

ENERGY CONSERVATION MEASURES AT  
AN AUTOMOTIVE INSTRUCTIONAL FACILITY

FRANK W. GODSEY  
Utilities Engineer, Physical Plant Department  
Texas State Technical Institute - Waco  
Waco, Texas

ABSTRACT

Energy consumption and costs to operate an automotive technical training facility at Texas State Technical Institute in Waco have been significantly reduced through implementation of several energy conservation measures.

This paper reviews building history and recent actions taken to reduce energy consumption and costs. Actual energy and cost savings are reported and compared to original estimates.

The conservation measures include group relamping with energy saving lamps, installation of occupancy sensor lighting controls, installation of a low speed chilled water pump, and installation of stand alone energy management systems with central communications capabilities.

Energy cost savings have exceeded seventeen thousand dollars per year and potential opportunities for further significant savings still exist. Detailed studies of hourly usage profiles and operating conditions have resulted in a recommendation that thermal storage and time-of-day rates be considered.

BUILDING OPERATING CHARACTERISTICS

Construction Description

The J. H. Kultgen Automotive Technical Center was built in 1970 to provide instructional facilities for a variety of automotive technical and mechanical disciplines. The single story 51,140 square foot building includes a 14,600 square foot high bay general lab which is similar to the service shops found in large modern auto dealer service centers. The rest of the building contains twelve large classroom and lab areas, faculty offices, toolrooms, and restrooms.

Construction of the building is a concrete slab and grade beam floor supported on drilled piers, concrete block masonry exterior walls, and steel interior columns. The roof over the general lab is prestressed concrete double tees with two inches of insulating concrete and built up roofing. The remainder of the roof is long span bar joist with galvanized steel deck, 1/2 inch rigid insulation board, and built up roofing.

The interior finishes are painted

concrete block exterior walls, plaster or drywall on metal and wood studs for interior partitions, movable partition walls between large labs, and suspended acoustical ceilings with lay-in insulation. The general lab ceiling is exposed concrete double tees.

There are only a few tall narrow windows with fixed glass which amount to less than five percent of the exterior wall area.

Mechanical Systems

The general lab has five rooftop 15 ton AC package units, three of which have natural gas heating, and eight large roof mounted exhaust fans.

Two 76 ton roof mounted air cooled water chillers serve the rest of the building through a 20 HP pump and loop system.

Heat to the rest of the building is provided by a 1,320 MBH output natural gas hot water boiler through a 10 HP pump and loop system.

Sixteen air handler units above the hallway ceilings are supplied by the four pipe hot water and chilled water system and provide heating or cooling to the labs, classrooms, and other areas. Each of the large classroom and lab air handler units was designed to furnish 100 percent outdoor air if desired. In addition, six wall mounted fan coil units are located in the hallways at entrance doors.

A 10 HP carbon monoxide exhaust system in the general lab is connected to an underfloor duct system.

Compressed air is piped throughout the building and is furnished by several air compressors located in the mechanical room and on the roof.

Domestic hot water is provided by a 75 gallon 360,000 BTUH input natural gas water heater and 1/3 HP recirculating pump.

The large classrooms and labs are pneumatically controlled as independent zones by individual thermostats.

Lighting

Hallway and restroom lighting is mostly by two tube 4 foot fluorescent recessed fixtures. The classroom, lab, and office lighting is primarily by four tube 4 foot fluorescent fixtures. The general lab lighting is by two tube 8 foot fixtures.

Exterior lighting is controlled by a

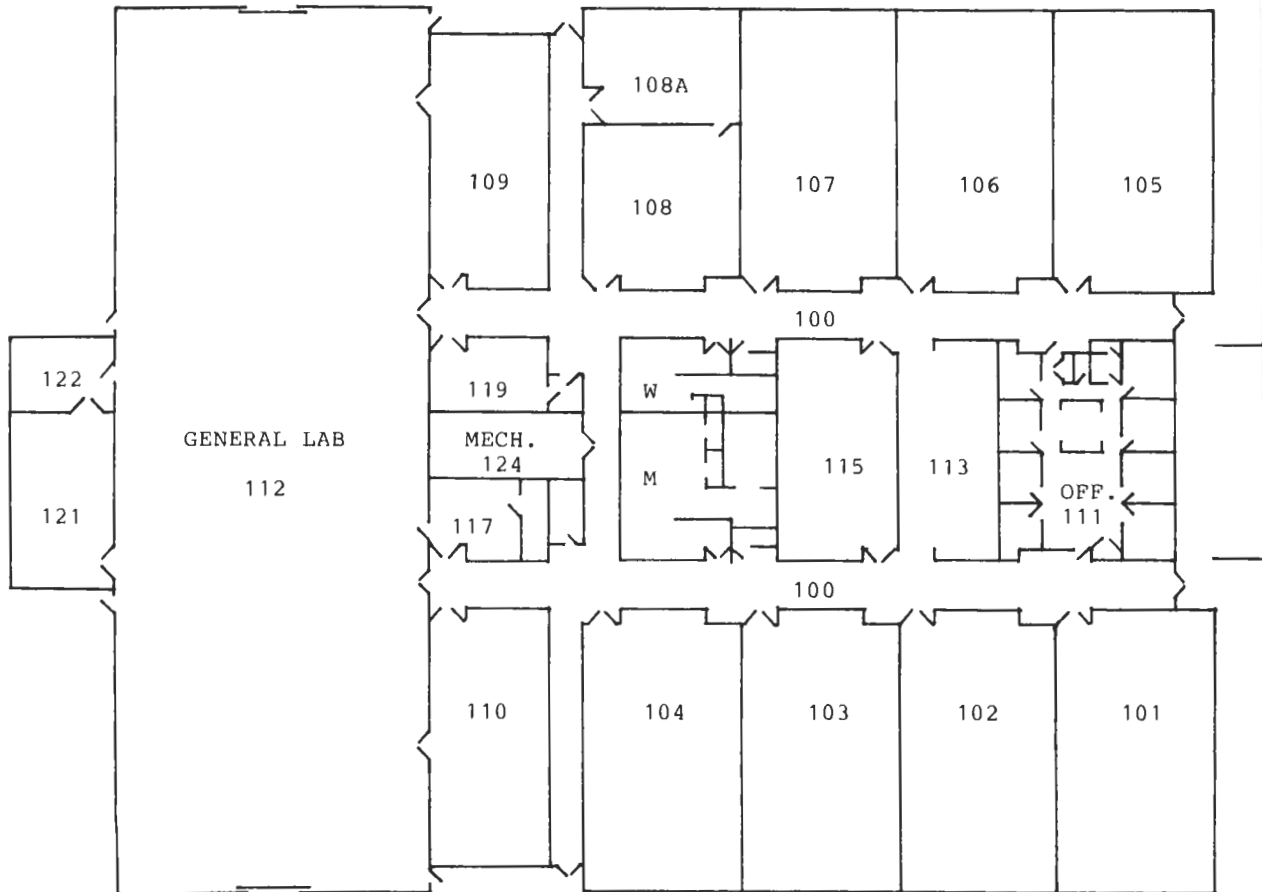


Figure 1 Plan of J. H. Kultgen Automotive Center

time clock.

#### Building Use

The Kultgen Center is normally occupied five days a week every week except about 10 days during Christmas and New Years. The hours are 8 AM to 5 PM Monday through Friday and some classes and labs are held from 6 PM to 10 PM on Monday through Thursday.

The hot water recirculating pump operates whenever the outside air temperature falls below 50 degrees fahrenheit.

#### PREVIOUS ENERGY CONSERVATION ACTIONS

About one year after the Kultgen Center was built, the 100 percent outside air dampers on the hallway air handlers were modified to permit a maximum of 10 percent outside air.

Time clocks were installed to control the two 25 HP air compressors on the roof. Air conditioning of the general lab

was discontinued in an effort to save about \$8,000 per year. It is now used only during fall registration and other special events.

The 75 watt 8 foot slimline fluorescent tubes in the general lab were changed to 60 watt energy saving tubes.

The four pipe HVAC system is never operated in heating and cooling modes at the same time.

Some of these actions and other events had already helped to reduce total annual energy consumption from over 180,000 site btu/sqft in FY1983 to 76,000 site btu/sqft in FY1985.

#### RECENT ENERGY CONSERVATION MEASURES

As a result of a Technical Assistance Audit completed in January, 1986, the following Energy Conservation Measures were implemented under the Institutional Conservation Program during the period from November, 1986, through June, 1987.

In addition, the TA Audit recommended

the hallway fan coils be disabled and air compressor timeclock trippers be reinstalled. The estimated total savings was \$1,302 per year with implementation cost estimated as none. These two maintenance and operations items were accomplished along with the installation of the energy management systems.

#### Energy Saving Lamps

This ECM consisted of group relamping 2,046 40 watt fluorescent lamps with energy saving 34 watt lamps. The implementation cost was estimated at \$3,269, the savings at \$2,176, and the simple payback at 1.5 years. The material and labor costs were limited to \$1.00 and \$0.50 per lamp, respectively, in accordance with the Institutional Conservation Program guidelines. A revised estimate showed implementation cost of \$5,561 and would result in a simple payback of 2.6 years.

Since the originally calculated payback was less than two years, this ECM was not eligible for funding under the Institutional Conservation Program. However, it was expected to be accomplished and the effects were included in the estimate of savings for the occupancy sensor lighting controls.

The ECM was completed as planned in November, 1986, at a total actual cost of \$3,457.74 by using TSTI personnel.

#### Occupancy Sensors

This ECM originally consisted of installing 28 lighting occupancy sensors in 10 classrooms and labs and 5 sensors for exhaust fans. The implementation cost was estimated at \$6,276, the savings at \$3,141, and the simple payback at 2.0 years.

The ECM was completed as planned for the lighting sensors in May, 1987, at a total actual cost of \$7,209.75. The exhaust fan controls were included in the energy management systems.

#### Energy Management System and Chilled Water Pump

This ECM originally consisted of installing an energy management system to optimize the start/stop of the chillers and chilled water pump, optimize the air handlers run time, optimize the hot water pump run time, and replace the chilled water pump with a two speed pump. The implementation cost was estimated at \$27,752, savings at \$12,264, and the simple payback at 2.3 years.

The ECM as actually installed went considerably beyond the scope of the original in order to achieve much greater control.

Rather than the original 20 control points, a total of 27 are functional with 13 additional points available. Each of the classrooms or labs have individual control in order to meet their different

schedules. Twenty seven exhaust fans are controlled with their respective spaces, individually, or in groups. The hall fan coils are controlled as a group. The air compressors are controlled by two channels. The chilled water system, hot water pump, and boiler are controlled by individual channels.

Instead of replacing the chilled water pump with a two speed pump, a second low speed pump was installed along with the additional piping and controls to automatically select the correct pump for the pressure and flow required. This gives the benefits of greater reliability, lower energy consumption, and having a backup pump in case of failure. Most of the three way chilled water valves on the air handlers were modified to eliminate the bypass.

The energy management systems installed are capable of time-of-day scheduling, duty cycling, demand limiting, holiday scheduling, and optimum start/stop. They are also equipped with the hardware and software to communicate with a personal computer in the Physical Plant offices over the campus telephone lines. This permits immediate evaluation of conditions at the site, remote transmission of program changes, and the daily performance of an automatic data polling operation.

The ECM was completed in June, 1987, at an actual installed cost of \$62,907.85.

#### Summary of Original Estimates

The totals of the original estimates for the three Energy Conservation Measures installed were \$37,297 for the implementation cost, \$17,581 for the savings, and simple payback of 2.1 years. Addition of the \$1,302 estimated savings for the two M&Os brings the total savings estimate to \$18,883 with a simple payback of 2.0 years for the project.

#### METHODS OF GATHERING AND ANALYZING DATA

The original Technical Assistance Audit electricity and natural gas consumption and cost data for the period from September, 1984 through August, 1985 were compared to original source billing documents, reviewed, and revised to be used as a Base Year of data for further comparisons. No major discrepancies were found.

Electricity and natural gas billing information was compiled for the calendar years 1987 and 1988 using a modification of the "SUMP - Energy Records and Analysis Program" for Schools. The "SUMP" program was also used for analysis of the Base Year data and to make comparisons between years.

Electricity and natural gas consumption data were collected for 1986 but reliable natural gas consumption figures for the first four months of the

year were not available so that total energy consumption comparisons could not be reliably made.

General information comparing the effects of weather variability, building occupant loading, building scheduling, and changes in building configuration was reviewed to determine if any significant impact on energy consumption could be found.

#### DISCUSSION OF RESULTS

A general review of annual cooling degree days and heating degree days for the years studied did not reveal any significant variation from normal which would distort the energy consumption totals.

During the period from 1984 through 1988, the basic configuration of the Kultgen Center has remained unchanged. No space has been removed or added and the room configurations and equipment have not been altered. Faculty and student population has undergone only minor change on an average annual basis. Class scheduling has shown a slight trend toward more evening classes recently. None of these factors would seem to have a significant impact on total annual energy consumption.

#### Energy Consumption and Cost Comparisons

The review of electricity consumption and costs revealed that KWH consumption decreased by 32.0 percent for 1987 compared to the Base Year and decreased by 33.2 percent for 1988 compared to the Base Year. Electricity cost for 1987 decreased by 29.8 percent for 1987 compared to the Base Year and decreased by 31.5 percent for 1988 compared to the Base Year.

The use of 1987 for comparisons could be questioned since the project implementation was not completed until June, 1987. However, some individual items were completed as early as November, 1986, and the major electricity conserving items were all operational before the 1987 peak summer air conditioning season was under way. Also, the monthly energy consumption profiles for early 1987 and 1988 reflect the relative usage one might reasonably expect as a result of the ECM changes. Therefore, it is thought that 1987 represents a reasonably good period to use for comparisons. 1988 represents a period in which all of the Energy Conservation Measures were fully operational and the energy management systems continued to be fine tuned and programs improved.

The review of natural gas consumption and costs revealed that gas consumption decreased by 24.4 percent for 1987 compared to the Base Year and decreased by 13.6 percent for 1988 compared to the Base Year. Natural gas costs decreased by 35.6 percent

for 1987 compared to the Base Year and decreased by 22.0 percent for 1988 compared to the Base Year.

The review of total energy consumption and costs revealed that site btu per square foot decreased by 30.1 percent for 1987 compared to the Base Year and decreased by 28.5 percent for 1988 compared to the Base Year. Total energy costs decreased by 30.7 percent for 1987 compared to the Base Year and decreased by 30.3 percent for 1988 compared to the Base Year.

During the three years involved in the comparisons, the unit cost of electricity per KWH at the Kultgen Center increased by less than 3.2 percent so that the impact on the cost savings was minimal. The unit cost of natural gas per MCF dropped by 14.8 percent from the Base Year until 1987 and then increased by 6.0 percent from 1987 until 1988. Had natural gas unit costs remained constant, the cost savings for 1987 and 1988 compared to the Base Year would have been greater.

Actual total energy cost savings compared to the Base Year were \$17,745 for 1987 and \$18,001 for 1988. Using an average of \$17,873 annual energy cost savings and a total project cost of \$73,575 the actual simple payback is 4.1 years.

#### CONCLUSIONS

It has been possible to achieve substantial energy savings in a building which had already undergone several previous successful efforts to reduce energy consumption. The installation of energy management systems presents additional opportunities for further energy savings because of the detailed analysis of hourly, daily and weekly energy consumption and peak loading which is now possible.

The Technical Assistance Audit presented a reasonable picture of the energy saving opportunities which existed and of the savings which could be achieved, although the energy management system and two speed pump ECM may have been slightly optimistic.

The Institutional Conservation Program was extremely instrumental in facilitating the completion of Energy Conservation Measures which might not otherwise have been identified or accomplished.

#### FURTHER OPPORTUNITIES

Since the energy management systems have made possible the detailed analysis of the hourly and daily load profiles, the Kultgen Center has been evaluated as a possible candidate for thermal storage. It was found that building usage patterns, energy consumption and peak load profiles, and the very poor efficiencies and extremely bad condition of the old chillers present a very attractive opportunity for

additional cost savings. The Kultgen Center has been recommended as a serious candidate for detailed analysis and design for installation of thermal storage and a change to time-of-day electric rates.

Louis Engelbrecht at TSTI-Waco for his support of this project and Mr. James McClure of Estes, McClure and Associates for his encouragement and for the "SUMP - Energy Records and Analysis Program" for Schools.

**ACKNOWLEDGEMENTS**

The author gratefully acknowledges Mr.

BUILDING NO: 28-03		J. H. KULTGEN AUTO TECH CNTR			9/84 THRU 8/85	
CAMPUS: TSTI-WACO		TOTAL ENERGY COST			BASE YEAR	
MONTH	ELEC (\$)	NAT. GAS (\$)	COST/SQFT	SITE BTU/SQFT	COMPARISON TO	
					-----NA-----	
					% COST	% BTU
SEP	4,529.83	0.00	.089	4,625		
OCT	4,235.19	8.79	.083	4,365		
NOV	4,167.64	97.30	.083	4,637		
DEC	3,908.34	862.13	.093	7,650		
JAN	3,758.52	1,420.88	.101	10,135		
FEB	3,530.82	1,309.65	.095	9,081		
MAR	3,485.27	618.41	.080	6,151		
APR	4,215.68	118.66	.085	5,029		
MAY	4,853.86	107.03	.097	6,210		
JUN	5,583.01	0.00	.109	5,946		
JUL	6,182.80	0.00	.121	6,607		
AUG	5,677.20	0.00	.111	5,886		
<b>TOTALS:</b>	<b>54,128.16</b>	<b>4,542.85</b>	<b>1.147</b>	<b>76,322</b>		

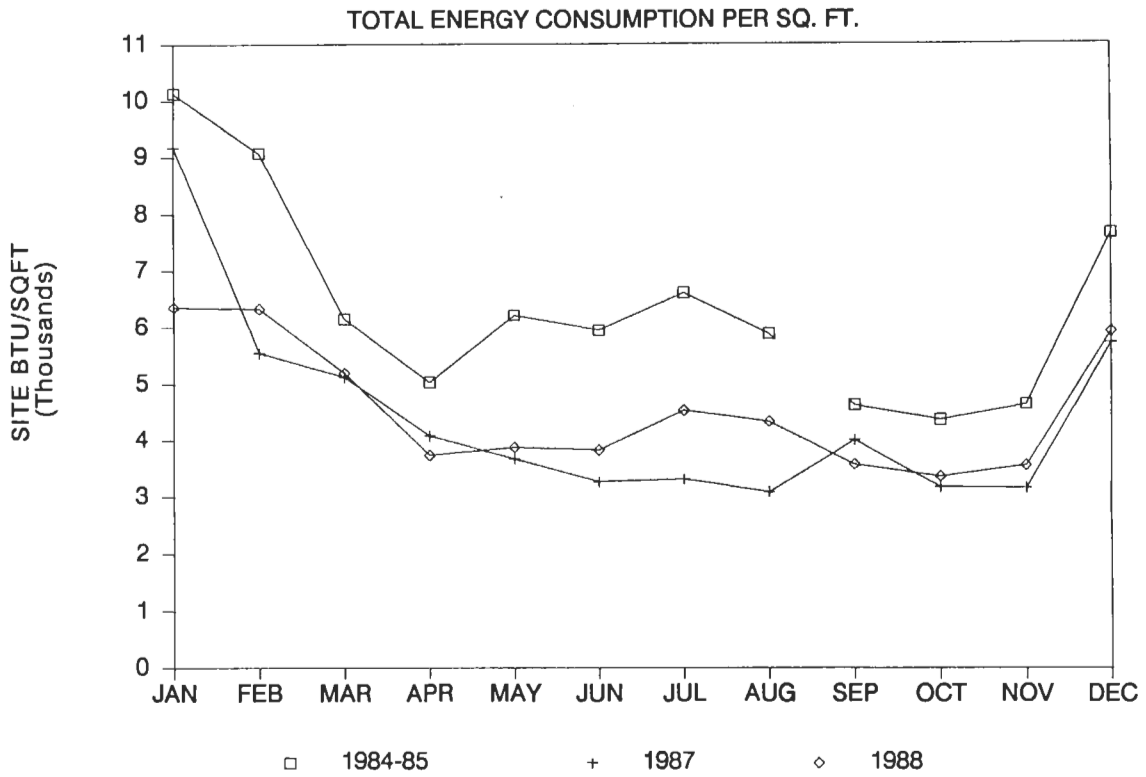
**Table 1 Base year energy consumption and cost**

BUILDING NO: 28-03		J. H. KULTGEN AUTO TECH CNTR (2 EMS)			1987	
CAMPUS: TSTI-WACO		TOTAL ENERGY COST			COMPARISON TO 9/84 THROUGH 8/85	
MONTH	ELEC (\$)	NAT. GAS (\$)	COST/SQFT	SITE BTU/SQFT	% COST	% BTU
JAN	2,964.48	1,163.79	.081	9,180	-19.8	-9.4
FEB	3,266.78	453.01	.073	5,552	-23.2	-38.9
MAR	3,422.76	262.83	.072	5,121	-10.0	-16.7
APR	2,713.53	133.72	.056	4,084	-34.1	-18.8
MAY	3,556.34	49.10	.071	3,682	-26.8	-40.7
JUN	3,258.68	12.11	.064	3,272	-41.3	-45.0
JUL	3,316.08	0.00	.065	3,310	-46.3	-49.9
AUG	3,093.92	15.28	.061	3,082	-45.0	-47.6
SEP	3,697.44	38.39	.073	4,002	-18.0	-13.5
OCT	3,083.97	56.13	.061	3,164	-26.5	-27.5
NOV	2,850.34	90.24	.058	3,150	-30.1	-32.1
DEC	2,758.70	651.58	.067	5,716	-28.0	-25.3
TOTALS:	37,983.02	2,926.18	.800	53,314	-30.3	-30.1

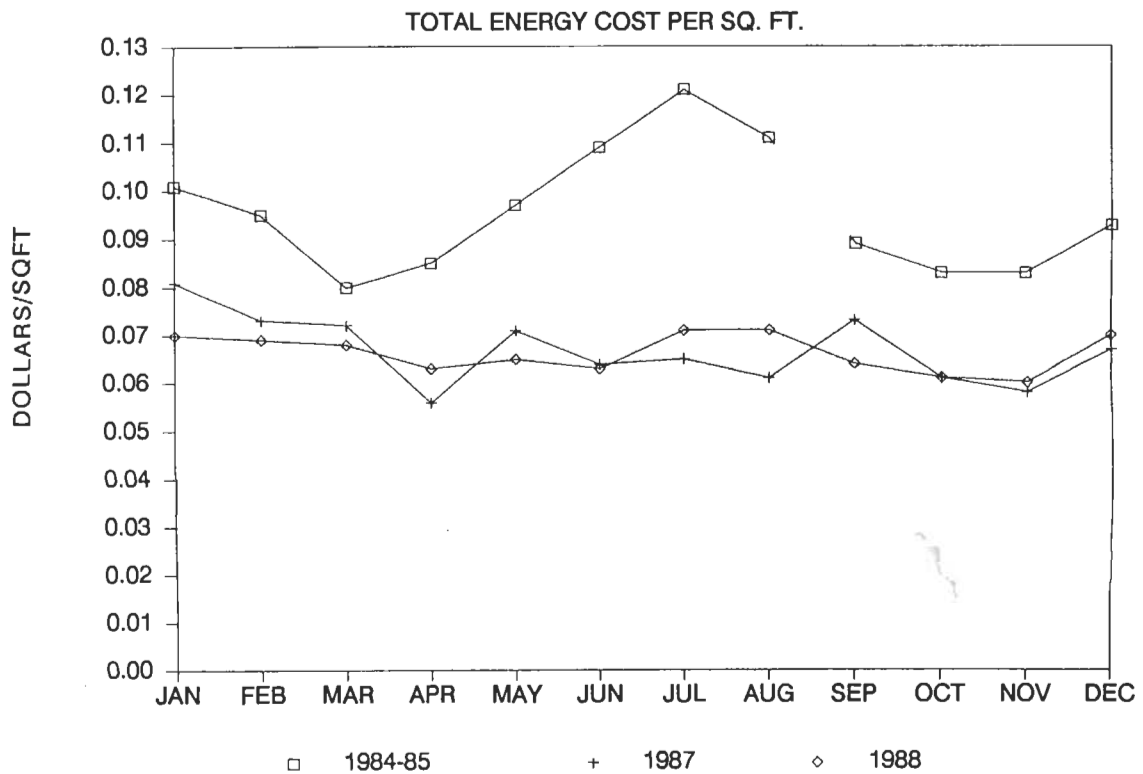
**Table 2 Energy consumption and cost for 1987**

BUILDING NO: 28-03		J. H. KULTGEN AUTO TECH CNTR (2 EMS)			1988	
CAMPUS: TSTI-WACO		TOTAL ENERGY COST			COMPARISON TO 9/84 THROUGH 8/85	
MONTH	ELEC (\$)	NAT. GAS (\$)	COST/SQFT	SITE BTU/SQFT	% COST	% BTU
JAN	2,758.63	830.86	.070	6,361	-30.7	-37.2
FEB	2,730.48	783.73	.069	6,328	-27.4	-30.3
MAR	2,995.47	485.12	.068	5,188	-15.0	-15.7
APR	3,068.27	143.38	.063	3,744	-25.9	-25.6
MAY	3,246.11	91.18	.065	3,878	-33.0	-38.3
JUN	3,143.80	99.67	.063	3,834	-42.2	-23.8
JUL	3,533.20	93.24	.071	4,528	-41.3	-31.5
AUG	3,511.57	97.79	.071	4,334	-36.0	-39.2
SEP	3,246.20	5.27	.064	3,578	-28.1	-22.6
OCT	3,078.33	50.96	.061	3,360	-26.5	-23.0
NOV	2,839.44	206.00	.060	3,561	-27.7	-23.2
DEC	2,940.12	657.66	.070	5,912	-24.7	-22.7
TOTALS:	37,091.62	3,544.86	.795	54,606	-30.7	-28.5

**Table 3 Energy consumption and cost for 1988**



**Figure 2 Total energy consumption per square foot**



**Figure 3 Total energy cost per square foot**

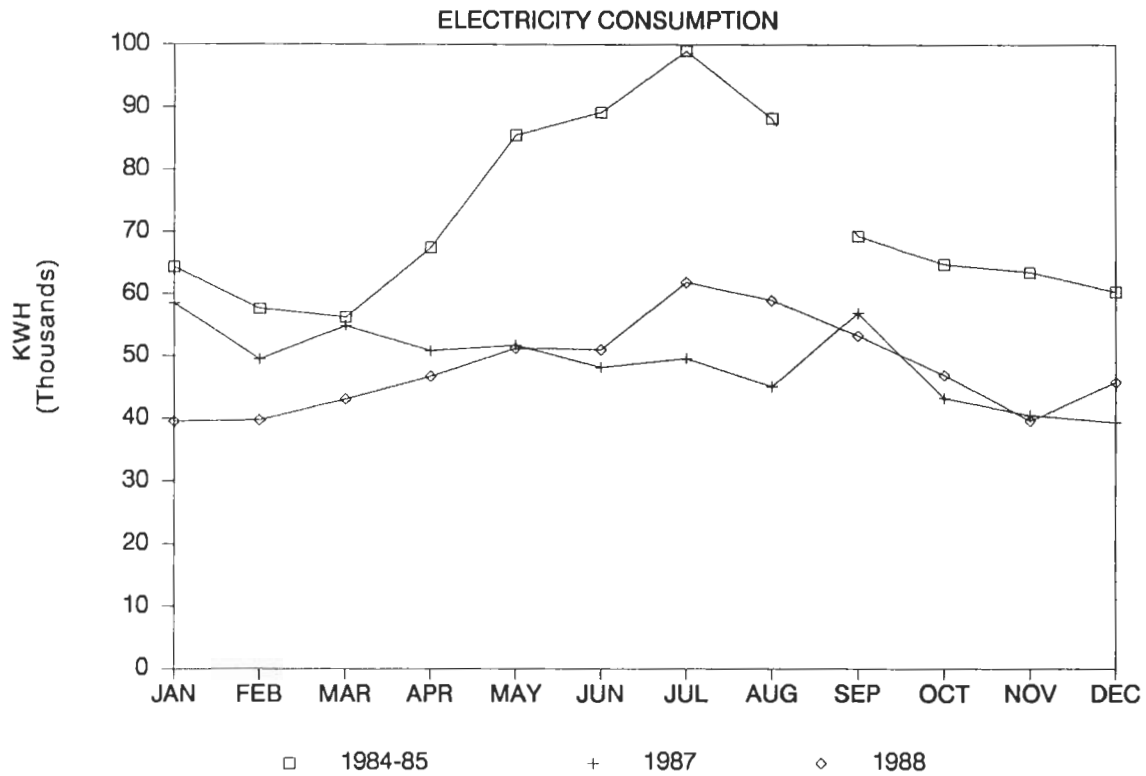


Figure 4 Electricity consumption

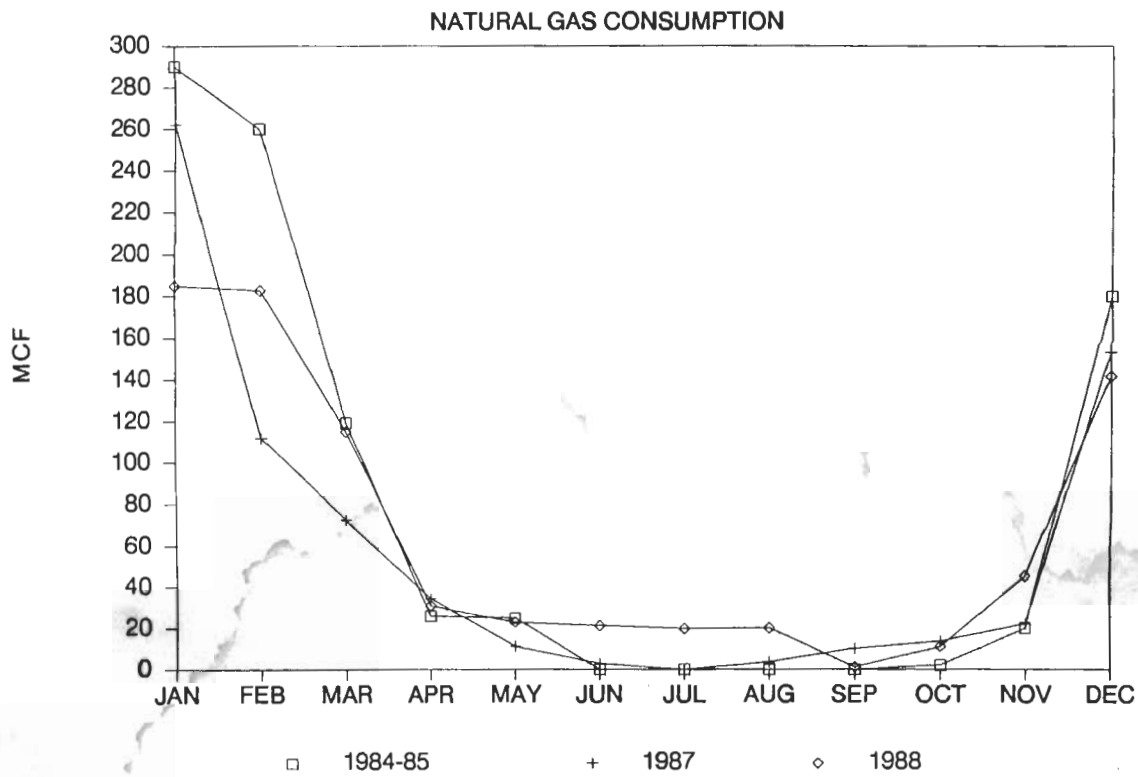


Figure 5 Natural gas consumption