ESL-TR-91/03-01

Prairie View A&M University Whole Campus Energy Analysis

Final Report

Requested by:

Prairie View A&M University
and
The Governor's Energy Office

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1. Executive Summary

Prairie View A&M University started a large scale energy management program in 1987 and 1988. This report presents an analysis of whole-campus energy consumption at the Prairie View A&M Campus where whole-campus indices were developed that normalize for weather, conditioned area, and campus enrollment. The resultant indices were then used to estimate whole-campus energy savings resulting from the guaranteed-savings energy management program at the Prairie View Campus.

The two primary findings are as follows:

(1) **Savings to date.** The current (April 1990) calculated guaranteed savings equal or exceed the monthly contracted savings rate. Electricity consumption has decreased sharply since April 1987. Natural gas usage, and electric demand have also decreased significantly.

The savings began to appear in October of 1987 at a rate of about $5,000 per month. These savings grew at a steady pace for the next 17 months until April 1989, when, for the first time, they approached the contract savings rate of $72,504 per month. The monthly savings rate continued to increase until reaching a peak of $89,834 in November 1989, then declined to a rate of $81,776 in April 1990.

When substantial completion occurred in September 1988 the estimated savings lagged behind the contracted guaranteed-savings rate. By the time the estimated savings reached the contracted rate, a savings deficit of $67,000 had accumulated.

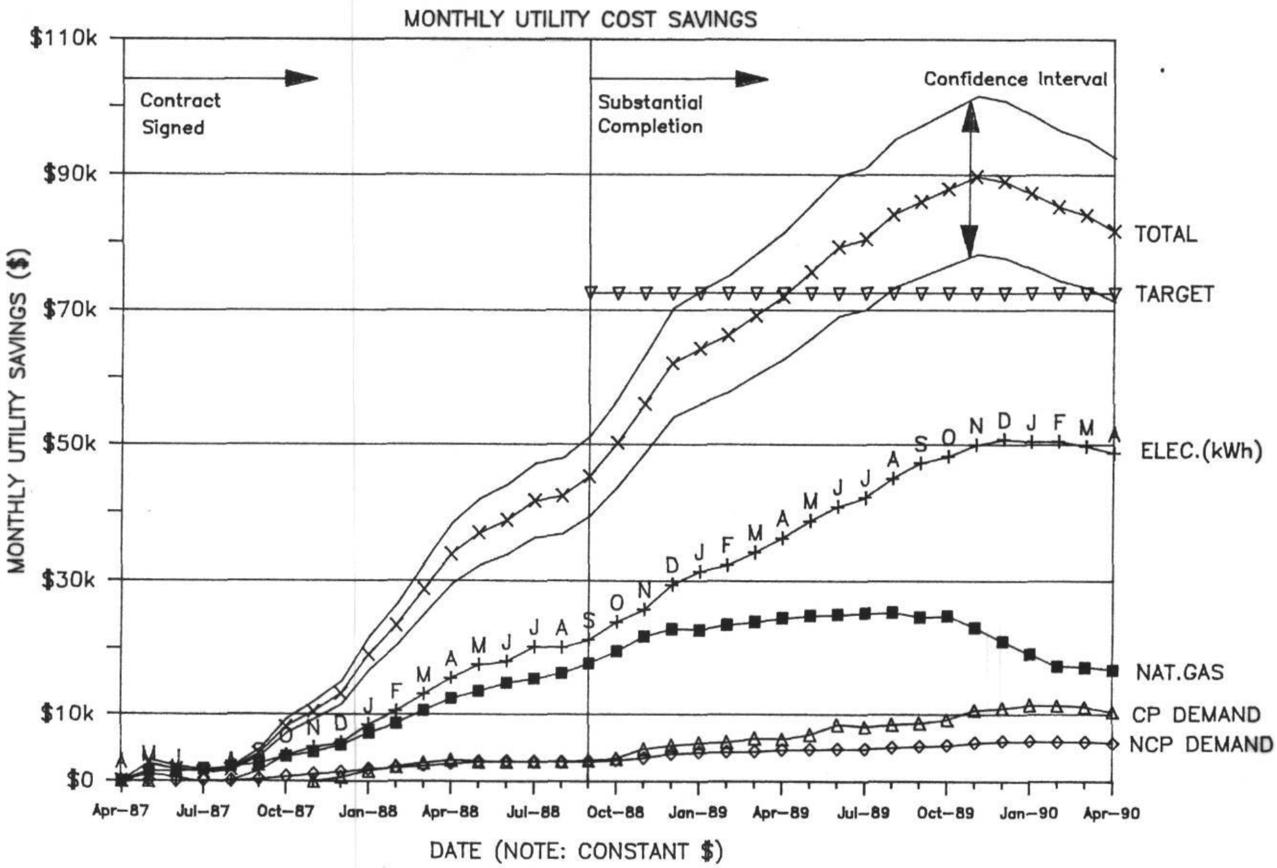
It should also be noted that a cumulative savings of $355,000 occurred from April 1987 (the signing of the guaranteed savings contract) to September 1988 (substantial completion). These additional savings are not part of the guaranteed savings but were considered in the comparisons shown in Figures 10, 11 and 12.

(2) **Projected savings over five years.** If the average savings rate that occurred during April 1990 (the latest data used in this analysis) is extended through August 1993, and is added to the savings that occurred prior to the guaranteed savings start date (April 1987 to September 1988) the total savings are projected to be $5,078,000 which is 119% of the guaranteed savings of $4,278,000.

If one deducts the $355,000 that accumulated prior to substantial completion the estimated savings are then $4,723,000 or 110% of the guaranteed savings of $4,278,000.

Out confidence in the estimated savings projections is about 13%. This 13% confidence interval represents a cumulative confidence interval (electricity + natural gas + electric demand) calculated using standard errors from a statistical analysis of the data.

***Figure 1:** Monthly Whole-Campus Utility Cost Savings.* **This figure displays the estimated whole-campus energy savings from April 1987 to April 1990, displayed as a sliding monthly indicator (constant dollars). Values are shown for the total energy savings (X), electricity usage (kWh - the plus symbol), natural gas consumption (the square symbol), coincident peak electric demand (the triangular symbol), the non-coincident peak demand (the diamond symbol), and the target savings amount (the inverted triangle). The confidence interval for the total estimated savings represents two standard errors (one SE is about 13%).**



2. Acknowledgements

The Energy Systems Laboratory at Texas A&M University would like to extend its thanks and appreciation to Prairie View A&M University and its staff for assistance in obtaining the utility and building data. Special thanks are due to the following people who provided assistance to the project: Mr. Kollye Kilpatrick, Mr. Gerald Kelley, and Ms. Linda Garette. Thanks also to Mr. Norman Ferguson of Johnson Controls; the City of Waller (natural gas billing data), the Texas Southeastern Gas Company, and the San Bernard Electric Cooperative.

Further thanks are extended to the staff at the Governor's Energy Office for their support and comments, including Mr. Malcolm Verdict and Dr. Steve Jaeger.

This project was funded and supported by the State of Texas, Governor's Energy Office, as part of Texas A&M's Technical Assistance Contract with the Governor's Energy Office using oil overcharge funds.

3. Introduction

This report presents results of an analysis of energy consumption at the Texas A&M Prairie View Campus. This analysis develops indices that are normalized for weather, conditioned area, and campus enrollment. The resultant indices are then used to estimate energy savings from a guaranteed-savings contract at the Prairie View A&M Campus.

The next section summarizes the findings of the analysis of the Prairie View A&M campus guaranteed-savings energy management program. Following the summary, historical energy consumption for the campus is reviewed and the energy savings resulting from the guaranteed-savings energy management program are tracked with normalized consumption indices.

The methodology and a brief description of the analysis used for normalization are discussed in the appendix.

4. Discussion

This report discusses information concerning an analysis of whole-campus energy consumption at the Texas Prairie View A&M Campus. To perform this analysis indices were developed that are normalized for weather, conditioned area, and campus enrollment. The resultant indices were then used to estimate energy savings resulting from a guaranteed-savings energy management program at the Prairie View A&M Campus.

We summarize our findings as follows:

Whole-campus energy savings.

1. The estimated cumulative savings began to appear in October of 1987 at a rate of about $5,000 per month.

2. These savings grew at a steady pace for the next 17 months until April 1989, when, for the first time, they approached the guaranteed-savings rate of $72,504 per month.

3. The monthly savings rate continued to grow until reaching a peak of $89,834 in November 1989, then declined to a rate of $81,776 in April 1990.

4. When substantial completion occurred in September 1988 the estimated savings lagged behind the contracted guaranteed-savings rate. By the time the estimated savings reached the contracted rate, a savings deficit of $67,000 had accumulated.

It should also be noted that a cumulative savings of $355,000 occurred from April 1987 (the signing of the guaranteed savings contract) to September 1988 (substantial completion). These additional savings are not part of the guaranteed savings but were considered in the comparisons shown in Figures 10, 11 and 12.

In other words, by the time that substantial completion occurred, Prairie View A&M had already realized a $355,000 savings, and even though a small deficit of $67,000 accumulated in the first 7 months following substantial completion; the net effect was to reduce the accumulated savings from $355,000 (October 1988) to $288,000 (May 1989) at which point the total accumulated savings again began to increase. This effect can be seen graphically in Figure 10.

5. If the average savings rate that occurred during April 1990 is extended through August 1993, and is

added to the savings that occurred prior to the guaranteed savings start date (April 1987 to September 1988) the total savings are projected to be $5,078,000 which is 119% of the guaranteed savings of $4,278,000.

If one deducts the $355,000 that accumulated prior to substantial completion the estimated savings are then $4,723,000 or 110% of the guaranteed savings of $4,278,000.

Electricity Use.

1. Electricity use can be characterized as "flat" with only a mild weather dependency which is consistent with institutional energy use.

2. Scheduling and/or enrollment are the primary indicators of electricity usage.

3. The largest monthly electricity use occurs most often in September, with the lowest electricity use occurring in December or January.

4. There has been a noted decrease in electricity consumption beginning in 1987 which coincides with the initiation of the guaranteed-savings contract.

5. The electricity use in the summer of 1989 had virtually no weather dependency which is different from all previous summers which showed a weak weather dependency.

6. The campus is billed for two types of electric demand -- the monthly peak that occurs when the electric grid experiences its peak and the largest campus peak during a given month.

7. Non-coincident peak demand varies much less from month to month than does coincident peak electric demand. Non-coincident peak demand is the maximum campus peak. Coincident peak demand is the campus electric demand at the hour of the system peak (i.e., summer - 4 to 6 p.m., winter - 6 to 8 a.m.). This trend (i.e., a reduction in electricity use during the coincident peak) may indicate that a substantial reduction of the campus-wide electrical load has resulted from the guaranteed-savings energy management program.

8. Coincident peak electric demand seems to have a much stronger cooling-season component than does non-coincident peak electric demand. This is probably due to the time-of-occurrence.

9. One can clearly see two different trends in the different types of electric demand for which the campus is billed; non-coincident peak electric demand steadily increased during the 1983 through 1988 period and declined noticeably beginning in the Summer of 1989. Whereas, only the cooling-season portion of the coincident peak electric demand increased during this period. Non-cooling season coincident peak electric demand has also decreased.

10. One can speculate that this difference may indicate that a major contributor to the coincident peak electric demand is the operation of the large chillers.

11. Conversations with the electric utility that serves Prairie View A&M indicate that the system peak occurs at 4 to 6 p.m. during the summer; usually on a Tuesday or a Wednesday. In the winter it occurs from 6 to 8 a.m., and in the spring or fall the time of day for the peak varies.

The time of occurrence of the non-coincident peak for specific months could not be easily determined. However, it was determined that the electric utility records the 15-minute demand on magnetic tape and these tapes are transcribed to a printout once-per-month; there is apparently no formal procedure for passing time-of-occurrence information on to Prairie View.

12. We recommend that the electric utility make monthly copies of the printout which shows the occurrence of the non-coincident campus peak electric load and the coincident campus peak electric load and provide it to the Prairie View A&M facilities management..

13. One possible area for future work would be a close examination of the historical 15-minute whole-campus electricity consumption data (i.e., the 15-minute tapes) to look for opportunities in electric load-shedding projects.

Natural Gas.

1. As expected, natural gas use has a strong weather dependence. This can clearly be seen from the monthly consumption data.

2. The highest peak use of natural gas occurred in December 1989.

3. The natural gas use throughout the winter of 1989/90 appeared to be abnormally high.

5. Historical Energy Consumption

In order to assess the impact of a campus-wide guaranteed-savings energy management program, whole-campus energy usage indices which use monthly energy consumption information were constructed for the period 1983 through 1990. This methodology utilizes the Princeton Scorekeeping Method (PRISM), a steady-state three parameter regression model (Fels 1986). The well documented PRISM method is the most commonly used method for evaluating before-after energy conservation retrofit savings. The majority of the information required for the analysis was available at the Prairie View A&M (PVAM) Physical Plant Offices, with supplemental information obtained from the utility suppliers, including: the City of Waller (natural gas), the Texas Southeastern Gas Company, and the San Bernard Electric Cooperative.

Figure 2 illustrates the erratic nature of the utility bills that Prairie View A&M pays. In Figure 2 the total monthly utility bills (triangle), electric bills (diamond), and natural gas bills (Texas Southeastern - plus symbol, and City of Waller - filled square symbol) are shown for the period April 1988 through November 1990. Although certain patterns can be seen in these data (i.e., natural gas consumption increasing during the winter months) it is difficult to determine if any savings have occurred.

Natural Gas Consumption. Unadjusted natural gas consumption for the PVAM Campus is shown in Figure 3 (MBtu x 1000 - million Btu per month times 1000) from April 1983 through April 1990. The total campus natural gas consumption (diamond symbol) includes gas purchased from the Texas Southeastern Gas Company (the solid line without a symbol), and gas purchased from the City of Waller (the plus symbol).

As expected, the consumption of natural gas is strongly influenced by the prevailing weather conditions, usually having a peak consumption during the month of January and dropping to its lowest consumption during July or August. The highest consumption during this seven-year period occurred in December of 1989 when record-breaking cold temperatures were experienced.

Unadjusted natural gas use versus average monthly temperature is shown in Figure 4 for the period April 1983 through April 1990. The data labels represent the year the gas was consumed. A strong weather-dependent, linear relationship can be observed in these data with only a very slight base-level, or non-weather-dependent consumption occurring at average ambient temperatures greater than 80 F.

Several interesting features can be seen in the unadjusted data. First, the extreme weather conditions experienced in December 1989 were within 5 F of conditions in December 1983, January 1984, January and February of 1985, and January 1988. However, it appears that in December 1989, the campus consumed significantly more natural gas -- a possible indication of excessive natural gas use during the winter of 1989/90. The abnormally high consumption for January, February and March 1990 may also be indicating excessive consumption. These months are the outliers labeled "90" that are considerably above the other months and warrant further investigation.

Electricity Consumption. Unadjusted electricity consumption (kWh) is shown in Figure 5 for the period January 1983 through April 1990. In Figure 6 this same electricity use is displayed against average monthly temperature for the same period. The electricity use for the campus can be characterized as having only a slight weather dependency; there is significant monthly variation which will be shown to be related to scheduling and/or enrollment effects.

The largest electricity consumption occurs in September (versus August or July for similar commercial buildings) -- most likely due to the combined cooling-related and student-related electricity requirements. The lowest consumption occurs during the months of December and January -- conversely, periods when the campus has the Christmas vacation. Another interesting feature is that February electricity use seems to always be larger than March electricity use -- most likely due to the one-week spring vacation period which occurs in March.

In general, it is fair to state that there has been a quantifiable decrease in the whole-campus electricity consumption beginning in 1987 (with the exception of August and September 1988). Also, consumption during the summer of 1989 had very little weather-related (cooling season) usage when compared to the previous years.

Peak Electric Demand. The PVAM Campus is billed for two different types of peak electric demand: non-coincident peak electric demand and coincident peak electric demand. The whole-campus electric peak demand is recorded by the electric utility company on a 15-minute interval using magnetic tapes that are transcribed for billing purposes once-per-month.

Non-coincident peak electric demand represents the maximum, monthly 15-minute electric power levels for the entire campus. Coincident electric peak demand reflects the highest 15-minute whole-campus electric power requirements that occurred when the electric utility experienced their 15-minute peak demand. The campus is charged separately for both coincident and non-coincident peak electric demand.

Figures 7,8 and 9 show the whole-campus coincident and non-coincident peak electric demand for the period January 1983 through April 1990. Figure 7 shows non-coincident peak electric demand (NON CO-PEAK) and coincident peak electric demand (CO-PEAK) in a time series from January 1983 through April 1990. Figure 8 shows the non-coincident peak electric demand displayed against the average monthly temperature, and Figure 9 shows the coincident peak electric demand displayed against the average monthly temperature.

Several features can be clearly seen in the campus electric demand. First, in Figures 7 and 8, non-coincident peak demand varies much less from season to season than does coincident peak electric demand (Figure 9) Coincident peak electric demand seems to have a much stronger cooling-season component than does non-coincident peak electric demand.

In Figure 7 there are two different trends in the electric demand; non-coincident peak electric demand seems to have steadily increased during the 1983 through 1988 period and declined noticeably beginning in the Summer of 1989. Whereas, the cooling-season portion of the coincident peak electric demand increased during this period.

One can infer that this difference in coincident peak electric demand is the operation of the large chillers. There is additional evidence to support this when one compares the scatter-plot profiles from Figure 8(non-coincident peak electric demand) with those of Figure 9(coincident peak electric demand) . First, there is a strong temperature-related component in both coincident and non-coincident peak electric demands. However, there is a marked difference in the amount of influence, and the manner in which occurs.

In the non-coincident demand, the cooling-influence is a smooth 2 MW increase; versus the 2 MW "step change" that occurs in the coincident demand at about 70 F (Figure 9) One might speculate that this is indicating that the coincident and non-coincident demand occur at different times of the day.

Our conversations with the electric utility indicate that the coincident or system peak occurs at 4 to 6 p.m. during the summer; usually on a Tuesday or a Wednesday. In the winter it occurs from 6 to 8 a.m., and in the spring or fall the time of day for the peak varies.

The time of occurrence of the non-coincident peak could not be easily determined. It was determined that the electric utility records the 15-minute demand on magnetic tape and has these tapes transcribed to a printout, once-per-month, but there appears to be no formal mechanism for passing this time of occurrence information on to the Prairie View facilities management office.

We recommend that the electric utility make copies of the printout which shows the occurrence of the non-coincident campus peak electric load that is generated by LCRA and send it to the Prairie View A&M facilities management.

6. Tracking Energy Savings with the Normalized Consumption

Figure 1, and Figures 10 through 12 show the normalized energy savings for the Prairie View campus. Figure 1 displays the estimated whole-campus energy savings from April 1987 to April 1990, displayed as a sliding monthly indicator (constant dollars). Values are shown for the total energy savings (x), electricity usage (kWh - the plus symbol), natural gas consumption (the square symbol), coincident peak electric demand (the triangular symbol), the non-coincident peak demand (the diamond symbol), and the target savings amount (the inverted triangle).

The confidence interval for the total estimated savings represents two standard errors (one SE is about 13%). The total standard error represents the cumulative error from estimating the consumption from all the fuel types. For the electricity usage and the natural gas usage the standard error is the CV(NAC) PRISM value. For the electric demand the standard error is the standard deviation of the 12 months used to calculate the sliding average.

Figure 10 displays the estimated cumulative whole-campus energy savings from April 1987 to August 1993. Figure 10 compares the normalized energy use rates from April 1987 (the signing of the guaranteed savings contract) to September 1988 (substantial completion). As previously indicated, a cumulative savings of $355,000 occurred prior to substantial completion. In other words, by the time that substantial completion occurred, Prairie View had already realized a $355,000 savings, and even though a small deficit of $67,000 accumulated in the first 7 months following substantial completion the net effect was to reduce the accumulated savings from $355,000 (October 1988) to $288,000 (May 1989) at which point the total accumulated savings again began to increase. This effect can be seen graphically in Figure 10.

Figure 11 displays the estimated 5-year, whole-campus energy savings from April 1987 to August 1993, displayed as a sliding monthly indicator (constant dollars). Values extending past April 1990 are extrapolated values which utilize the April 1990 savings rate for the electricity (kWh), electric demand (kW) values, and natural gas.

Figure 12 shows the cumulative 5-year, whole-campus estimated energy savings from April 1987 to August 1993 (constant dollars). The confidence interval shown for the total savings represents two standard errors (one SE is about 13%). If the average savings rate that occurred from April 1990 is extended through August 1993, and is added to the savings that occurred prior to the guaranteed savings (April 1987 to September 1988) the total savings are projected to be $5,078,000 which is 119% of the guaranteed savings of $4,278,000.

If one deducts the $355,000 that accumulated prior to substantial completion the estimated savings are then $4,723,000 or 110% of the guaranteed savings of $4,278,000.

***Figure** 2:Actual Utility Bills for the Prairie View Campus.* **The actual monthly utility bills for the Prairie View Campus are shown in this figure. In this figure the total monthly utility bills (triangle), electric bills (diamond), and natural gas bills (Texas Southeastern - plus symbol, and City of Waller - filled square symbol) are shown for the period April 1988 through November 1990.**

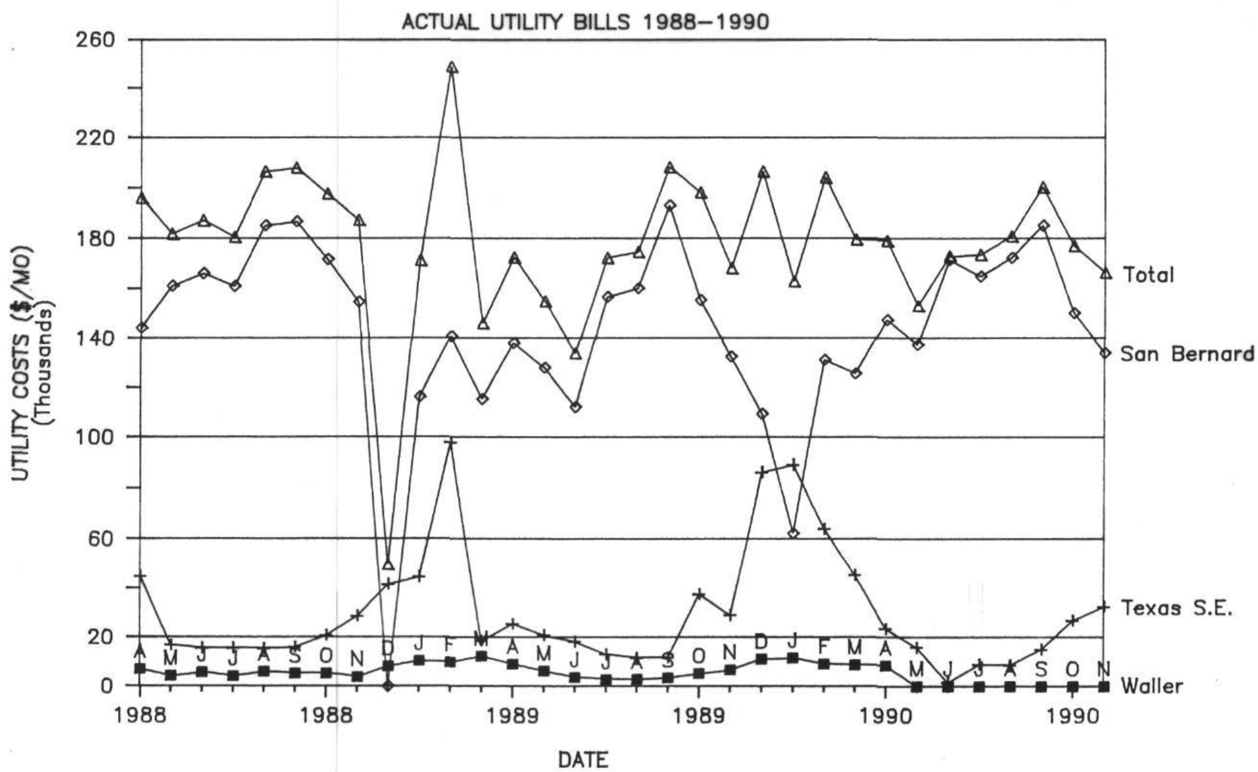


***Figure** 3: Historical Natural Gas Consumption.* The unadjusted natural gas consumption (MBtu - million Btu per month) is shown in this figure from April 1983 through April 1990. The total campus consumption (diamond symbol) includes gas purchased from the Texas Southeastern Gas Company (the solid line without a symbol), and gas purchased from the City of Waller (the plus symbol).

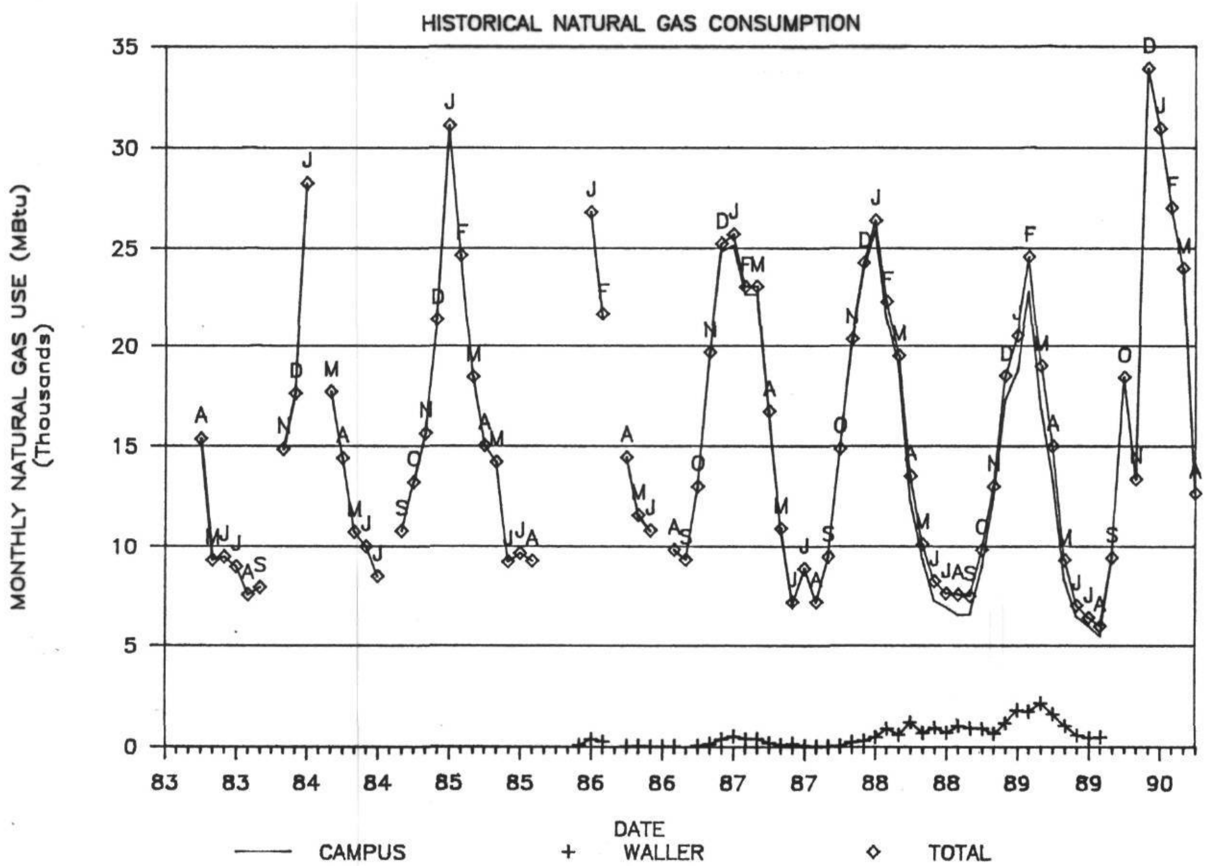


Figure 4: ***Natural Gas Use vs. Ambient Temperature.*** **Unadjusted natural gas use versus average billing-period temperature is shown in this figure for the period April 1983 through April 1990. The data labels represent the year the gas was consumed.**

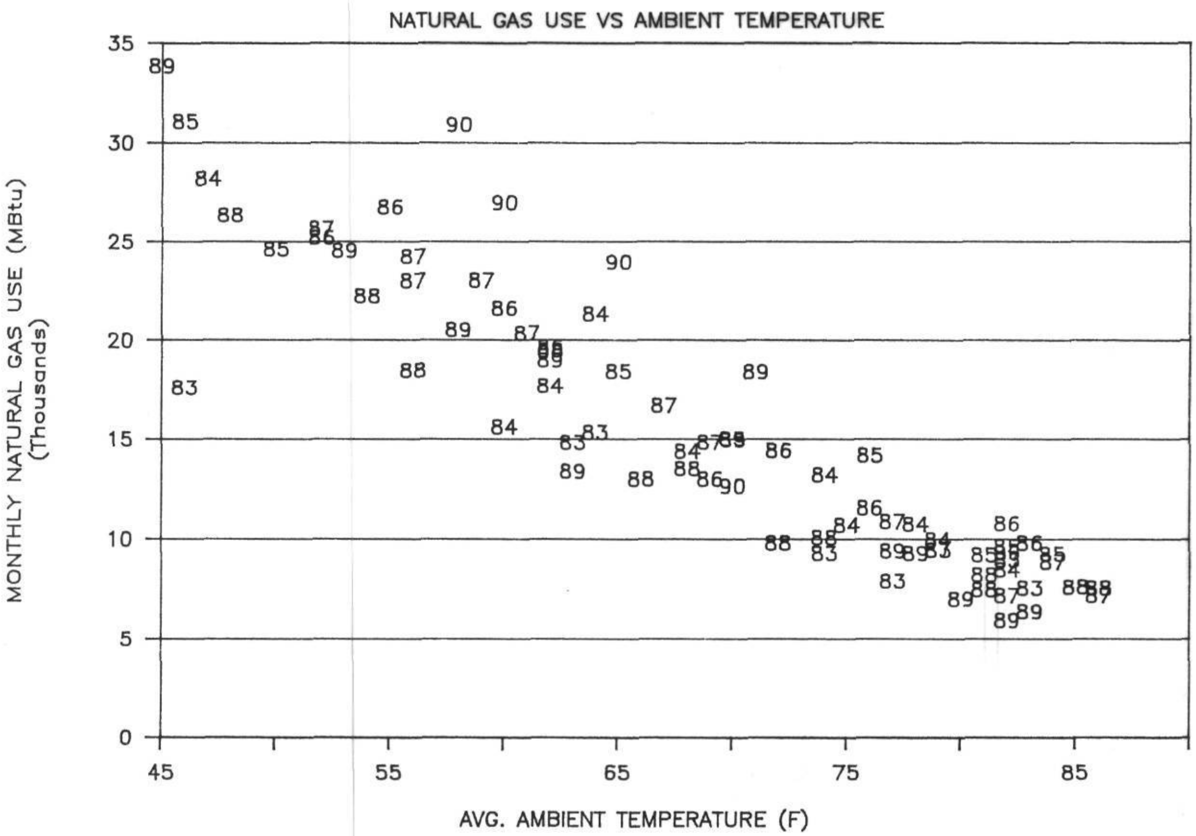


***Figure 5:** Historical Electricity Consumption (kWh).* This figure shows unadjusted electricity usage (million kWh) for the campus during the period January 1983 through April 1990.

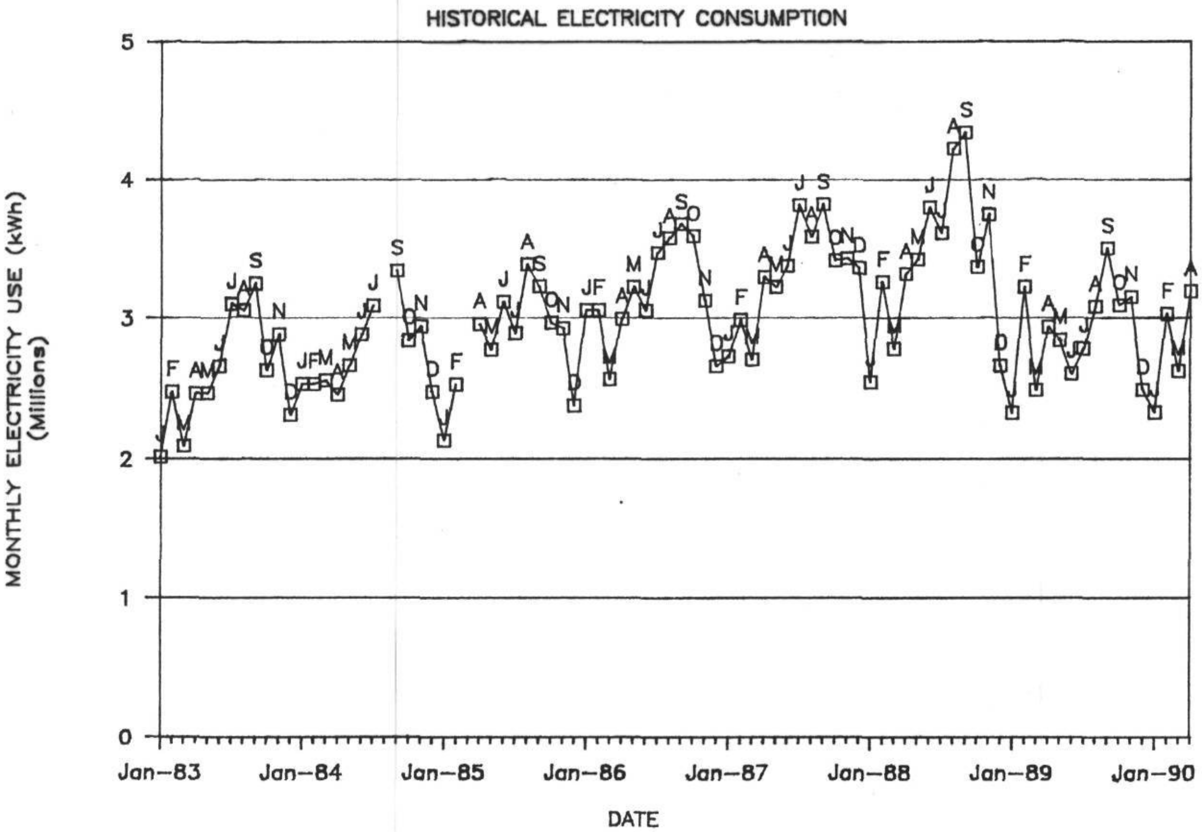


Figure 6: *Electricity Use vs. Ambient Temperature.* **Unadjusted whole-campus electricity consumption is displayed against average billing-period temperature for the period January 1983 through April 1990.**

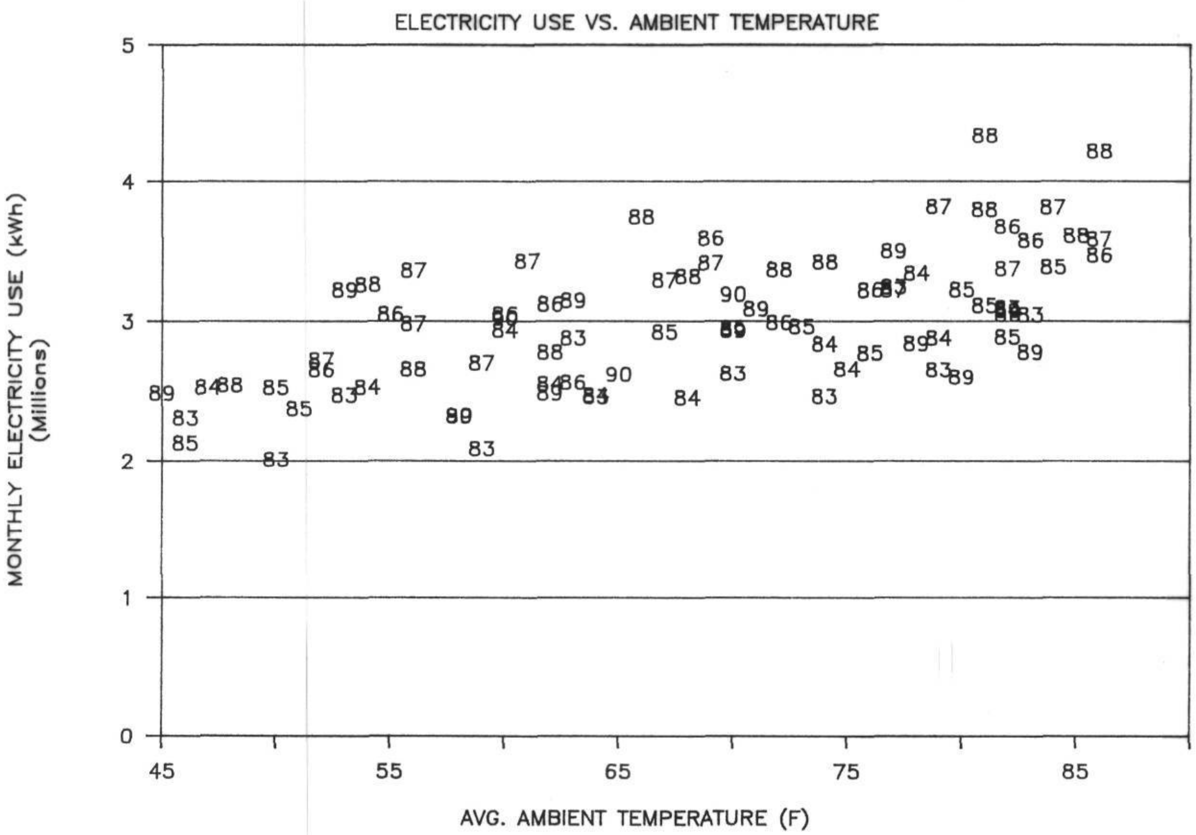


Figure 7: *Historical Peak Electric Demand.* **This figure shows peak electric demand during the period January 1983 through April 1990. Values for non-coincident peak electric demand (NON CO-PEAK) and coincident peak electric demand (CO-PEAK) are shown. The non-coincident peak electric demand represents the whole-campus electric demand peak. The coincident peak electric demand represents the whole-campus electric demand that occurred during the utility's peak electric demand.**

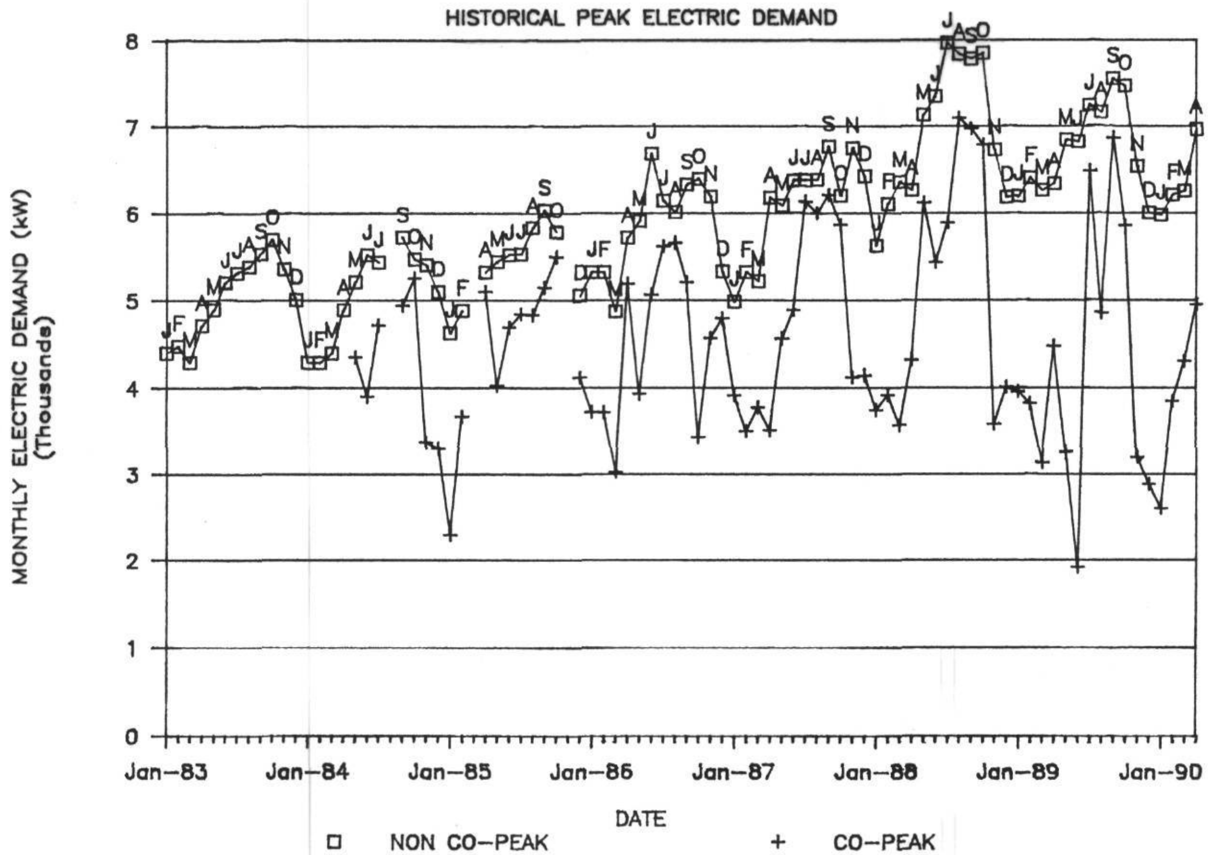


Figure 8: *Non-Coincident Peak Electric Demand vs. Ambient Temperature.* **Non-coincident peak electric demand is displayed in this figure against the average billing-period temperature during the period January 1983 through April 1990.**

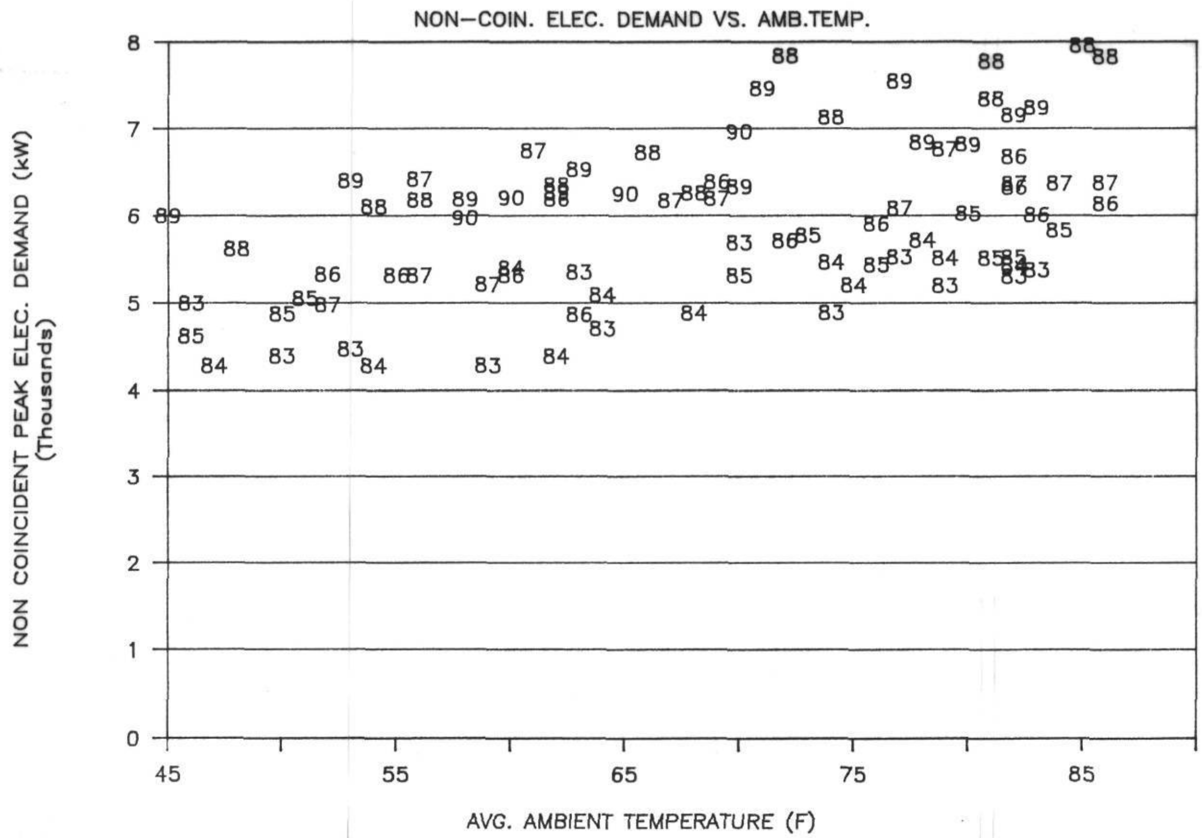


Figure 9: *Coincident Peak Electric Demand vs. Ambient Temperature.* **Coincident peak electric demand is displayed in this figure against the average billing-period temperature for the period January 1983 through April 1990.**

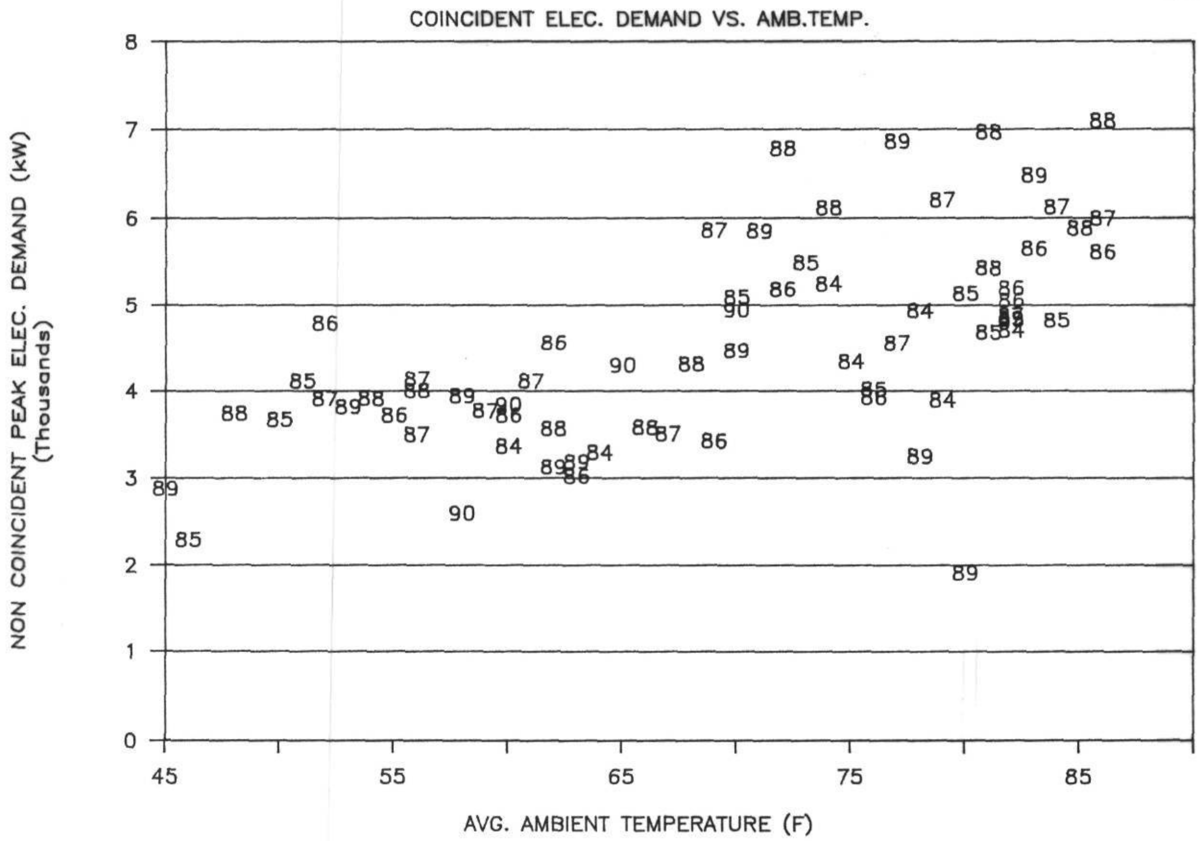


Figure 10: ***Estimated Monthly Cumulative Savings in Excess of Guaranteed Savings.*** **This figure displays the estimated cumulative whole-campus energy savings in excess of the guaranteed savings from April 1987 to August 1993, displayed as a sliding monthly indicator (constant dollars). The confidence interval for the total estimated savings represents two standard errors (one SE is about 13%).**

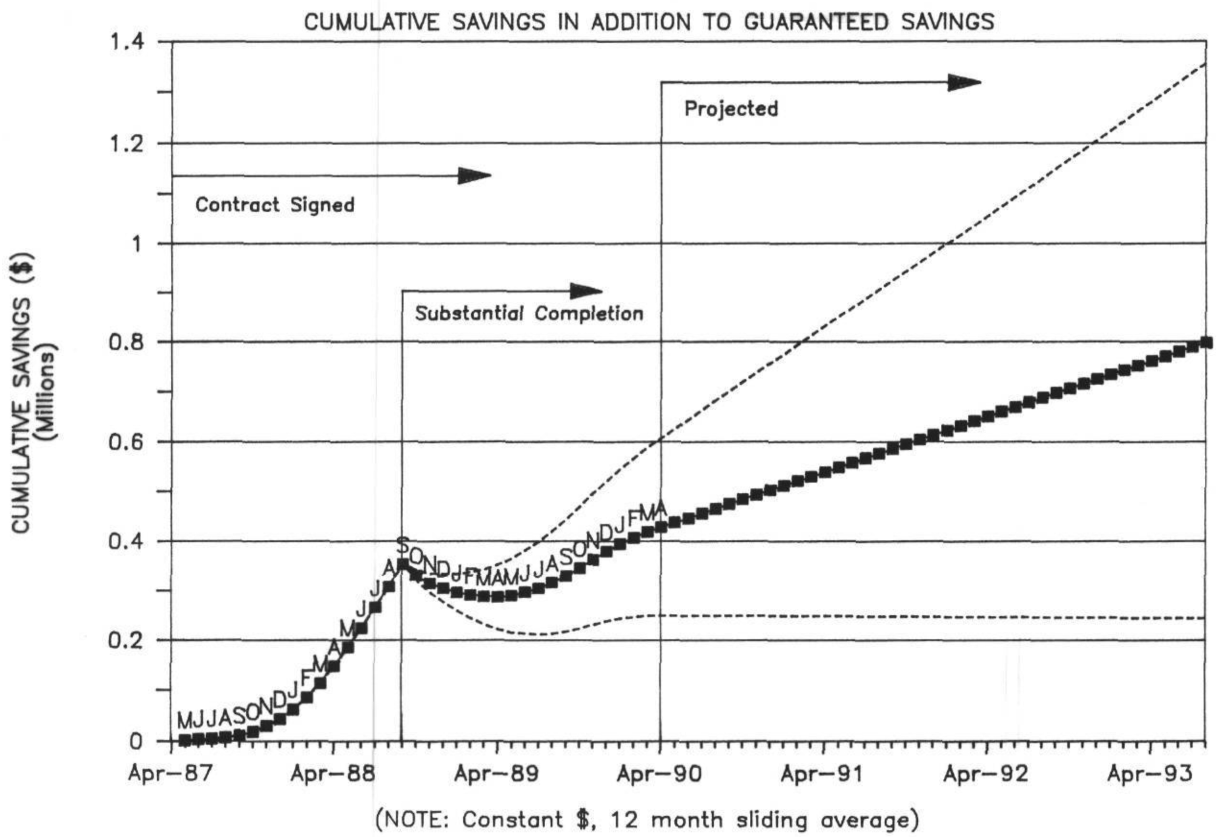


Figure 11: Estimated 5-Year Whole-Campus Utility Cost Savings. **This figure displays the projected 5-year, whole-campus energy savings from April 1987 to August 1993, displayed as a sliding monthly indicator (constant dollars). Values extending past April 1990 are projected values which utilize the April 1990 savings rate for the electricity (kWh), electric demand (kW) values, and natural gas.**

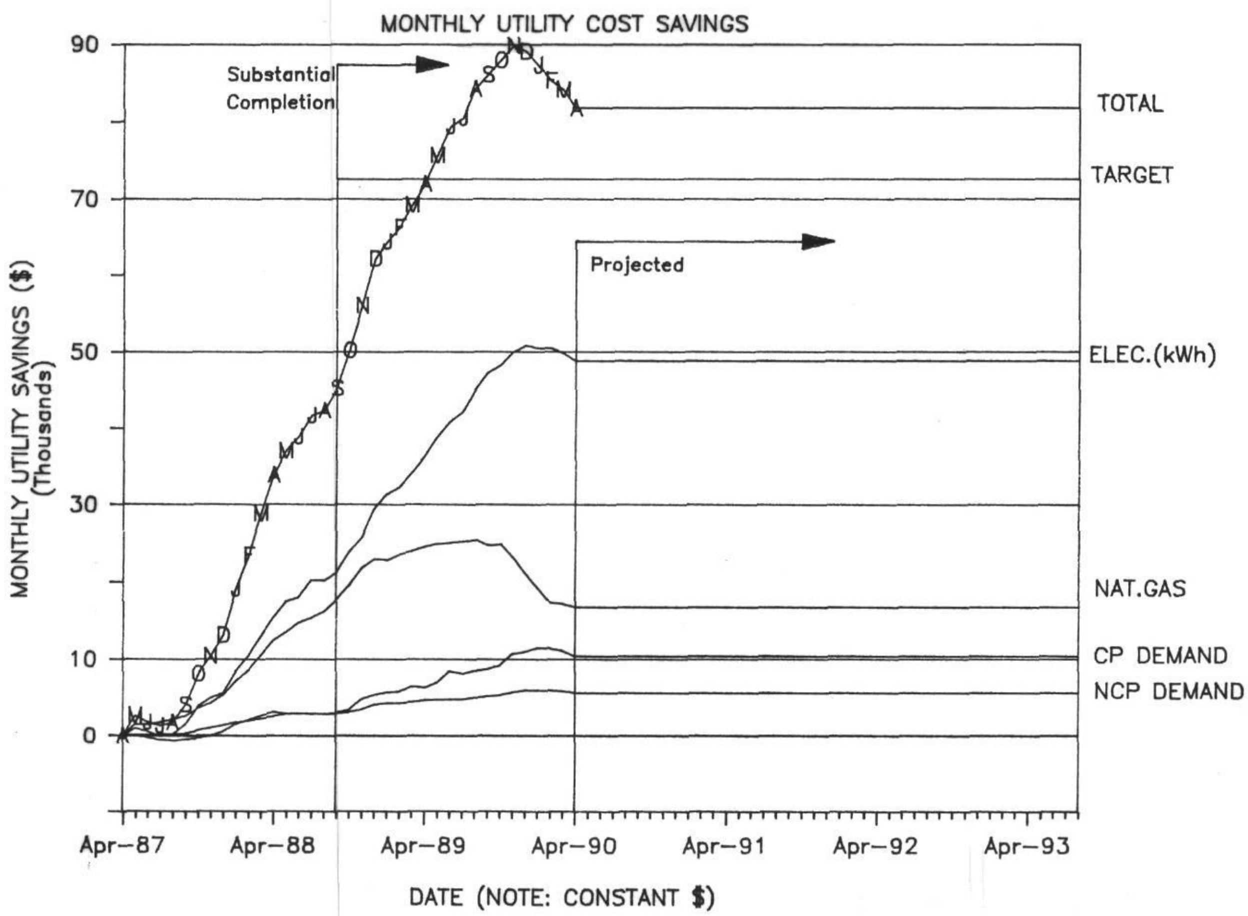
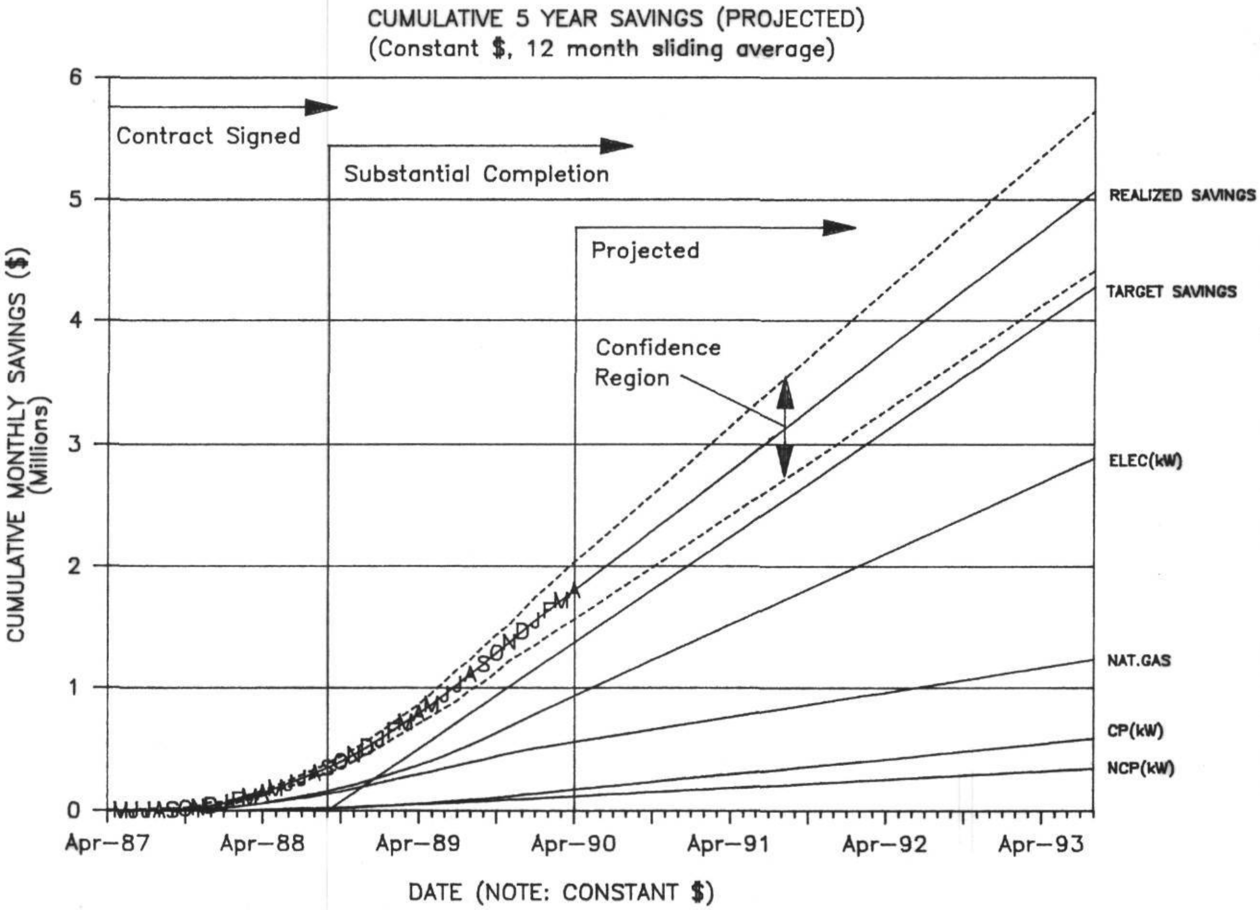


***Figure 12:** Estimated Cumulative 5-Year Whole-Campus Utility Cost Savings.* This figure shows the cumulative 5-year, whole-campus estimated energy savings from April 1987 to August 1993 (constant dollars). The "realized" savings are based on analysis of measured consumption through April 1990 and are projected thereafter. The "J, F, M..etc." data labels represent labels for the monthly consumption data. The confidence interval shown for the total savings represents two standard errors (one SE is about 13%).



Appendix A. Factors Considered for Normalization

We have found that campus operators have a need for concise, timely energy information (Haberl et al. 1989). Year-to-year comparisons of energy usage need to account for varying weather conditions, for additions to the conditioned floor area , and for changes in the student enrollment. Such annual indices require weather-normalization, an adjustment for square footage of conditioned area for each major fuel, and can be expressed as a production factor that is adjusted for student enrollment. For the Prairie View A&M campus this meant one index each for electricity use (kWh), coincident electric demand (kW), non-coincident electric demand (kW), and natural gas usage.

A.1. The Normalization Process

A multi-step procedure for normalizing the energy usage of the Prairie View A&M (PVAM) campus was chosen: (1) model the temperature dependence with Sliding PRISM - the Princeton Scorekeeping Method, a three-parameter steady-state model (Fels 1986), next
(2) adjust the Normalized Annual Consumption (NAC) by dividing it by the appropriate conditioned area for each fuel type, then
(3) adjust the NAC/ft^2 by expressing it as a value per 1000 students, and finally
(4) express the normalized indices using constant dollars.

To complete our assessment of the guaranteed-savings contract the monthly differences between the normalized values (from the April 1987 start of the guaranteed-savings contract) were added through April 1990, and displayed as cumulative totals.

These assessments were then extended as 5-year trend lines, which assumes that the April 1990 savings level continues for the duration of the period. Confidence intervals to indicate the uncertainty of the estimates were also calculated.

A.2. Weather Normalization

As shown in Figure 3 through Figure 9 the campus energy consumption has several weather-related components. Therefore, to compare energy consumption for different years, a procedure must be applied that evens-out the differences, or normalizes for weather.

In order to assess the variations in weather conditions for the PVAM Campus, 10 years of daily minimum-maximum temperatures were obtained from the National Weather Service (NWS 1990) for the Houston station (Figure 13). Figure 13 shows average monthly temperatures for the period January 1980 through May 1990 along with the ten-year monthly average (the plus symbol), and the variation between the monthly average and the 10-year average (the diamond symbol).

Both electricity usage and natural gas usage were normalized for varying weather conditions using PRISM. PRISM regresses energy consumption against heating or cooling degree days (taken at the balance-point temperature which gives the best fit) and includes thorough goodness-of-fit statistics. For either heating or cooling data, the model yields a slope (fuel-use/degree-day), base-level consumption (fuel-use/day), and a balance point temperature (F). The three-parameter PRISM change-point model is shown in Figure 14 -- the Princeton Scorekeeping, Cooling Only Model (PRISM CO). Such a model is composed of a base-level, or non-weather dependent consumption (a), the change-point, or balance point temperature (T_{bp}), a cooling slope (b_c), and an error term (e). In order to calculate a total normalized energy index for the entire campus it was necessary to analyze electricity use and natural gas use separately. The analysis of the natural gas consumption utilized PRISM HO the heating only model.

A.3. 12-Month Sliding Indicators

Next, 12-month sliding indicators were developed for the electricity consumption, coincident peak electric demand, non-coincident peak electric demand, and natural gas consumption. Sliding indicators display a moving average of the previous 12-months of consumption. Sliding PRISM was applied to the electricity consumption (PRISM CO), and to the natural gas consumption (PRISM HO). A 12-month moving average was used for both coincident and non-coincident peak electric demand.

A.4. Campus Square Footage

Next, the annual, weather-normalized consumption was divided by the cumulative conditioned areas it served. Since the campus buildings may receive some combination of hot-water (generated by consuming natural gas), chilled water or electricity this involved a separate index for each fuel type.

In Figures 15, 16, and 17 the cumulative campus conditioned areas are shown. In Figure 15 the cumulative campus square footage is shown for assigned, educational and general building designations from 1916 to 1990. In Figure 16 the cumulative square footage is shown for all buildings, those buildings receiving electricity, buildings receiving heating from the central plant, and buildings that receive cooling from the central plant. In Figure 17 cumulative conditioned area is shown for those buildings receiving electricity (diamond symbol), buildings receiving heating from the central plant (plus symbol), and buildings receiving cooling from the central plant (square symbol) for the period January 1983 through April 1990. To display this figure annual increases were averaged over 12-month periods.

The annual normalized natural gas consumption was divided by the conditioned area for heating. The annual normalized electricity and electric demand values were divided by the conditioned area for electricity.

A.5. Campus Enrollment

The next step in the normalization process was to express the energy consumption in terms of the number of students that were enrolled at the campus. In Figure 18 the historical campus enrollment by semester is shown. In this figure values are displayed for the monthly enrollment (square symbol), and for a 12-month moving average (+). Natural gas consumption, electricity use and electric demand were each expressed as a consumption per 1,000 students using the moving average student enrollment figure.

A.6. Use of Constant Dollars

The final adjustment to the consumption figures involved expressing the consumption in terms of constant dollars. Current costs for April 1990 were used for the constant dollar indices. The following values were used in the conversions:

1 kWh = 3413 Btu
1 MCF = 1.09 MBtu
N.G. = $2.11 /MBtu
kWh = $0.034645/kWh
kW (coincident) = $4.46/Peak-kW
kW (non-coincident) = $2.75/Peak-kW

These cost figures were obtained from the PVAM utility suppliers: Natural Gas costs were from the Texas Southeastern Gas Company, and Electricity costs were from the San Bernard Electric Cooperative.

Appendix B. Normalized Campus Energy Consumption

B.1. Weather & Area Normalized Consumption

Figure 19 displays weather and area normalized consumption expressed as 12-month sliding-average annual energy costs ($\$/ft^2$) for the period April 1987 through April 1990. Values are shown for the total energy use (x), electricity usage (kWh - the plus symbol), natural gas consumption (the square symbol), coincident peak electric demand (kW - the triangular symbol), and the non-coincident peak demand (kW - the diamond symbol).

B.2. Weather, Area & Enrollment Normalized Consumption

Figure 20 displays weather, area and enrollment normalized consumption expressed as 12-month sliding-average annual energy costs ($\$/ft^2$-1000 students) for the period April 1987 through April 1990. Values are shown for the total energy use (x), electricity usage (kWh - the plus symbol), natural gas consumption (the square symbol), coincident peak electric demand (kW - the triangular symbol), and the non-coincident peak demand (kW - the diamond symbol).

Appendix C. References

Haberl, J., Englander, S., Reynolds, C. 1989. *Whole-campus Performance Analysis Methods: Early Results from Studies at the Princeton Campus,* Proceedings of the 6th Annual Symposium on Improving Building Energy Efficiency in Hot and Humid Climates, Texas A&M University, Held in Dallas, Texas, October.

Fels, M. 1986. "Special Issue Devoted to Measuring Energy Savings: The Scorekeeping Approach", Energy and Buildings, Volume 9, Nos. 1 & 2.

N.W.S. 1990. "Local Climatological Data -- Monthly Summary," National Climatic Data Center, (Houston Airport), Asheville NC: National Weather Service (data for January 1980 through May 1990).

Figure 13: *Historical Monthly Average Ambient Temperature (Houston).* **Average monthly temperatures (Houston) for the period January 1980 through May 1990 are shown in this figure along with the ten-year monthly average (the plus symbol), and the variation between the monthly average and the 10-year average (the diamond symbol).**

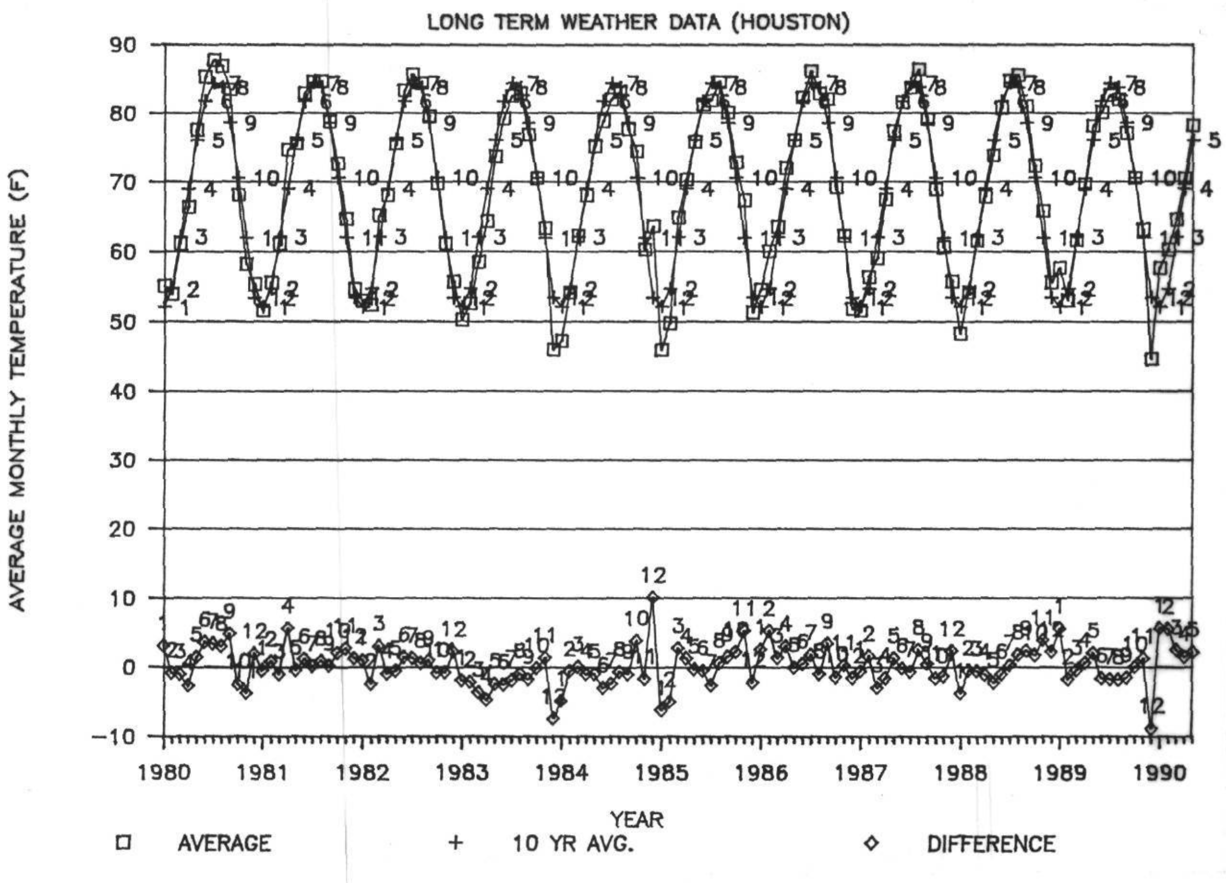
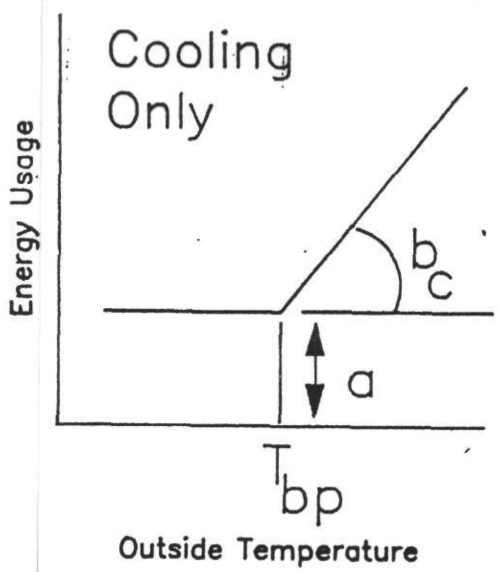


Figure 14: *Three-parameter Change-point Model.* A three-parameter change-point model is shown in this figure such as is used in the Princeton Scorekeeping, Cooling Only Model (PRISM CO), . Such a model is composed of a base-level, or non-weather dependent consumption (a), the change-point, or balance point temperature (T_{bp}), a cooling slope (b_c), and an error term (e).



$$F = a + b_c (T_a - T_{bp})^+ + e$$

***Figure 15:** Cumulative Campus Square Footage (Assigned, Education & General).* This figure displays the campus growth from 1916 to 1990. Square footage is shown for all buildings (GROSS), assignable space (ASSIGN), and education and general buildings (EDU.& GEN).

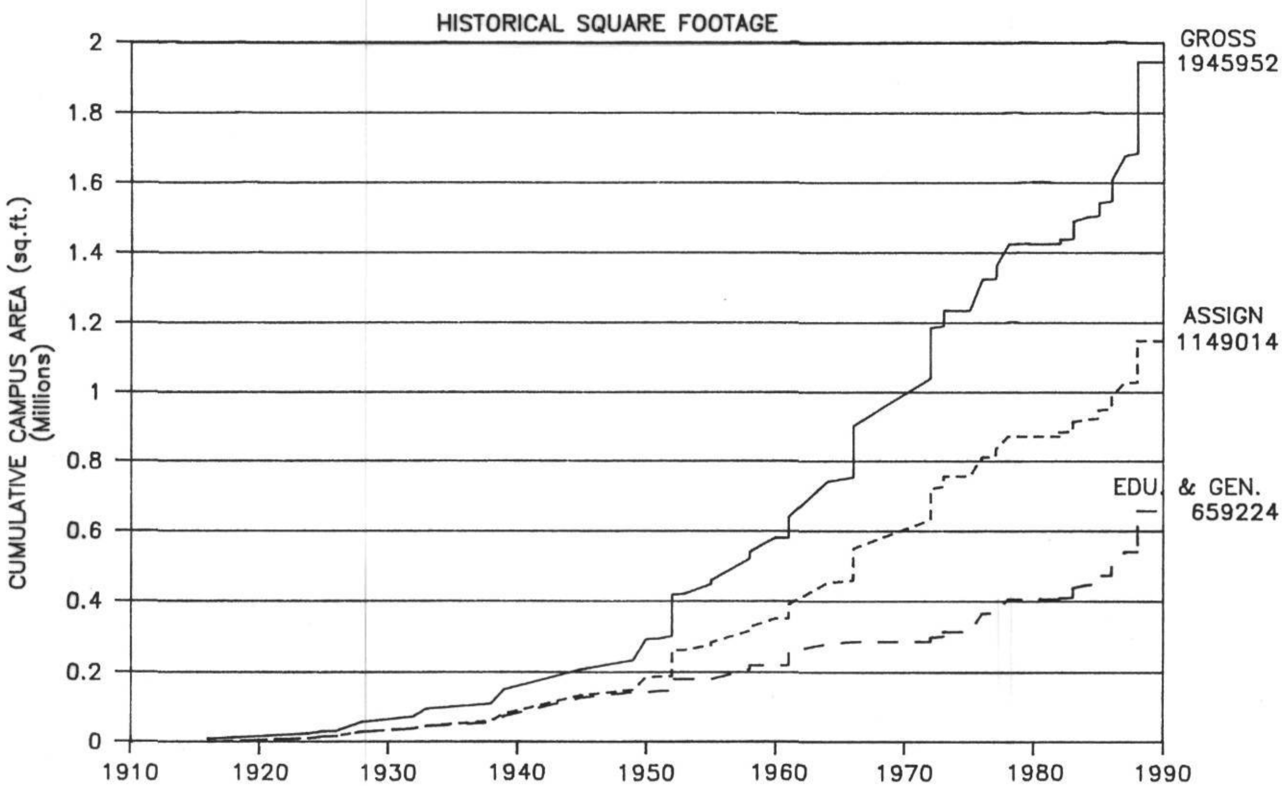


Figure 16: *Cumulative Campus Square Footage (Heating, Cooling & Electric).* **This figure displays the campus growth from 1916 to 1990. Square footage is shown for all buildings (GROSS), those buildings receiving electricity (ELECTRICITY), buildings receiving heating from the central plant (HEATING), and buildings that receive cooling from the central plant (COOLING).**

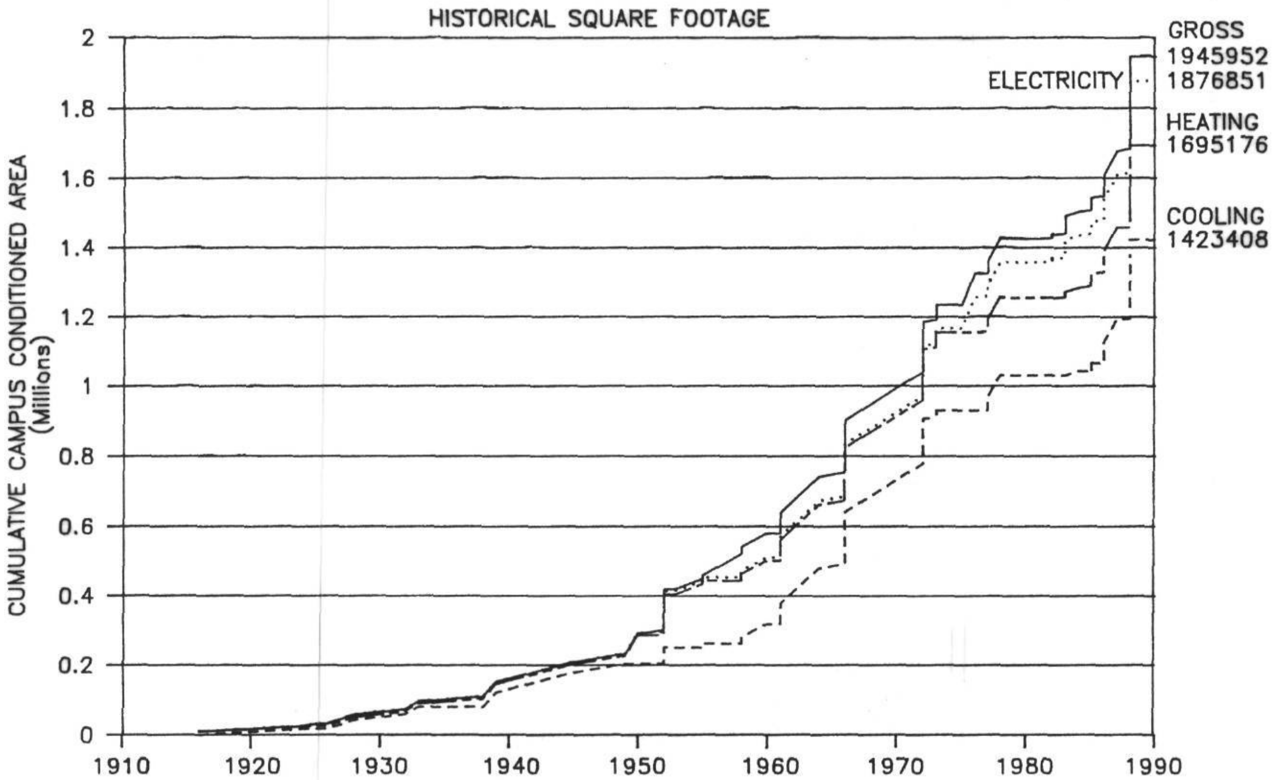


Figure 17: *Cumulative Campus Square Footage (1983-1990).* **Campus square footage for the period January 1983 through April 1990 is shown in this figure. Those buildings receiving electricity (diamond symbol), buildings receiving heating from the central plant (plus symbol), and buildings receiving cooling from the central plant (square symbol) are indicated. To display this figure annual increases were averaged over 12 monthly periods.**

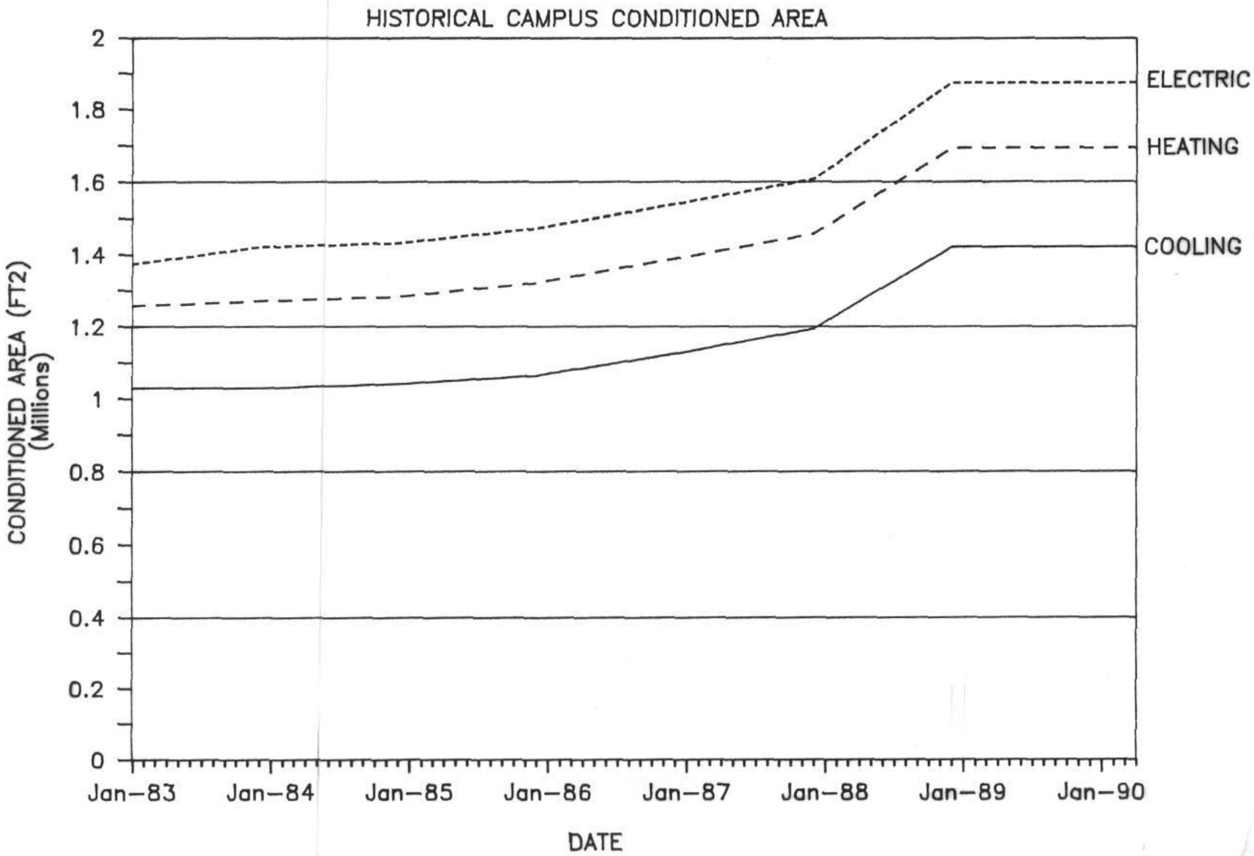


Figure 18: *Historical Campus Enrollment by Semester.* **This figure displays annual campus student enrollment. Values are displayed for the monthly enrollment (square symbol), and for a 12-month moving average (+).**

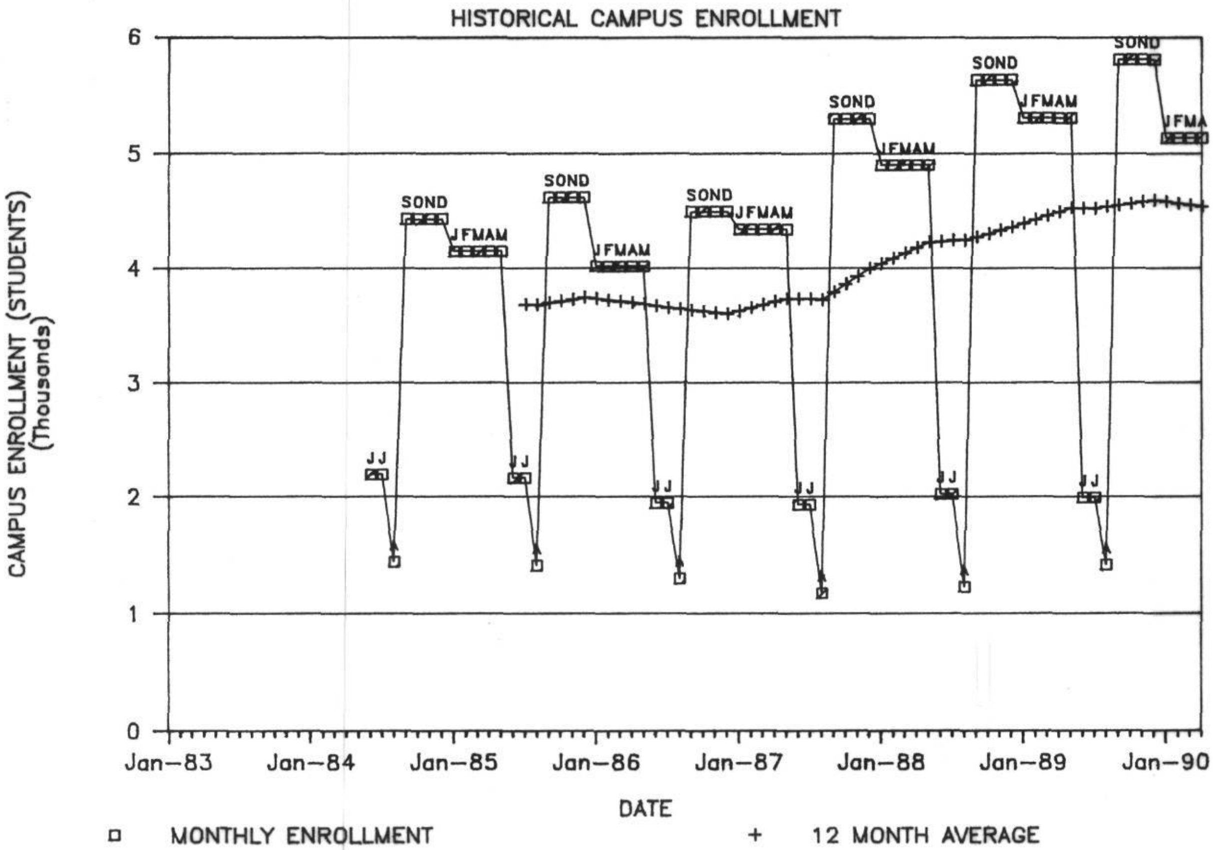


Figure 19: Weather Normalized Energy Costs Adjusted for Conditioned Area. **This figure displays 12-month sliding-average annual energy costs ($\$/ft^2$) for the period April 1987 through April 1990. Values are shown for the total energy use (x), electricity usage (kWh - the plus symbol), natural gas consumption (the square symbol), coincident peak electric demand (kW - the triangular symbol), and the non-coincident peak demand (kW - the diamond symbol). The electricity (kWh) and natural gas sliding averages have been weather normalized using a sliding PRISM analysis.**

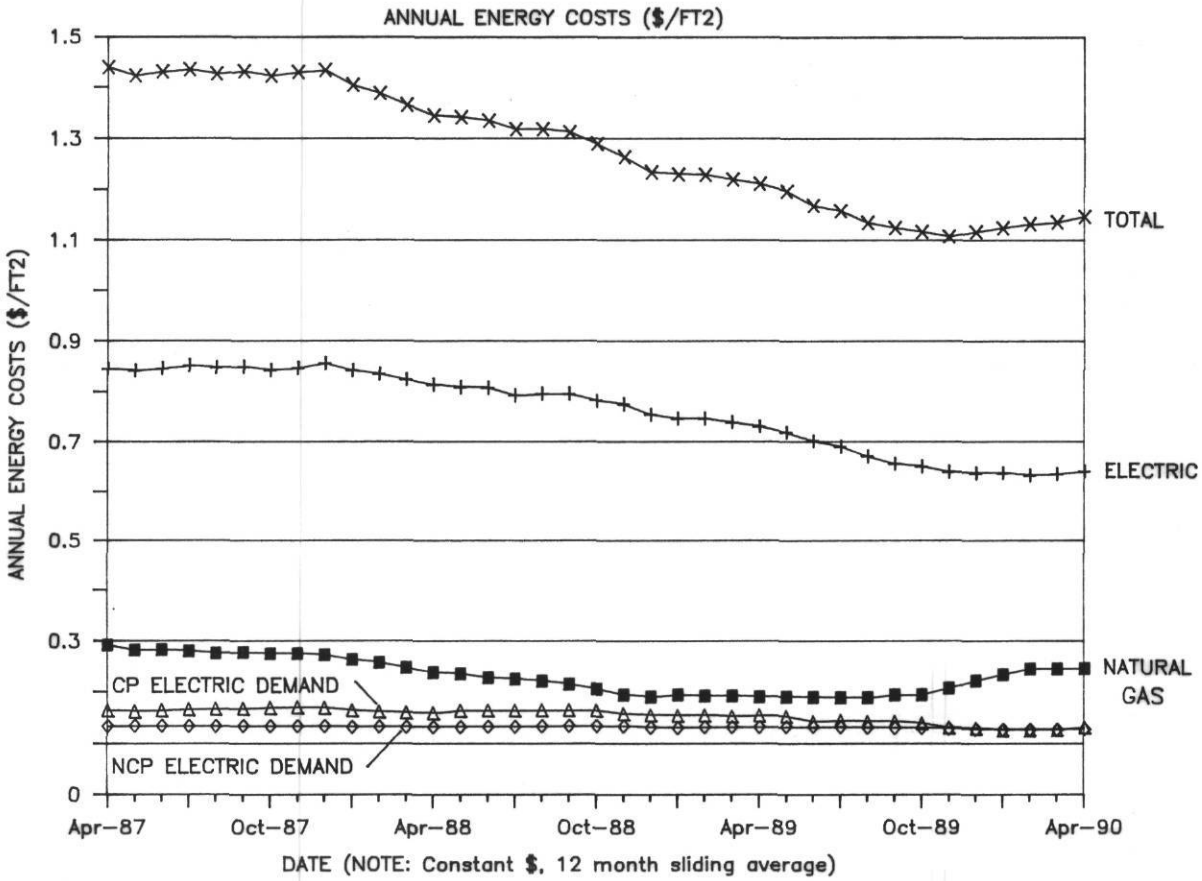


Figure 20: ***Weather Normalized Energy Costs Adjusted for Conditioned Area and Enrollment.*** **This figure displays 12-month sliding-average annual energy costs (\$/ft²-student) for the period April 1987 through April 1990. Values are shown for the total energy use (x), electricity usage (kWh - the plus symbol), natural gas consumption (the square symbol), coincident peak electric demand (kW - the triangular symbol), and the non-coincident peak demand (kW - the diamond symbol).**