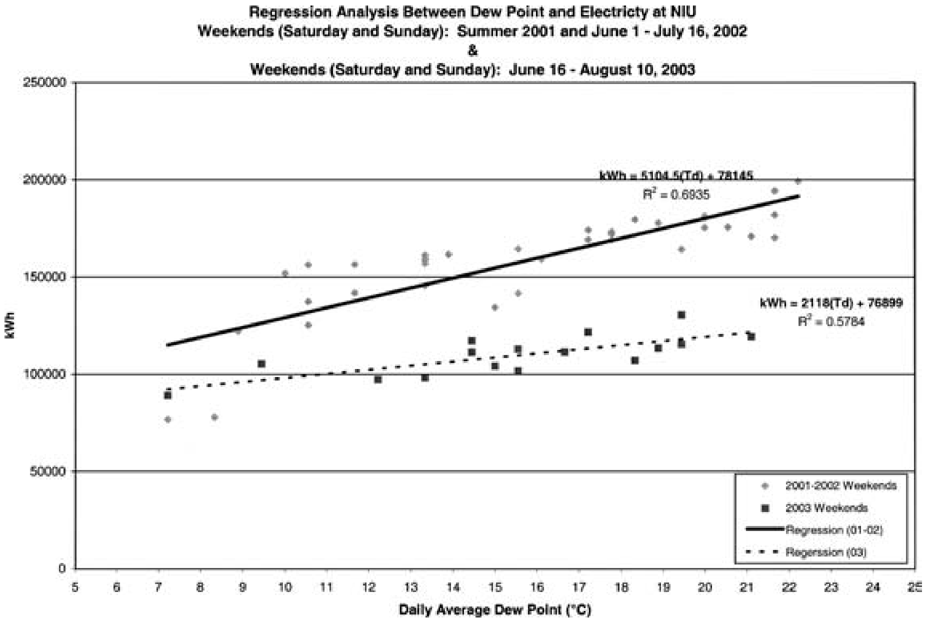

Figure 11. *The relationship of daily electricity usage data to daily average dew point values for weekends during summer 2001 and 13 June–16 July 2002. The least squares 'best fit' line is in black. Daily electricity values for weekend days (Saturdays and Sundays) from 16 June–10 August 2003, are shown in squares with the 'best fit' line being dashed.*

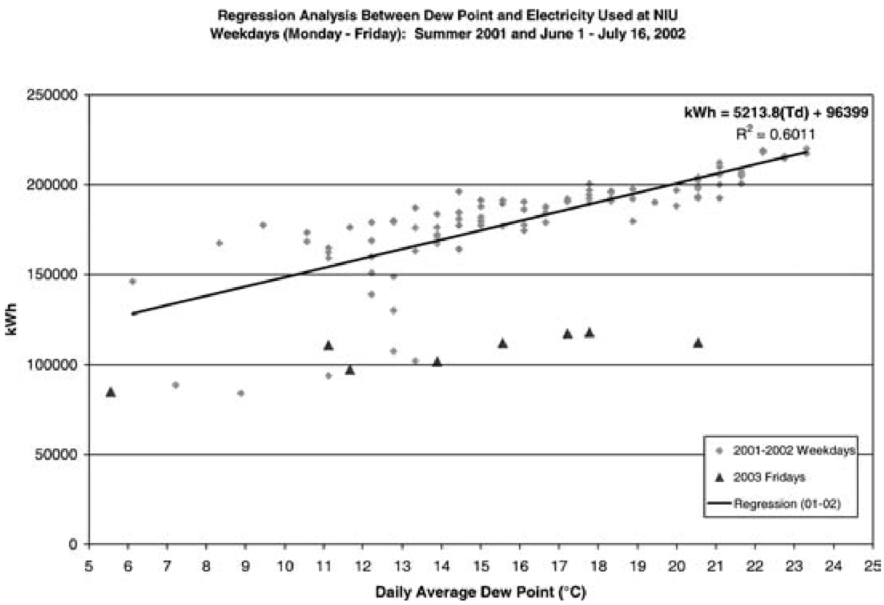

Figure 12. *The relationship of daily electricity usage data to daily average dew point values for weekdays during summer 2001 and 13 June–16 July 2002. The least squares 'best fit' line is in black. Daily electricity values for Fridays in 2003 (16 July–10 August) are shown in triangles.*

Table 3. *Average electrical usage and estimated average savings, 16 June–10 August 2003.*

	Average 2003 electricity usage (kWh)	Average savings from 2001 and 2002 average usage (kWh)
Fridays	106,897	63,366
Saturdays–Sundays	109,279	49,055

2003. For an average 16 June–10 August period, 7,446,963 kWh are used in the two NIU substations. In summer 2003, the university saved 1,268,492 kWh or approximately 17% of this total because the air conditioning was shutdown. Although those savings appear significant, more savings would have been realised if the shutdown days had experienced higher dew point levels.

3.3. Development of a daily electricity predictive model

The vertical distance between the 2001–2 and 2003 trend lines (Figure 11) can be used to estimate weekend daily energy savings based on dew point level. These differences and savings were computed for various daily

Table 4. *Estimated electrical usage for weekend days during a normal (2001–2002) summer and for a shutdown summer (2003), with savings calculated between the two.*

Daily average dew point (°C)	From 2003 Weekend day trend kWh = 2118* (Td) + 76899	From 2001–2002 Weekend day trend kWh = 5104.5* (Td) + 78145	Savings (kWh)
10°C	98,079	129,190	31,111
15°C	108,669	154,713	46,044
18°C	115,023	170,026	55,003
20.5°C	120,318	182,787	62,469
23°C	125,613	195,549	69,936
25°C	129,849	205,758	75,908

Table 5. *Estimated electrical usage for weekdays during a normal (2001–2002) summer and for Fridays during a shutdown summer (2003), with estimated Friday savings calculated.*

Daily average dew point (°C)	From 2003 Friday trend kWh = 2036.4* (Td) + 78047	From 2001–2002 Weekday trend kWh = 5213.8* (Td) + 96399	Savings (kWh)
10°C	98,411	148,537	50,126
15°C	108,593	174,606	66,013
18°C	114,702	190,247	75,545
20.5°C	119,793	203,282	83,489
23°C	124,884	216,316	91,432
25°C	128,957	226,744	97,787

average dew points (Table 4). A similar method that incorporated information from Figure 12 was used in the Friday decision model (Table 5). The greater Friday savings were realised again in these tables, which illustrates that air conditioning systems as well as operations (computers, lights, etc.) were turned off, unlike on Fridays of previous years.

These tables can be used to calculate past weekend savings and predict future savings (based on weather forecasts). Daily savings can be estimated by substituting past or predicted daily averaged dew points for Friday–Sunday in the regression equations. Based on weather forecasts for an approaching weekend, an air conditioning shutdown could be implemented or avoided due to predicted savings. For example, a forecast for a dry weekend (10°C Td) would yield minimal savings. In this case, these savings would be further reduced through startup and shutdown costs (broken belts, man hours, etc.) at the beginning and end of each weekend. In other words, on weekends when demand for air conditioning is minimal it may be wiser not to implement a shutdown.

4. Conclusions

Northern Illinois University (NIU) administrators implemented a four-day work week from 16 June–10 August 2003, with the intention of offsetting some of the budget cuts passed on by the State of Illinois through a three-day shutdown of air conditioning systems. By obtaining daily electricity data from two campus substations and establishing relationships with daily average dew points, we were able to estimate the savings for the 2003 summer.

An examination of summer (June–August) average daily dew points showed that the summer of 2003 was relatively 'dry' with a value of 14.9°C. The summer 2003 value fell into the lowest 20% of the distribution during a 45-year period (1959–2003).

The relationship between daily electrical usage (when air conditioning systems were operational) and daily average dew point was found to be relatively strong, with R-values $>+0.75$ and so provided an opportunity to estimate savings during 2003. Shutting down the campus air conditioning systems on three-day weekends caused a noticeable drop in electricity usage, with total weekend savings equalling 1,268,492 kilowatt-hours or 17% of NIU's average electrical usage during the eight-week period (16 June–10 August). If the dew points during the summer of 2003 had been higher, the savings to the university due to the shutdown would have been much greater. With this information in hand, NIU administrators will be able to weigh shutting down the air conditioning systems against other potential money-saving actions in future years. This case study has demonstrated the potential value that can come from using climate information in practical decision-making.

Acknowledgments

The group would like to extend many thanks to everyone who contributed to the project. Mr Mike Saari, Mr Kevin Howard, Mr Jason Starke and Ms Pat Peshia from the NIU Heating Plant showed us how the air conditioning systems work, identified critical dew point thresholds, and provided electricity usage data for buildings on campus. The group would also like to thank Stan Changnon, Suzy Changnon and the anonymous reviewers, for their editorial comments and advice.

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