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LoanSTAR Monitoring and Analysis Program

Potential Operation and Maintenance (O&M) Savings at the State Capitol Complex

Submitted to the
Texas Governor's Energy Office
By the
Monitoring Analysis Task

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EXECUTIVE SUMMARY

This report presents the results of a study of the potential cost savings by improving operations and maintenance (O&M) practices at eight buildings of the State Capitol Complex, monitored by the LoanSTAR program. This report discusses the methodology of identifying the O&M improvements, and summarizes the potential savings of these measures.

The O&M cost saving opportunities are summarized in the following table. Four buildings (SFA, LBJ, WBT, and JER) can have all or some of their air handlers turned off during unoccupied hours, while three buildings (SFA, LBJ, and WBT) can have all or some of their exhaust fans turned off during unoccupied hours. All buildings have significant energy saving potential by turning off lights and office machines during the unoccupied hours.

Summary of the O&M Opportunity and Savings

Building Name	Air Handler Units	Exhaust Fan	PC and Machines	Lights	Savings $/year
SFA	✓	✓	✓	✓	$162,400
LBJ	✓	✓	✓	✓	$135,300
WBT	✓	✓	✓	✓	$102,300
JER	✓		✓	✓	$31,300
JHR			✓	✓	$26,000
INS			✓	✓	$14,300
ARC			✓	✓	$8,000
JHW			✓	✓	$6,700
Savings $/year	$327,900	$6,600	$96,800	$55,000	$486,300

The savings estimated for each O&M measure are shown in the table above. The results show that a total of $486,300 annual savings (11.5% of current total energy cost)

can be expected for these eight buildings. The savings due to air handler and exhaust fan shutdown (including reduced heating and cooling expense) account for 69% of the total savings. This can be easily achieved by the building operators without extra cost. The savings from turning off lights and office machines account for 31% of the total savings.

It was found that the annual savings change significantly from building to building because the O&M measures and building size vary from building to building. Three buildings (SFA, LBJ, and WBT) account for 83% of the total savings for the eight buildings. Consequently, it is suggested that the highest priority be given to O&M modification in these three buildings.

The main body of this report first describes the methodology used to obtain potential O&M energy savings, and then summarizes the saving potentials for each building by O&M type as well as total savings potential of each type for all eight builddings. In the appendix, a more detailed discussion is included that addresses how the savings potentials were calculated.

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POTENTIAL OPERATION AND MAINTENANCE (O&M) SAVINGS AT THE STATE CAPITOL COMPLEX

INTRODUCTION

O&M savings refer to energy savings due to improved operation and maintenance of building systems. In many cases, improved operation of the building system, such as turning off the lights and HVAC systems during unoccupied hours, does not cost extra money, yet can save substantial energy and operating cost.

Eight buildings, at the State Capitol Complex, including Lyndon B. Johnson (**LBJ**), William B. Travis (**WBT**), Stephen F. Austin (**SFA**), Lorenzo De Zavala Archives (**ARC**), James E. Rudder (**JER**), John H. Reagan (**JHR**), State Insurance (**INS**), and John H. Winters (**JHW**) have been chosen to investigate the impact of O&M improvements on energy consumption and cost.

These buildings range in size from 80,000 to 491,000 square feet to total about 2.2 million square feet. The annual energy consumption costs vary from $129,736 to $1,117,585, totalling more than $4.2 million for these eight buildings from September 1, 1990 to August 31, 1991, according to gas and electric bills provided by the State Purchasing and General Services Commission (See Appendix A). The annual operating cost for each building is shown as a percentage of the total cost of all eight in a pie chart (Figure 1). Four buildings (JHW, SFA, LBJ, and WBT) account for 80% of the total cost.

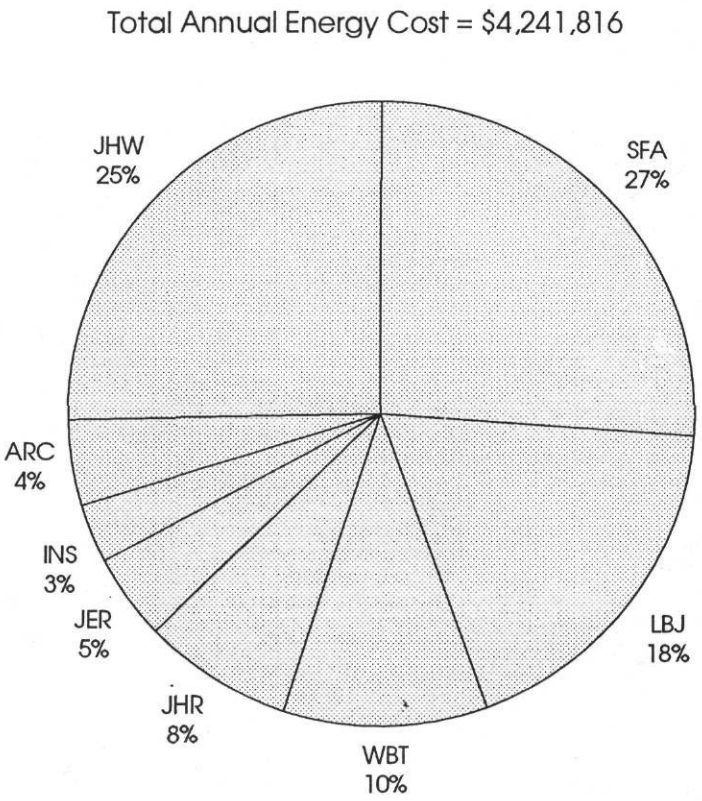

***Figure 1:** Annual Energy Operating Cost for Each Building as a Percentage of Total Annual Energy Operating Costs for Eight Buildings*

These buildings consume significant amounts of electricity and thermal energy supplied from two central plants. On average, consumption ranges from 1.8 W/ft² (ARC) to 5.6 W/ft². (JER). Many things can be learned from simple utility billing data such as W/ft², or $/ft². These buildings have had their hourly energy data, such as W/ft², recorded by the LoanSTAR program. However, LoanSTAR also provides a wealth of additional data, which allows areas of potential energy savings not available through simple utility building data to be explored. Hourly LoanSTAR monitored data shows that these eight buildings have ratios of the minimum to the maximum electricity consumption

in a range of 0.48 to 0.70 with an average value of 0.61[1]. These ratios are high when compared to buildings with similar uses, for example, Business Building-UTA, University Hall-UTA, Steindam-UT, Stroman H. S., and Victoria, H. S., which have ratios from 0.09 to 0.38 with an average of 0.19 when their HVAC systems are turned off during unoccupied hours. If the peak value is regarded as the approximate day time consumption, and the minimum value is regarded as the nighttime consumption, then the energy consumption of these eight buildings during unoccupied hours is between 48% and 70% of the energy consumption during occupied hours. Clearly, large energy savings may be expected from these buildings using simple operation and maintenance modifications, such as turning off lights, office machines, air handlers and exhaust fans during unoccupied hours.

A summary of general characteristics and energy use for these buildings is given in Table 1. It includes building size, HVAC type, annual cost, annual unit floor area cost, and the ratio of the minimum to the maximum electricity consumption. Note that four buildings, which have dual duct constant volume systems, have an average annual energy cost or energy use index (EUI) of $\$2.20/ft^2$, while four other buildings with variable volume systems have an average annual EUI of $\$1.56/ft^2$. Obviously, the system type is a major factor influencing the operating energy cost. However, the ratios of the minimum to the maximum electricity consumption are 0.60 and 0.63 respectively for buildings with constant volume systems and the buildings with variable volume systems. Therefore, this ratio depends mainly on the operation method rather than the system type. Consequently, the O&M savings potential should be evaluated by this ratio rather than the EUI.

[1] For example, see the LoanSTAR Monthly Energy Consumption Report (MECR), August 1992, published by the Monitoring Analysis Task of the LoanSTAR Program.

Table 1: *Summary of Building Characteristics and Energy Use for Eight Buildings in the Texas State Capitol Complex*

Building Name	Floor area (ft^2)	HVAC Type	Annual Energy Cost $	Annual $/$ft^2$ energy use	Annual Average Electric. W/ft^2	Ratio of Min/Max Electric. W/ft^2
SFA	470,000	Dual duct constant volume	1,117,585	2.38	4.5	0.55
LBJ	308,000	Dual duct constant volume	782,331	2.54	5.2	0.68
ARC	120,000	Dual duct constant volume	185,229	1.38	1.8	0.48
JER	80,000	Dual duct constant volume	331,305	2.48	5.6	0.70
JHR	169,746	Dual duct VAV	198,728	1.95	4.5	0.64
INS	102,000	Dual duct VAV	129,736	1.27	3.0	0.67
JHW	503,000	Single duct VAV	1,072,283	2.13	3.5	0.67
WBT	491,000	Single duct VAV	443,991	0.90	2.1	0.52
Total/Ave.	2,243746		4,261,188	2.04	3.8	0.61

Figure 2 shows gas and electricity cost from September 1990 to August 1991 for eight buildings at the State Capitol Complex. Clearly, the cost of gas is only 4% of the total cost, while electricity accounts for the remaining 96% of the cost. Since these buildings have predominately interior zones, it is expected that cooling must be a major energy cost and that heating costs would be small.

The practical operating and maintenance measures in this report, identified from field visits and short term tests using the monitoring systems, can result in a total of $486,300 savings annually in these eight buildings, or 11.5% of the total operating cost of $4,241,816. These measures, which require essentially no cost to implement, should not reduce the comfort level of the occupants.

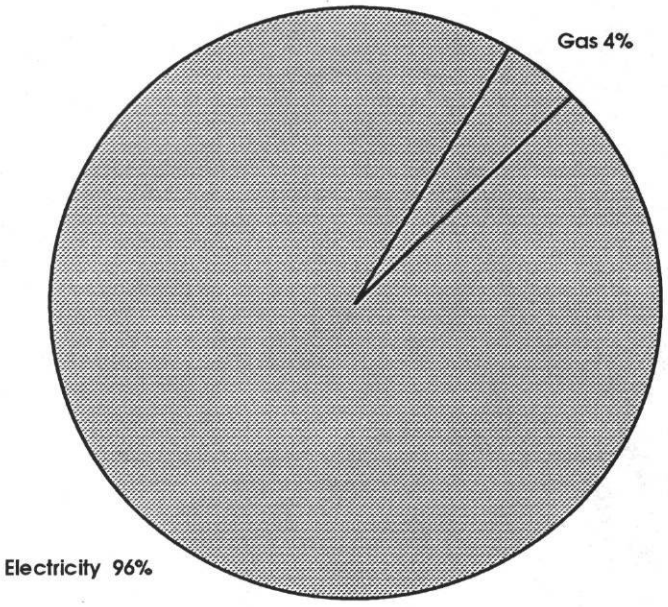

***Figure 2**: Operating Energy Cost Over September 1990 to August 1991 for Eight Buildings at State Capitol Complex*

This report briefly describes the methodology used to identify these O&M opportunities, presents the O&M savings expected from each measure and provides a more detailed description of the buildings and measures in the Appendix.

METHODOLOGY AND O&M OPPORTUNITY

The methodology used to find practical O&M opportunities, that will not degrade the indoor air conditions after they are implemented is outlined below.

1. Investigate the building operating patterns using LoanSTAR monitored electricity and thermal consumption data. The ratio of the minimum to the maximum electricity consumption is useful for determining the importance of turning off air-handling units, lights, exhaust fans, PCs and office machines. If this ratio is significant, substantial amounts of energy can be saved by turning off these machines. The eight buildings

investigated in this project have an average ratio of 0.61, which is large when compared to similar buildings in the LoanSTAR program.

2. Interview the building operators to determine the actual operating patterns, critical areas where equipment cannot be turned off, and the extent to which O&Ms are feasible. (For example, how many air handler units can be turned off during unoccupied hours without adverse effects on computers and occupants needs to be determined.)

3. Determine space temperatures, hot deck/cold deck temperatures, and lighting levels by daytime walk-throughs with the building operator. This step can locate the areas with higher lighting levels than needed, inappropriate set point temperatures, and determine the operating conditions of the cold and hot decks within the AHUs.

4. Determine space temperatures, percentage of office machines left on, and percentage of lighting and PCs left on by nighttime walk-throughs with the building operators. Both step 3 and step 6 provide information needed to determine potential savings from turning off these machines during unoccupied hours.

5. Survey actual computer and office machine loads on representative PCs, CRTs, printers, and copiers and compare to previously published reports[2] [1, 2, and 3]. These results are used with the results of step 4 (above) to determine potential savings from turning off these machines during unoccupied hours.

6. Determine the effect of turning off AHUs and/or lights by conducting short term tests on selected areas.

7. Inventory the AHUs and office machines in two buildings (LBJ and WBT) to establish criteria for other buildings.

These procedures were carried out in each building. The results are briefly summarized in Table 2. The night walk-throughs proved that many lights and office

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2 For example see the paper by Norford et al. in the proceedings of the 1988 ACEEE Summer Study. pp. 3.182-3.191, 1988 Washington, DC, ACEEE

machines are left on in every building after the workers have left the offices. For example, two walk-through surveys performed at 11:00 p.m. in the SFA, LBJ, and WBT buildings found that approximately 50% of the PCs and office machines and 60% to 70% of the lights were left on.

The lights are supposed to be turned off by custodial crews during the 5:30 p.m. to 2:00 a.m. period. If the workers turn off their office lights and machines when they leave, substantial electricity savings are expected.

The investigation has found that the air handlers in four buildings (SFA, LBJ, WBT, JER) can be turned off during unoccupied hours and turned back on in time to "freshen" the space in the morning, except for those serving the computer areas. However, four other buildings (JHR, INS, ARC, and JHW) cannot have their air handlers turned off because the air handlers serve both general office zones and computer areas where 24-hour operation is required. Further investigation is needed to determine the cost needed to modify systems in these buildings so major air handlers can be shut off during unoccupied hours to determine the corresponding savings.

Three buildings (SFA, LBJ and WBT) can have some or all of their exhaust fans turned off, while five other buildings must keep their exhaust fans running continually to ensure good indoor air quality.

The O&M savings were calculated for the electricity consumption and the thermal energy use in each building. The method used is summarized in Appendix B. The cooling and heating energy consumption profiles of buildings for which air handler shutdown during unoccupied hours is proposed were used to estimate the thermal savings expected from turning off air handlers. Details are given in Appendix C.

Table 2: Summary of O&M Opportunities

Building Name	Lights	Exhaust Fan	Air Handler Units	PC and Machines
SFA	✓	✓	✓	✓
LBJ	✓	✓	✓	✓
WBT	✓	✓	✓	✓
JER	✓		✓	✓
JHR	✓			✓
INS	✓			✓
ARC	✓			✓
JHW	✓			✓

RESULTS AND DISCUSSION

The O&M savings are summarized in Figure 3 by each O&M measure and by building. Clearly, three buildings (SFA, LBJ and WBT) account for the majority of the savings in the eight buildings. The savings of Figure 3 are listed in Table 3 to show the savings of each O&M measure more clearly. Turning off air handlers in four buildings alone (SFA, LBJ, WBT, JER) during unoccupied hours can result in savings from $6,300 to $47,000 annually with a yearly total of $115,600. The heating and cooling savings from turning off air handlers totals $221,300. Turning off exhaust fans in three buildings results in savings from $1,300 to $3,800 annually with a total of $6,600. Turning off office machines results in substantial savings for every building as well, ranging from $2,900 to $28,300, with a total of $96,800 for all eight buildings. Turning off lights during unoccupied hours results in savings from $2,400 to $10,900 with a total of $55,000 for the eight buildings. The total savings for all O&M opportunities are $486,300 annually.

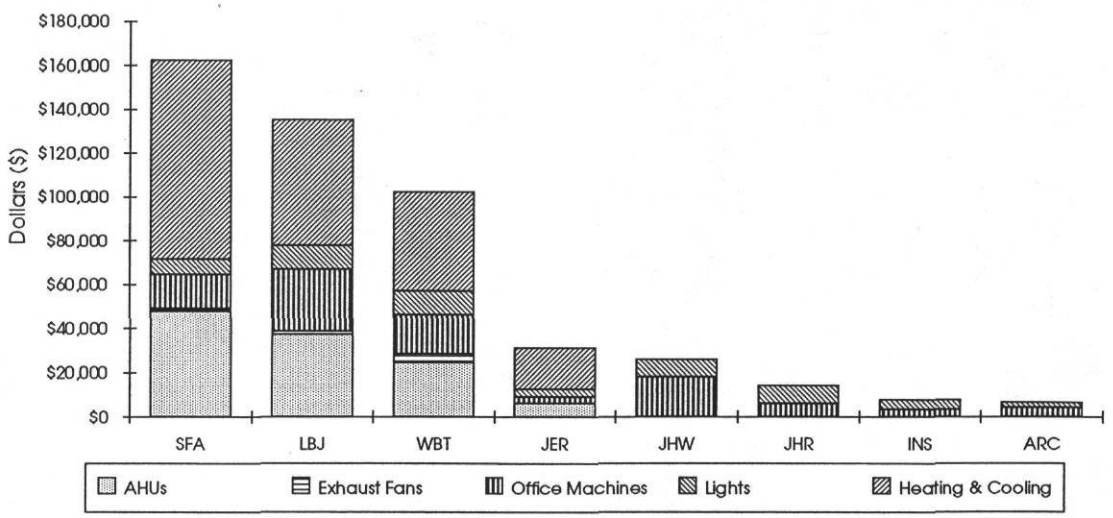

Figure 3: *Potential Annual O&M Savings for Eight Buildings in the State Capitol Complex*

Figure 4 shows the impact of each O&M measure on the total savings of eight buildings. The heating and cooling reductions account for 44% of the total savings while turning off air-handling units results in 24% of the total savings. These two together account for 68% of the total savings. The building operators can implement methods to achieve these savings easily. Furthermore, preliminary manual trials can be performed in each building to determine the optimum turn-on time in the morning to assure a "fresh" and healthy environment. Turning off office machines and lights during unoccupied hours results in 31% of the total savings. These savings can be realized by promoting an awareness of energy savings and environmental protection among the employees. One possible mechanism for this could be including an energy-saving news component to the newsletter with some possible employee recognition and presentation of measured results when the systems are turned off.

***Table 3**: Potential Annual O&M Savings for Eight Buildings in the Texas State Capital Complex*

Building Name	AHUs		Exhaust Fans	Office Machine	Lights	Total	$/kW
	Electric.	Heating & Cooling					
SFA	$47,600	$90,900	$1,500	$15,500	$6,900	$162,400	$0.02651
LBJ	37,200	57,600	1,300	28,300	10,900	135,300	0.03483
WBT	24,500	45,200	3,800	17,900	10,900	102,300	0.03483
JER	6,300	18,600	0	2,900	3,500	31,300	0.03470
JHW	0	0	0	18,100	7,900	26,000	0.03480
JHR	0	0	0	6,100	8,200	14,300	0.03470
INS	0	0	0	3,700	4,300	8,000	0.03480
ARC	0	0	0	4,300	2,400	6,700	$0.02540
Total	$115,600	$212,300	$6,600	$96,800	$55,000	$486,300	

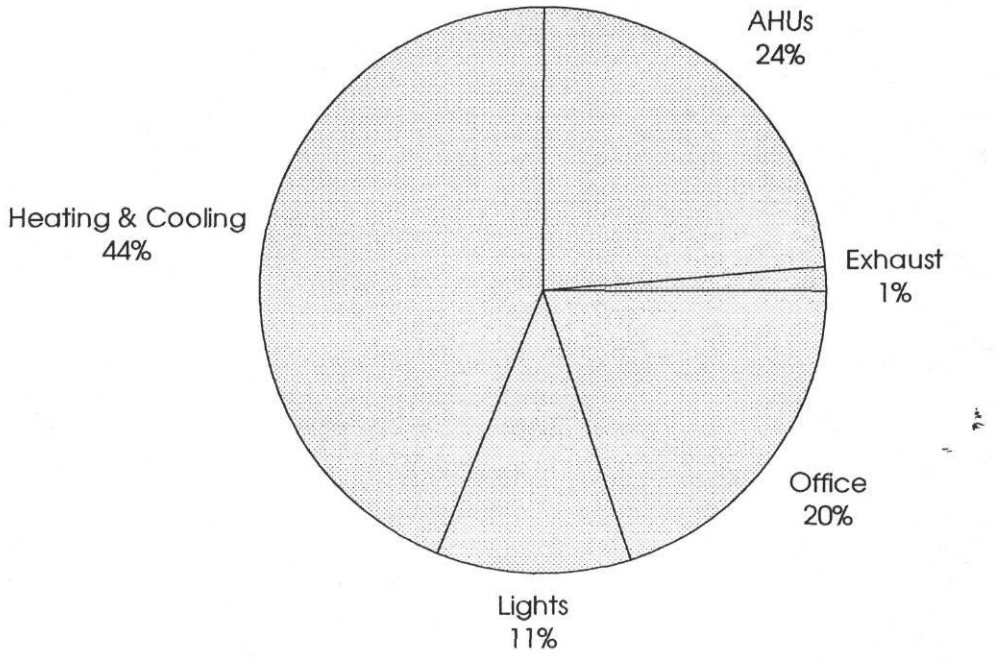

***Figure 4**: Energy Savings Fractions by Each O&M Measure*

The energy savings of the eight buildings are compared in Figure 5, which shows the savings for each building as a percentage of the total savings of the eight buildings. The savings of the SFA building are 34% of the total, while the savings of the ARC building are only 1% of the total. This large variation is largely due to differences in size and O&M measures from building to building. It is suggested that the SFA, WBT and LBJ buildings be given top priority for O&M modifications since these three buildings account for 83% of the total savings[3].

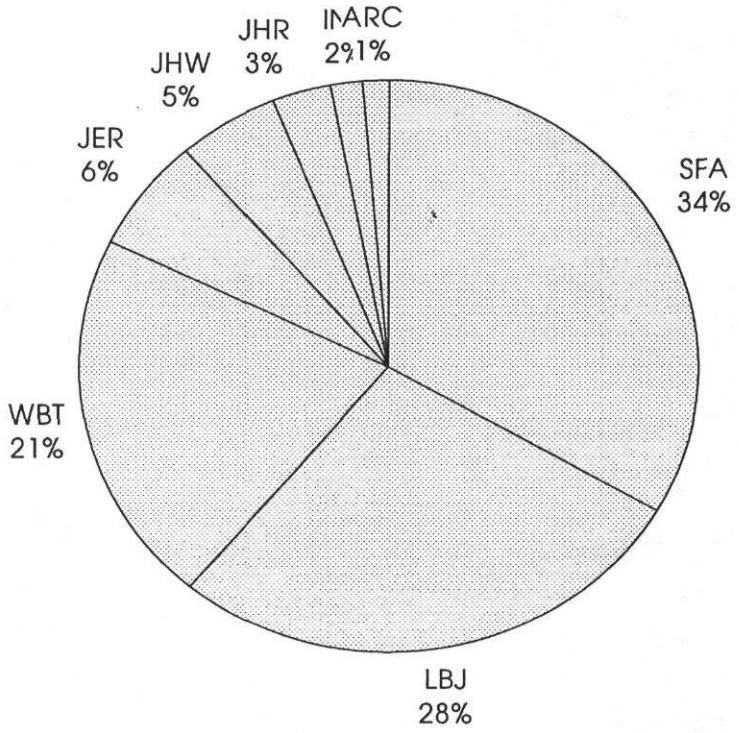

***Figure 5**: Energy Savings Percentage Distribution within Eight Buildings*

[3] Note that whenever ambient temperatures allow, WBT can have its air-handling units turned off during unoccupied hours. However, the air-handling units may not have enough capacity to warm up the building in the morning on extreme days because there are no outdoor air pre-heating coils. Furthermore, the heat exchanger that serves WBT may be undersized and cannot deliver enough heat to the entire building even if preheating coils were installed. These measures were addressed in the ECRM report by ACR Engineering and are addressed further in Appendix F of this report.

The O&M savings and total energy costs are compared in Table 4 for each building. The ratio of O&M savings to the annual cost ranges from 2.4% (JHW) to 23.04% (WBT) with an average of 11.46%. Although the savings ratio changes significantly from building to building, the O&M savings are substantial for every building.

***Table 4**: Comparison of O&M Savings to the Total Energy Cost*

Building Name	Total Energy Cost	O&M Savings	% Savings
SFA	$1,117,585	$162,400	15
LBJ	782,331	135,300	17
WBT	443,991	102,300	23
JHR	331,305	14,300	4
JER	198,728	31,300	16
INS	129,736	8,000	6
ARC	165,857	6,700	4
JHW	1,072,283	26,000	2
TOTAL	$4,241,816	$486,300	11.46

CONCLUSION

Potential O&M improvements have been investigated for eight buildings in the State Capitol Complex. The feasibility of air handler and exhaust fan shutdown was verified using day time walk-throughs with building operators. The energy savings potential of turning off lights and office machines was studied using night walk-throughs with building operators, short term measurement, and analysis of LoanSTAR measured electricity consumption data.

The study has found that four buildings can have all or some of their air handler units turned off during unoccupied hours, three buildings can have some or all of their exhaust fans turned off during unoccupied hours, and all the buildings have great energy savings potential by turning off lights and office machines during the unoccupied hours.

The potential savings have been estimated for each O&M measure for every building. The results show that a total of $486,300 (11.5% of total energy cost) annual savings can be expected for the eight buildings with an average of $60,788 for each building. The savings due to air-handling unit and exhaust fan shutdown account for 69% of the total savings, which can be easily achieved by the building operators without extra cost. The savings due to turning off lights and office machines account for 31% of the total savings which may be achieved by promoting an educational program addressing the importance of energy conservation and environmental protection to the state employees.

It was found that the annual savings vary significantly from building to building because the O&M measures and building size vary from building to building. The SFA, LBJ and WBT total 84% of the total savings for the eight buildings. Consequently, it is suggested that the highest priority be given to O&M modification in these three buildings.

REFERENCES

1. Norford, L. K., et. al. 1988, "The Sum of Megabytes Equals Gigawatts: Energy Consumption and Efficiency of Office PC's and Related Equipment," Proceedings of Commercial and Industral Building Technologies.

2. Haberl, J., and Komor, P., 1990, "Improving Energy Audits: How Annual Monthly Consumption Data Can Help," ASHRAE Journal August 1990.

3. Haberl, J., and Komor, P., 1990, "Improving Energy Audits: How Daily and Hourly Consumption Data Can Help," ASHRAE Journal, September, 1990.

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APPENDIX A: BUILDING AND O&M OPPORTUNITY

This appendix addresses the building structures, HVAC system types and the building energy performance monitored by the LoanSTAR program. All eight buildings are located at the State Capital Complex, Austin, Texas and have normal office hours from 8:00 a.m. to 5:00 p.m. during week days with HVAC systems operating 24 hours a day.

A-1. Lyndon B. Johnson (LBJ) Building

Building: The entire building contains 308,080 square feet and is used solely as an office building with an eleven-floor main section (a ground floor and a penthouse mechanical room) and a two-level section on the south side of the main section. The LBJ building is constructed with 3 to 4 inch granite slab walls. The roof deck is insulated with poured-in-place vermiculite all-weather materials. All windows are single pane. The building was constructed in 1969 and is in average condition (See Figure A-1).

It is important to note that part of the building is occupied more than 9 hours (8:00 a.m. to 5:00 p.m.). The entire fourth floor and a small area on the tenth floor, which houses mainframe computers, are occupied continuously. Forty percent of the fifth floor is occupied by office workers until as late as midnight during week days. The west side of this floor is a computer area. Other areas are occupied on average two days a week until as late as midnight to 2:00 a.m. when the legislature is in session.

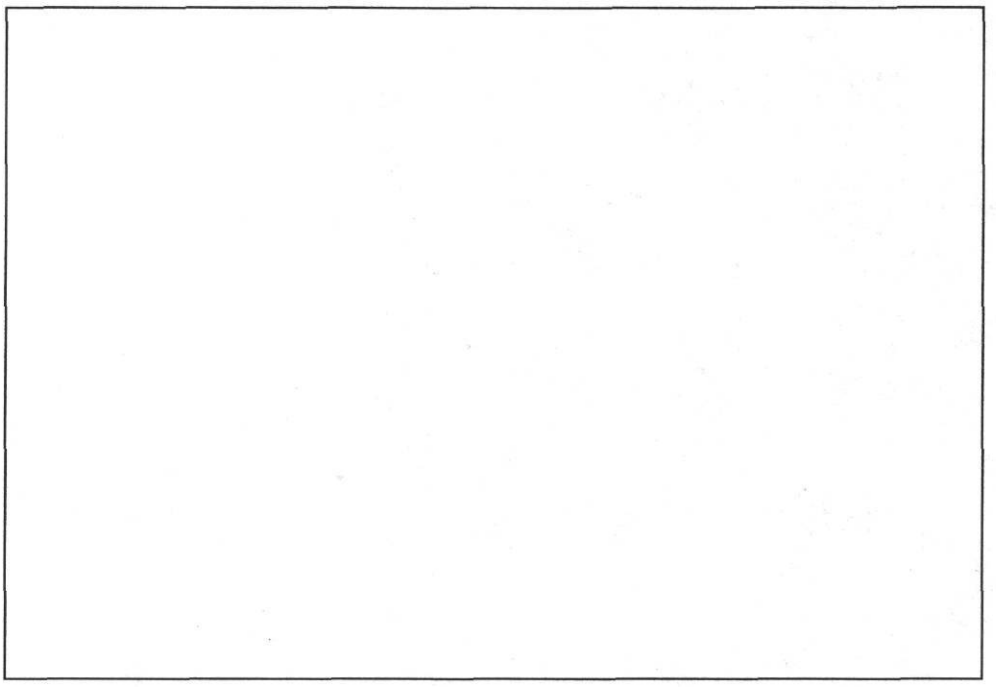

***Figure A-1**: Picture of Lyndon B. Johnson (LBJ) Building*

Heating, Ventilating, and Air Conditioning: LBJ obtains its chilled water from the SFA central plant at a temperature of 41°F, but produces hot water using two boilers located in the penthouse. There are 11 dual duct constant volume air-handling units, with one serving each floor. In addition, there are 15 stand-alone air handler units, which serve the computer spaces. This configuration permits most of the systems to be turned off during unoccupied hours.

Lighting: Most of the LBJ floor area is illuminated by fluorescent lamps. F40, four-foot, 34 watt lamps account for about 800 kW of total lighting load. There is a limited amount of incandescent (30 kW) lighting, mainly on the ground floor and first floor elevator lobbies. Total building lighting is 830 kW, or about 2.7 watts per square foot. Most lights are turned on and off manually by the custodial crew from 5:30 p.m. to 12:30 a.m.

Miscellaneous Energy-using Systems: Mainframe computers on the fourth floor represent a significant portion of the total electric consumption in the LBJ building, using

457 kW on average. On the third floor, there is a un-interruptable power supply system totaling 225 kW.

History of operating cost and electricity consumption: The annual operating costs totaled $782,331 from September 1, 1990 to August 31, 1991, according to utility bills, which equal $2.54/ft^2 per year. The annual average electricity consumption was measured at 5.2W/ft^2 with a ratio of 0.68 from the minimum to the maximum using LoanSTAR hourly data.

O&M opportunity and savings: Seventeen air handlers can be turned off during unoccupied hours, with a total power savings of 510 hp or 247 kW (See Appendix F for detail). Three exhaust fans can also be turned off during unoccupied hours, with a total savings of 17.5 hp or 8.5 kW. A substantial amount (396 and 253 kW, respectively)of lights and office machine power can also be saved during unoccupied hours.

The O&M savings were calculated using the method described in Appendices B and C. Turning off air handlers during unoccupied hours can result in electricity savings of $37,200 per year directly and cooling energy consumption savings of (thermal effects) $57,600 indirectly. Turning off exhaust fans can result in $1,300 savings during unoccupied hours. Turning off lights can result in $10,900 savings in electricity consumption, and $28,300 in electricity consumption can be saved by turning off office machines during unoccupied hours.

The O&M opportunities and savings are summarized in Table A-1. Column 1 lists the O&M opportunity, such as turning off air handlers, exhaust fans, lights and office machines. Column 2 lists the number of air handlers and exhaust fans that can be turned off during unoccupied hours. Column 3 lists the total power reduction for each O&M measure. Column 4 lists the total savings resulting from each O&M measure in units of dollars per year. Note that the savings due to air handler shutdown include both electricity and chilled water savings.

Table A-1: Summary of O&M Opportunity and Savings for Lyndon B. Johnson (LBJ) Building

Name	Number	Power Savings (kW)	Savings $/year
Air handlers shutdown	17	247	$94,800
Exhaust fan shutdown	3	8.5	$1,300
Lights turned off		396	$10,900
Office machines turned off		253	$28,300
Total		904,5	$135,300

A-2. William B. Travis (WBT) Building

Building: The WBT has twelve floors plus a basement, covering a total area of 491,000 square feet. Walls are constructed of granite slabs 3 to 4 inches thick and insulated with one inch of expanded polystyrene. The roof deck is insulated with 2 inches of rigid board. The windows in the building are double-pane. The building was constructed in 1985 and is in excellent condition.

Although the building is used solely as an office building with office hours from 8:00 a.m. to 5:00 p.m. during week days, parts of the fourth floor and eighth floor are occupied 24 hours per day for computer processing. Occasionally, workers stay late in other areas of the building, but only on an infrequent basis. The WBT building houses the Railroad Commission and the Texas Education Agency.

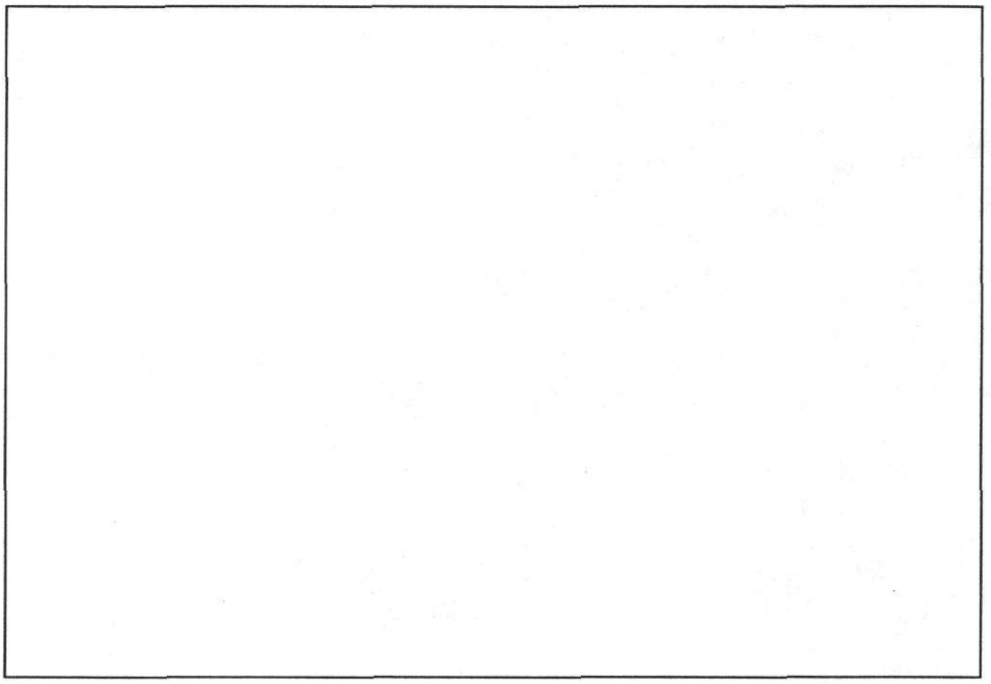

***Figure A-2**: Picture of William B. Travis (WBT) Building*

Heating, Ventilation, and Air Conditioning: The WBT receives chilled water and hot water from the SFA central plant at temperatures of 41 °F and 160 °F respectively. Twenty-two VAV air-handling units are used to serve floors two through twelve, two units for each floor. The ground floor has three single-zone constant volume units. The systems can be turned off floor by floor.

Currently, air handlers have no outdoor air intake because the systems cannot keep the building warm enough during cold weather and cannot remove enough moisture during hot weather.

All air handlers in this building are designed to be controlled by the Sam Houston energy management system located in the Sam Houston building. However, because of the HVAC problems described above, all air handler motor starters in the building have been switched to manual control instead and operate 24 hours per day.

Lighting: Most of the WBT floor area is illuminated by fluorescent lamps. F40, four-foot, 35 watt lamps in two by four foot, four lamp fixtures account for 585 kW, and F20 U-tube lamps in two by two foot fixtures account for 44 kW. There is a limited amount of incandescent (25 kW) and mercury vapor (16 kW) lighting, mainly on the first floor. Total building lighting is 670 kW, or about 1.5 watts per square foot.

Lights are supposed to be turned off by the custodial crews in the evenings from 5:30 p.m. to 2:30 a.m. However, the lights on some floors stay on until midnight or later, while others may have their lights turned off by 8:00 p.m. The main hallway lights remain on continuously.

Domestic Water and Hot Water: There are 7.5 hp duplex pumps located in the basement which pressurize domestic water to the building. The only domestic hot water in the building is provided by small electric hot water heaters located in the janitor's closets on each floor and by electric water heaters in the kitchen area.

Miscellaneous Energy-Using Systems: Computers and office equipment account for a significant amount of the total building energy consumption. The computers operate 24 hours per day, weekends included.

History of Operating Cost and Electricity Consumption: The annual operating costs totaled $443,991 from September 1, 1990 to August 31, 1991, according to utility bills from the State Purchasing and General Services Commission, equalling $0.90/ft^2 per year. The annual average electricity consumption was measured at 2.1W/ft^2 with a ratio of 0.52 from the minimum to the maximum using LoanSTAR hourly data.

O&M Opportunity and Savings: Twenty-five air handlers can be turned off during unoccupied hours, with a total power savings of 345 hp or 162 kW. Four exhaust fans can be turned off during unoccupied hours, with a total savings of 52 hp or 25 kW. The air handlers and exhaust fans could be turned off automatically if the current Honeywell Excel EMS system was reactivated. In addition, a planned ECRM includes the installation of

preheat coils on the fresh air intake; this would allow the AHUs to be turned off during unoccupied hours in the winter (See Appendix F for detail). A substantial amount (396 and 157 kW,respectively) of lights and office machine power can be saved during unoccupied hours.

The O&M savings were calculated using the method attached in Appendicies B and C. Turning off air handlers during unoccupied hours can result in electricity savings of $24,500 per year directly and cooling energy consumption savings (thermal effects) of $45,200 indirectly. Turning off exhaust fans can result in savings of $3,800. Turning off lights can result in $10,900 savings in electricity consumption, and $17,900 in electricity consumption can be saved by turning off office machines during unoccupied hours.

The O&M opportunities and savings are summarized in Table A-2. Column 1 lists the O&M opportunity, such as turning off air handlers, exhaust fans, lights and office machines. Column 2 lists the number of air handlers and exhaust fans which can be turned off during unoccupied hours. Column 3 lists the total power reduction for each O&M measure. Column 4 lists the total savings due to each O&M measure in units of dollars per year. Note that the savings due to air handler shutdown include both electricity and chilled water savings.

***Table A-2**: Summary of O&M Opportunity and Savings for William B. Travis (WBT) Building*

Name	Number	Power Savings (kW)	Savings $/year
Air handler shutdown	25	162	69,700
Exhaust fan shutdown	4	25	3,800
Lights turned off		396	10,900
Office machines turned off		157	17,900
Total		740	102,300

A-3. Stephen F. Austin (SFA) Building

Building: The SFA has eleven floors, plus an upper and lower basement, covering a total area of 470,000 square feet. The walls are constructed of Sunset Red granite, three to four inches thick, with no insulation. The roof is flat structure insulated with five inches of all-weather concrete. All glass areas are single pane. The building was constructed in 1973 and is in good physical condition.

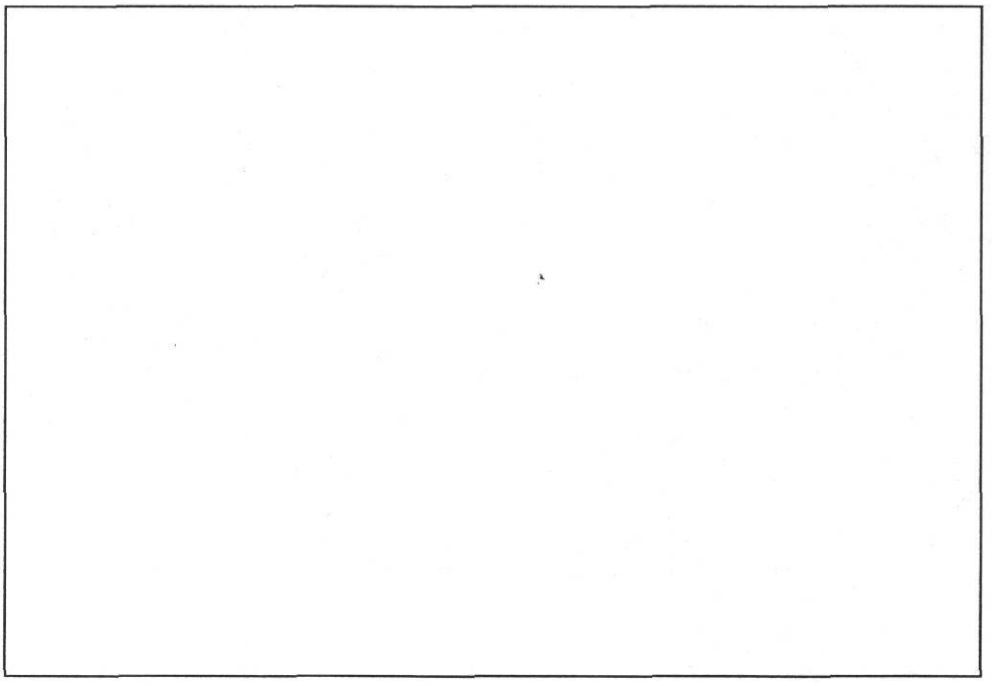

***Figure A-3**: Picture of Stephen F. Austin (SFA) Building*

Parts of the third and eighth floors are occupied until 11:30 p.m. and 1:00 a.m., respectively, by two to four persons. Workers stay late in other sections of the building, but only on an infrequent basis.

SFA houses the Texas Veterans Land Board, the Texas Water Commission, the General Land Office, and the Department of Agriculture.

Heating, Ventilating, and Air Conditioning: The SFA basement and upper basement contain centrifugal chiller and natural gas fired steam boilers. The chiller serves the SFA, LBJ, and WBT buildings with chilled water at 41°F to 42°F. The boilers supply steam to produce hot water, which is then pumped to the SFA and WBT buildings.

There are two dual-duct constant-volume air-handling units for each floor, or 22 AHUs in total for the building. The hot deck is controlled by a direct acting controller which maintains hot deck temperatures in a linear fashion according to outside air temperature. When outdoor air temperature is 40°F, hot deck is maintained at 96°F; when outdoor air temperature is 80°F, the hot deck is kept at 80°F. The systems can be turned off floor by floor.

Lighting: Most of the SFA floor area is illuminated by fluorescent lamps. F40, four-foot, watt-miser lamps account for about 950 kW. There is a limited amount of incandescent (60 kW) lighting, mainly on the ground floor. Total building lighting is 1010 kW, or about 2.2 watts per square foot.

Light switches are located in each office area. Lighting distribution panels are located in the mechanical rooms on each floor. Most lights are turned on and off manually by the custodial crew in the evenings; relatively few office occupants turn off the lights as they leave. The custodial crew starts work at 5:30 p.m. and works until 12:30 a.m. As the cleaning is completed in each room, the custodian turns off the lights. However, this operating procedure results in lights on some floors staying on until midnight or later, while others may be turned off by 8:00 p.m.

Miscellaneous Energy-Using Systems: Computers and office equipment account for a large portion of total energy use. The third floor mainframe computers total about 84 kW, and those on the eighth floor about 60 kW.

History of Operating Cost and Electricity Consumption: The annual operating costs totaled $1,117,585 from September 1, 1990 to August 31, 1991 according to utility

bills, equalling $4.5/ft^2$ per year. This extremely high unit floor cost is because this building supplies chilled and hot water to two other buildings. The annual average electricity consumption was measured at 4.5 W/ft^2 with a ratio of 0.55 of the minimum to the maximum using LoanSTAR hourly data.

O&M Opportunity and Savings: Twenty-two air handlers can be turned off during unoccupied hours, with a total power savings of 837 hp or 415 kW (See Appendix F for detail). Five exhaust fans can be turned off during unoccupied hours, with a total savings of 12 hp or 6 kW. A substantial amount (335 and 157 kW)of lights and office machine power can be saved during unoccupied hours.

The hot water pump to the WBT building can be turned off in the summer if a sweating problem on the hot water lines in the WBT building could be solved by O&M. This would necessitate the installation of valves at the main risers in the WBT building.

The steam control valves on the WBT steam to hot water heater exchanger need to be enlarged. In addition, the size of the existing heat exchanger should be verified and, if necessary, increased. See Appendix F for detail.

The O&M savings were calculated using the method attached in Appendix B and C. Turning off air handlers during unoccupied hours can result in electricity savings of $47,600 per year directly and cooling energy consumption savings of (thermal effects) $90,900 indirectly. Turning off exhaust fans can result in savings of $1,500. Turning off lights can result in $6,900 savings in electricity consumption, and $15,500 savings in electricity consumption for turning off office machines during unoccupied hours.

The O&M opportunities and savings are summarized in Table A-3. Column 1 lists the O&M opportunity, such as turning off air handlers, exhaust fans, lights and office machines. Column 2 lists the number of air handlers and exhaust fans which can be turned off during unoccupied hours. Column 3 lists the total power reduction for each O&M measure. Column 4 lists the total savings due to each O&M measure in units of dollars per

year. Note that the savings due to air handler shutdown include both electricity and chilled water savings.

Table A-3: Summary of O&M Opportunity and Savings for Stephen F. Austin (SFA) Building

Name	Number	Power Savings (kW)	Savings $/year
Air handlers shutdown	22	415	138,500
Exhaust fan shutdown	5	6	1,500
Lights turned off		335	6,900
Office machines turned off		189	15,500
Turn off Hot Water Pump	1	3.73	181*
Total		945	162,400

A-4. Lorenzo De Zavala Archives (ARC) Building

Building: The ARC building is a 5-story, 120,000 square foot building. Completed in 1960, it contains the Texas State Library and Archives, as well as offices for related departments. The building is constructed of Texas granite to match the nearby Capitol Building with few windows. The main portion of the building is five stories high, while the portion of the building containing the archives has seven stories in the same building height.

The building is occupied from 7:30 a.m. to 6:00 p.m., Monday through Friday, and the first floor is also open on Saturday for public access.

* This savings is not considered as O&M savings since retrofit is involved.

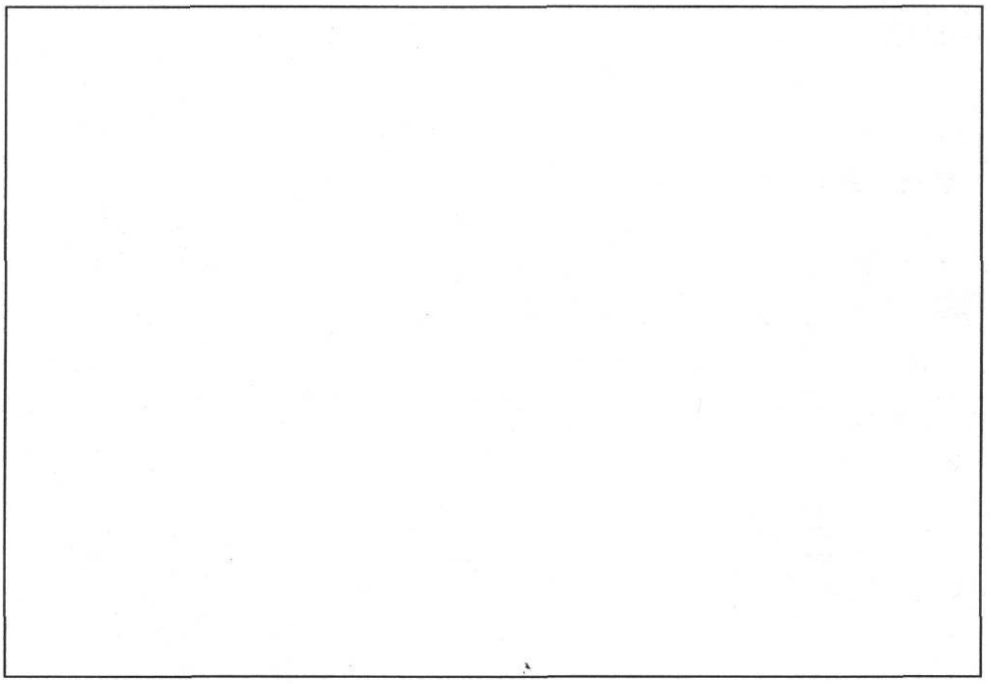

***Figure A-4**: Picture of Lorenzo De Zavala Archives (ARC) Building*

Heating, Ventilating, and Air Conditioning: The ARC building receives steam and chilled water from the central plant in the Sam Houston Building. Mechanical equipment serving the building is located in a basement mechanical room and the fifth floor penthouse. The chilled water pumps (20 and 30 hp) are located in the basement mechanical room. All air-handling equipment is located in the penthouse and includes 3 cold deck AHUs, 2 hot deck AHUs, and one multi-zone AHU. Two of the cold deck fans (40 hp) serve exterior zones in a dual duct system with the two hot deck fans (25 hp). The remaining cold deck fan (15 hp) serves interior zones of the buildings as a single zone AHU. The multi-zone constant volume dual duct AHU (15 hp) serves all the archive floors. Three return air fans (two at 15 hp and one at 5 hp) serve the building. The three cold deck and two hot deck fans have cable-operated inlet vanes for air volume regulation based on duct static pressure. However, the existing inlet vanes are difficult to adjust and

do not operate properly. A steam to hot water heat exchanger and a heating water circulating pump (10 hp) are also located in the penthouse. All controls in the building are pneumatic. Compressed air is supplied from a compressor located in the penthouse.

Lighting: The building lighting is almost 100% fluorescent with a small amount of incandescent lighting in the 2-story main lobby. The incandescent lighting is for aesthetics and the fixtures are not suitable for fluorescent retrofit. The fluorescent light fixtures all typically hold 4 lamps. All fluorescent lamps are 34 watt. Energy efficient ballasts have been installed in corridor light fixtures. Lights are normally turned off each night as custodial crews finish each area.

Domestic Hot Water: Domestic hot water is provided by a steam to hot water generator and a 1.4 hp circulating pump located in the basement mechanical room.

Miscellaneous Energy-Using Systems: This building has a computer room located in the basement. Chilled water is used by the room AHUs to provide cooling. The building was provided with a small DX, water-cooled chiller to serve the computer room, but this chiller has been disconnected from the piping and a small pump installed to circulate chilled water from the central power plant to the computer room.

History of Operating Cost and Electricity Consumption: The annual operating costs totaled $185,229 from September 1, 1990 to August 31, 1991, according to utility bills, which equals $1.38/ft^2 per year. The annual average electricity consumption was measured at 1.8 W/ft^2 with a ratio of 0.48 from the minimum to the maximum using LoanSTAR hourly data.

O&M Opportunity and Savings: No air handlers can be turned off during unoccupied hours. No exhaust fans can be turned off during unoccupied hours. However, a substantial amount (40 kW and 48 kW) of light and office machine power can be saved during unoccupied hours.

The O&M savings were calculated using the methods attached in Appendicies B and C. Turning off lights can result in $2,400 savings in electricity consumption, and $4,300 in electricity consumption by turning off office machines during unoccupied hours.

The O&M opportunities and savings are summarized in Table A-4. Column 1 lists the O&M opportunity, such as turning off air handlers, exhaust fans, lights and office machines. Column 2 lists the number of air handlers and exhaust fans which can be turned off during unoccupied hours. Column 3 lists the total power reduction for each O&M measure. Column 4 lists the total savings due to each O&M measure in units of dollars per year. Note that the savings due to air handler shutdown include both electricity and chilled water savings.

***Table A-4**: Summary of O&M Opportunity and Savings for Lorenzo De Zavala Archive (ARC) Building*

Name	Number	Power Savings (kW)	Savings $/year
Air handlers shutdown	0	0	0
Exhaust fan shutdown	0	0	0
Lights turned off		40	2,400
Office machines turned off		48	4,300
Total		88	6,700

A-5. James E. Rudder (JER) Building

Building: The JER has five floors plus a basement area, covering a total of 80,000 square feet, with masonry construction. Windows are single glazed with interior blinds. The roof deck is flat with insulation. The building underwent a major remodeling and

renovation in 1988, which incorporated a new chilled water generating system and air-handling system.

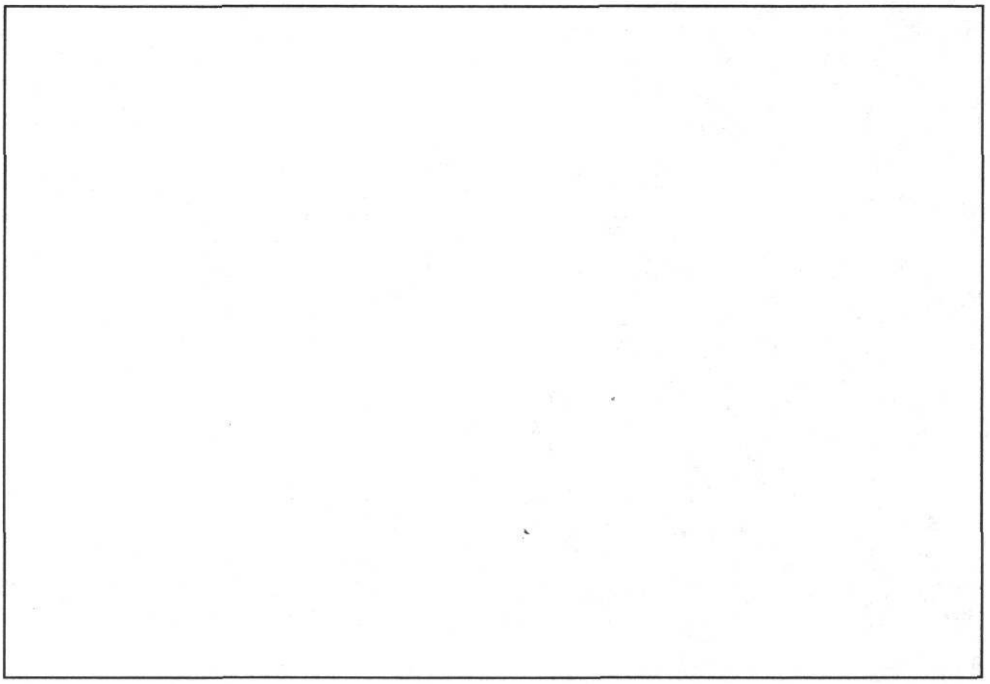

Figure A-5: Picture of James E. Rudder (JER) Building

The building is used as an office and administration building, containing the offices of the Secretary of State, a print shop, a major data processing area and computer facility. The building is occupied from 7:00 am to 6:00 p.m. on week-days.

Heating, Ventilating, and Air Conditioning: A 200 ton centrifugal chiller is used to supply chilled water to the administration portion of the building. Another 60 ton reciprocating chiller provides chilled water to the data processing area. The building uses steam from the SHB central plant for heating.

The Administrative areas of the building are heated and cooled by individual blow - through multi-zone air-handling units, one for each floor. The air-handling units are arranged in the "Texas multi-zone" configuration, with individual hot water heating coils

in each main zone duct, and three zones on each floor. The hot deck of the air-handling unit does not contain a heating coil.

Each zone duct serves several fan-powered boxes which permit individual control for individual office, or group of offices. The fan powered boxes permit the introduction of return plenum air into the supply air stream to the controlled space to prevent overcooling.

Return air fans are provided for each multi-zone air-handling unit.

Lighting: Fluorescent, with 4 ft, 34 watt energy efficient lamps installed in 1988. The fixtures are set up for multiple switching with 33%, 66% or 100% of full rated capacity available. In addition, the light fixtures in the rest rooms are controlled by motion sensors. Total building lighting is 190 kW or 2.3 W/ft^2.

Domestic Hot Water: Domestic hot water is provided by individual electric water heaters on each floor.

Miscellaneous Energy-Using System: This building has a 4,000 square foot computer facility. Chilled water is provided by three floor-mounted package air-handling units. These are supplied by a nominal 60-ton reciprocating chillier.

History of Operating Cost and Electricity Consumption: The annual operating costs totaled $198,728 from September 1, 1990 to August 31, 1991 according to utility bills provided by the provided by the State Purchasing and General Services Commission, which equals $2.48 $/ft^2$ per year. The annual average electricity consumption was measured at 5.6 W/ft^2 with a ratio of 0.70 from the minimum and the maximum using LoanSTAR hourly data.

O&M Opportunity and Savings: Six air handlers can be turned off during unoccupied hours, with a total power of 95 hp or 46 kW (See Appendix F for detail). No exhaust fans can be turned off during unoccupied hours. A substantial amount (60 and 32 kW) of lights and office machine power can be saved during unoccupied hours.

The O&M savings were calculated using the methods attached in Appendicies B and C. Turning off air handlers during unoccupied hours can result in electricity savings of $6,300 per year directly and cooling energy consumption savings of (thermal effects) $18,600 indirectly. Turning off lights can result in $3,500 savings in electricity consumption, and $2,900 savings in electricity consumption for turning off office machines during unoccupied hours.

The O&M opportunities and savings are summarized in Table A-5. Column 1 lists the O&M opportunity, such as turning off air handlers, exhaust fans, lights and office machines. Column 2 lists the number of air handlers and exhaust fans which can be turned off during unoccupied hours. Column 3 lists the total power reduction for each O&M measure. Column 4 lists the total saving due to each O&M measure in units of dollars per year. Note that the savings due to air handler shutdown include both electricity and chilled water savings.

***Figure A-5**: Summary of O&M Opportunity and Savings for James E. Rudder (JER) Building*

Name	Number	Power Savings (kW)	Savings $/year
Air handlers shutdown	6	46	24,900
Exhaust fan shutdown	0	0	0
Lights turned off		60	6,300
Office machines turned off		32	2,900
Total		138	31,300

A-6. John H. Reagan (JHR) Building

Building: The JHR was constructed with five stories in 1961 and contains 121,000 square feet of floor area. The building has Texas Granite wall and narrow single pane

windows at 10 ft O. C. on all four sides. The building is currently in good condition. The building houses offices for various state government agencies as well as several large hearing rooms on the first floor. Most areas of the building are occupied from 7:00 a.m. to 6:00 p.m. on week days. However, the meeting rooms and lobby on the first floor are in heavy use from 7:00 a.m. to 10:00 p.m. on week days, and the fifth floor computer room operates 24 hours.

Heating, Ventilating and Air Conditioning: The building gets chilled water and hot water from the SHB central plant. The basement houses the mechanical equipment serving this building. The air handler consists of two 75 hp cold deck fans with variable speed controls and one 50 hp hot deck fan with inlet vanes. There is also a 25 hp, 2 speed return air fan and a 5 hp fresh air unit which supplies conditioned outside air to the building air handler.

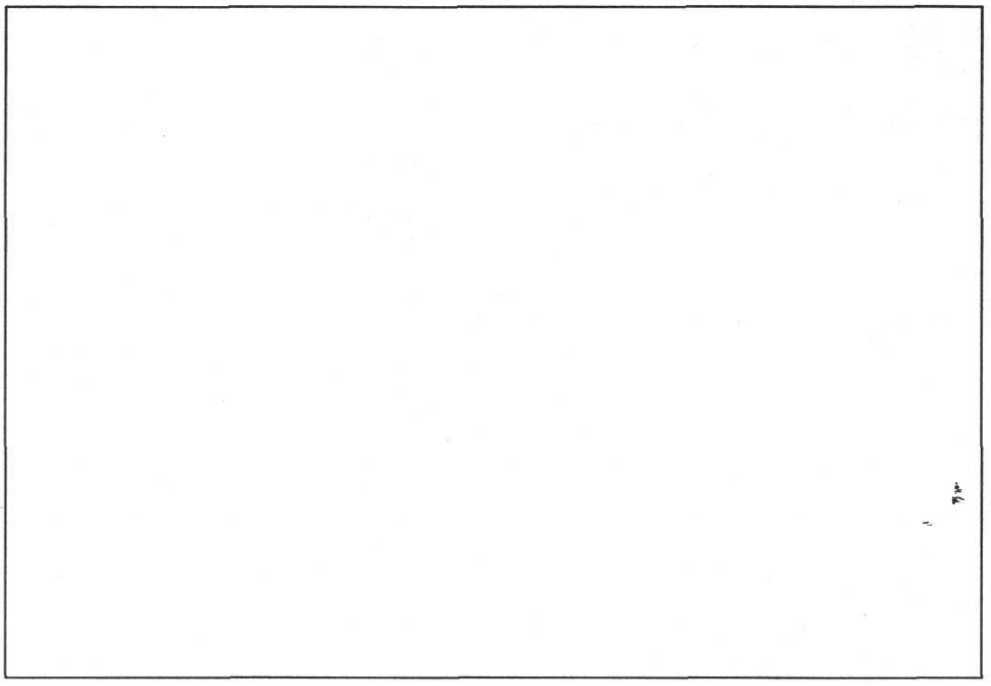

***Figure A-6**: Picture of John H. Reagan (JHR) Building*

Lighting: Fluorescent lighting is used in this building except for the first floor where some incandescent lighting is installed. Lighting levels are very high in corridors except on the fifth floor where the lights have been delamped to reduce energy usage in the Legislative Council computer area. The incandescent lights on the first floor are for esthetic purposes and do not appear suitable for fluorescent retrofit.

Domestic Hot Water: Domestic hot water is provided by a steam to hot water generator and a 3/4 hp circulating pump.

Miscellaneous Energy-Using System: There is a Liebert mainframe chillier in the basement UPS room, which provides chilled water to the Legislative Council's two IBM mainframes in the fifth floor computer room.

History of Operating Cost and Electricity Consumption: The annual operating costs totaled $331,305 from September 1, 1990 to August 31, 1991 according to utility bills provided by the State Purchasing and General Services Commission, which equals $1.95/ft^2 year. The annual average electricity consumption was measured at 4.5 W/ft^2 with a ratio of 0.64 from the minimum to the maximum using LoanSTAR hourly data.

O&M Opportunity and Savings: No air handlers can be turned off during unoccupied hours. No exhaust fans can be turned off during unoccupied hours. A substantial amount (151 and 68 kW) of lights and office machine power can be saved during unoccupied hours.

The O&M savings were calculated using method attached in Appendicies B and C. Turning off lights can result in $8,200 savings in electricity consumption, and $6,100 savings in electricity consumption for turning off office machines during unoccupied hours.

The O&M opportunities and savings are summarized in Table A-6. Column 1 lists the O&M opportunity, such as turning off air handlers, exhaust fans, lights and office machines. Column 2 lists the number of air handlers and exhaust fans which can be turned

off during unoccupied hours. Column 3 lists the total power reduction for each O&M measure. Column 4 lists the total savings due to each O&M measure in units of dollars per year. Note that the savings due to air handler shutdown include both electricity and chilled water savings.

Table A-6: Summary of O&M Opportunity and Savings for John H. Reagan (JHR) Building

Name	Number	Power Savings (kW)	Savings $/year
Air handlers shutdown	0	0	0
Exhaust fan shutdown	0	0	0
Lights turned off		151	8,200
Office machines turned off		68	6,100
Total		219	14,300

A-7. State Insurance (INS) Building

Building: The INS is a 4-story, 102,000 square feet building. It was built in 1961 with Texas Granite walls and large single pane windows with granite and aluminum solar screens installed four feet outside all windows.

The building is used solely as an office building and is occupied from 7:30 am to 6:00 p.m. on week days. The computer facility area operates 24 hours per day.

Heating, Ventilating, and Air Conditioning: The building receives steam and chilled water from the SHB central plant. A dual duct VAV system is used to serve the whole building. Dual duct mixing boxes are used to provide heating and cooling to the various zones on each floor.

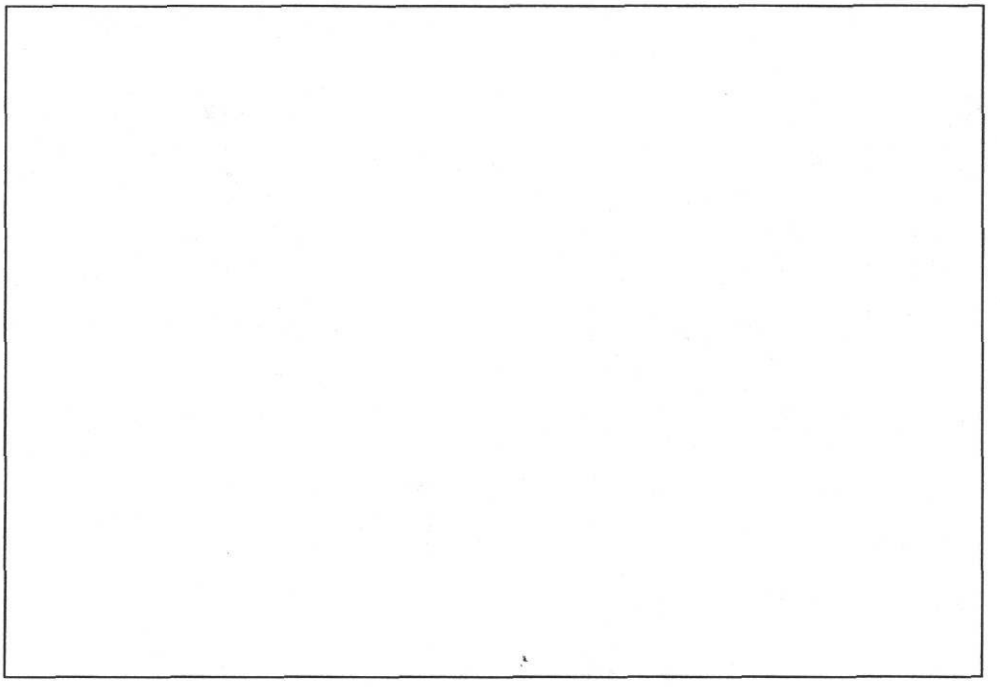

***Figure A-7**: Picture of State Insurance (INS) Building*

Lighting: Fluorescent lighting is used for the building except the main lobby and elevator lobbies where incandescent light (34 W) is used. The fluorescent lights are typical 2 lamp, 4-foot fixtures installed end to end on 14 foot centers. Lighting in recently renovated areas of the building consists of 4 lamp, 4 foot fluorescent fixtures. The incandescent fixtures are installed in a plaster ceiling without access and are of insufficient size for retrofit with fluorescent bulbs. Lighting levels in corridors are higher than required due to the quantity of fixtures. Lights are turned off by custodial personnel as cleaning is finished for each area.

Domestic Hot water: Domestic hot water for the building is provided by a steam to hot water generator and 1/6 hp circulating pump.

Miscellaneous Energy-Using Systems: The computer room has its own climate control system using two fan-coil units with chilled water coils and two fan coils with DX coils.

History of operating cost and electricity consumption: The annual operating costs totaled $129,736 from September 1, 1990 to August 31, 1991 according to utility bills provided by the State Purchasing and General Services Commission, which equals $1.27/ft^2 per year. The annual average electricity consumption was measured at 3.0 W/ft^2 with a ratio of 0.67 from the minimum to the maximum using LoanSTAR hourly data.

O&M opportunity and savings: No air handlers can be turned off during unoccupied hours. No exhaust fans can be turned off during unoccupied hours. A substantial amount (70 and 41 kW)of lights and office machine power can be saved during unoccupied hours.

Turning off lights can result in $4,300 savings in electricity consumption, and $3,700 savings in electricity consumption for turning off office machines during unoccupied hours.

The O&M savings were calculated using the methods attached in Appendicies B and C. The O&M opportunities and savings are summarized in Table A-7. Column 1 lists the O&M opportunity, such as turning off air handlers, exhaust fans, lights and office machines. Column 2 lists the number of air handlers and exhaust fans which can be turned off during unoccupied hours. Column 3 lists the total power reduction for each O&M measure. Column 4 lists the total savings due to each O&M measure in units of dollars per year. Note that the savings due to air handler shutdown include both electricity and chilled water savings.

Table A-7: Summary of O&M Opportunity and Savings for State Insurance (INS) Building

Name	Number	Power Savings (kW)	Savings $/year
Air handlers shutdown	0	0	0
Exhaust fan shutdown	0	0	0
Lights turned off		70	4,300
Office machines turned off		41	3,700
Total		111	8,000

A-8. John H. Winters (JHW) Building

Building: The JHW complex is a combination office/computer facility with a conditioned floor area of 503,000 square feet. The building houses computing operations for the Texas Department of Mental Health and Mental Retardation and the Texas Health department. It also houses the State Headquarters for the Texas Department of Human Services.

Most employees work 8:00 a.m. to 5:00 p.m. on week days; however, a portion of the building is occupied 24 hours per day year around.

Heating, Ventilating, and Air Conditioning: Chilled water is produced inside the building using three 607-ton Trane centrifugal chillers. There are three variable volume air handler units with electric reheat. Forty-four Leibert units are used to serve the three computer areas.

Lighting: Lighting in the building is supplied predominantly by 3 lamp 34 watt fluorescent fixtures. However, there is an architectural crescendo of hundreds of recessed incandescent in the ground floor lobby area.

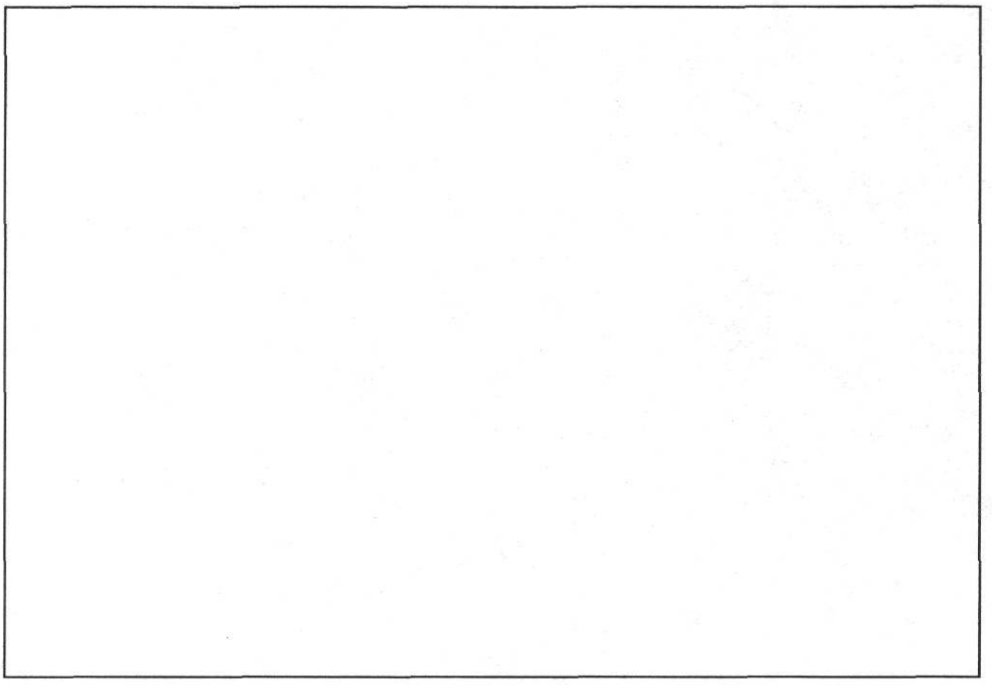

***Figure A-8**: Picture of John H. Winter (JHW) Building*

The lighting in the executive office area is controlled by individual switches while light switches for the large central workstation area control gangs of lights. Lights were generally observed to operate well beyond the time of occupancy and usually were not turned off until custodial crews had completed cleaning a specific floor.

Domestic Hot Water: Domestic hot water is provided by a single centrally located electric water heater.

Miscellaneous Energy-Using System: This building houses three computer center areas which total 80,000 square feet. These account for a steady electrical load of about 824 kW.

History of Operating Cost and Electricity Consumption: The annual operating costs totaled $1,072,283 from September 1, 1990 to August 31, 1991 according to utility bills, which equals $2.13/ft^2 year. The annual average electricity consumption was

measured at 3.5 W/ft^2 with a ratio of 0.67 from the minimum to the maximum using LoanSTAR hourly data.

O&M Opportunity and Savings: No air handlers can be turned off during unoccupied hours. No exhaust fans can be turned off during unoccupied hours. A substantial amount (144 and 161 kW)of lights and office machine power can be saved during unoccupied hours.

The O&M savings were calculated using the methods attached in Appendicies B and C. Turning off lights can result in $7,900 savings in electricity consumption, and $18,100 savings in electricity consumption for turning off office machines during unoccupied hours.

The O&M opportunities and savings are summarized in Table A-8. Column 1 lists the O&M opportunity, such as turning off air handlers, exhaust fans, lights and office machines. Column 2 lists the number of air handlers and exhaust fans which can be turned off during unoccupied hours. Column 3 lists the total power reduction for each O&M measure. Column 4 lists the total saving due to each O&M measure in units of dollars per year. Note that the savings due to air handler shutdown include both electricity and chilled water savings.

***Table A-8**: Summary of O&M Opportunity and Savings for John H. Winters (JHW) Building*

Name	Number	Power Savings (kW)	Savings $/year
Air handlers shutdown	0	0	0
Exhaust fan shutdown	0	0	0
Lights turned off		144	7,900
Office machines turned off		161	18,100
Total		305	26,000

APPENDIX B: SAVING CALCULATION

The horsepower of air-handling units and exhaust fans, kilowatts of PCs, office machines and lighting that can be turned off are best estimated and measured for each of the buildings according to the methodology mentioned in the methodology section.

The savings of air-handling units and exhaust fans were calculated according to the formula:

$$S_{AHU,EX}(\$/year) = hp \times R \times N \times \$/kWh$$

where hp is the horsepower which can be turned off; R is the ratio of load factor to motor efficiency (0.65 has been chosen as a conservative estimate); N is the number of hours when air-handling units and exhaust fans are turned off. The N is calculated as 1,743 hours (365 day -116 days = 249 days x 7 hours/day=1,743 hours) for night shutdown, 2,784 hours (116 days x 24 hours/day =2,784 hours) for weekend shutdown, and 1,900 hours (31 hours x 52 weekends = 1,900 hours) for partial weekend shutdown[4].

The lighting savings were calculated as:

$$S_{lighting} = \frac{2}{3} kW \times 1,743 \times \$/kWh$$

where kW is estimated lighting load during unoccupied period using LoanSTAR monitored data, the coefficient 2/3 is used to account for the actual need of custodial purpose. The time period (1,743 hours) is calculated based on 249 week days and 7 hours each day.

The PC and office machine savings were calculated according to the formula:

$$S_{pc,machine} = kW \times 5,772 hours \times \$/kWh$$

[4] The 116 weekend and holiday is calculated as 52 weeks times 2 days per weekend plus 12 holidays.

where kW is estimated according to the short-term measurement conducted in the LBJ and WBT buildings and actual inventory in the SFA and WBT buildings. The 5772 hours account for the weekday nights (249 days 7:00 p.m. to 7:00 a.m.) turn-off time and weekend days (116 days 24 hours) turn-off time.

These operation modifications also result in substantial cooling energy savings due to shutdown of the air-handling units at night. This saving is estimated using the method described in Appendix C. It is important to note that the thermal savings do not include the impact of turning off lights and office machines. However, it is believed that the thermal savings are substantial due to the turning off the lights and office machines during unoccupied hours. Therefore, the savings estimates are very conservative.

APPENDIX C: THERMAL EFFECT SAVING ESTIMATION

To assist in analyzing the thermal energy use impact due to partial shutdown of the air handlers during unoccupied hours (10 p.m. to 5 a.m. on weekdays and 24 hours on weekends), an energy use index has been developed. The index was derived from the historical cooling and heating energy use of typical office buildings in the LoanSTAR data base.

The only buildings in the Capitol Complex which have historical cooling energy use data are W. B. Travis and Winters. No building have history of heating energy use. The only channel monitoring energy use is the one which monitors natural gas consumption to the boilers producing steam to heat three buildings in the complex (SFA, WBT, and LBJ). The cooling energy use of Winters and the gas use of SFA, WBT, and LBJ are used to get unoccupied EUI_{OC} (cooling) and EUI_{Oh} (heating). All temperature data used in generating the index were from the Austin NWS and were recorded as part of the LoanSTAR program.

Procedure for estimating EUI_{OC}

Step 1: Historical data used were from the Winters building (March 1991 through July 1992).

Step 2: The historical hourly cooling energy use data were regressed against the NWS dry-bulb temperature. The hourly data were used for regression because the hourly cooling energy use had to be predicted.

Step 3: NWS temperatures were sorted into occupied/unoccupied hours and the temperatures from the unoccupied hours were used to predict the cooling energy use during the unoccupied hours on a monthly basis.

Step 4: The predicted monthly unoccupied hours cooling energy use was normalized for missing hours and conditioned area to get EUI_{CO} (Btu/ft²/month).

$$\overline{EUI}_{oc} = \sum_{i=1}^{12} EUI_{oc} \times IGF_j / IGF$$

where $\overline{EUI}_{oc}$ is the yearly savings in cooling energy use (per unit conditioned area) due to air handler shutdown, IGF_j (W/sf) is the average lighting and equipment usage during the unoccupied hours for building j, and IGF is the average lighting and equipment usage during the unoccupied hours for Winters. IGF can be estimated by taking a month of WBE data and computing the mean WBE density during the unoccupied hours.

Procedure for estimating EUI_{oh}

Step 1: Historical data used were from SFA, LBJ and WBT (July 1991 through July 1992)

Step 2: The historical daily natural gas use data were regressed with the NWS average daily dry-bulb temperature. Since the hourly data from the natural gas data had large on/off unit counts, daily average values were used in the regression analysis (in steps of 1 MBtu).

Step 3: NWS temperatures were sorted into occupied/unoccupied hours. The temperatures from the unoccupied hours were used to compute an average daily unoccupied hour temperature and to predict the heating energy use during that period on a monthly basis.

Step 4: The predicted monthly unoccupied period heating energy use was normalized for conditioned area to get EUI_{oh}(Btu/ft^2-month).

Step 5: The heating energy use was renormalized for internal gains because it is based on average consumption of three buildings (SFA, LBJ, and WBT) with different IGFs. Therefore, the yearly savings in heating energy use (per unit conditioned area) due to air handler shut-down are ($\overline{EUI_{oh}}$):

$$\overline{EUI_{oh}} = \sum_{i=1}^{12} EUI_{oh}$$

APPENDIX D: UTILITY BILLS

This appendix summarizes the utility bills provided by the State Purchasing and General Service Commission.

***Table D-1**: Energy Cost Summary for JHW - John H. Winters Human Services Complex*

Month	Electricity		Gas		Total Cost
	kWh	Cost $	MCF	Cost	
September	1,882,000	$94,990.00	0	$0.0	$94,990.00
October	1,670,000	$85,239.20	0	$0.0	$85,239.20
November	1,924,000	$100,201.92	0	$0.0	$100,201.92
December	1,848,000	$95,195.60	0	$0.00	$95,195.60
January	1,966,000	$94,004.84	0	$0.00	$94,004.84
February	1,672,000	$72,908.00	0	$0.00	$72,908.00
March	1,654,000	$73,256.76	0	$0.00	$73,256.76
April	1,672,000	$91,745.36	0	$0.00	$91,745.36
May	1,886,000	$95,056.40	0	$0.00	$95,056.40
June	1,746,000	$88,910.18	0	$0.00	$88,910.18
July	1,826,000	$92,302.10	0	$0.00	$92,302.10
August	1,790,000	$88,472.40	0	$0.00	$88,472.40
Total	21,536,000	$1,072,282.76	0	$0.00	$1,072,282.76

***Table D-2**: Energy Cost Summary for JER-James Earl Rudder Building*

Month	Electricity		Gas		Total Cost
	KWh	Cost $	MCF	Cost	
September	349,000	$18,034.20	0	$0.00	$18,034.20
October	307,000	$16,136.32	0	$0.00	$16,136.32
November	350,000	$18,435.20	0	$0.00	$18,435.20
December	296,000	$16,043.20	0	$0.00	$16,043.20
January	312,000	$15,664.48	0	$0.00	$15,664.48
February	288,000	$13,014.00	0	$0.00	$13,014.00
March	290,000	$13,373.80	0	$0.00	$13,373.80
April	212,000	$13,709.16	0	$0.00	$13,709.16
May	444,000	$20,646.40	0	$0.00	$20,646.40
June	321,000	$16,504.93	0	$0.00	$16,504.93
July	331,000	$16,982.35	0	$0.00	$16,982.35
August	332,000	$20,183.52	0	$0.00	$20,183.52
Total	3,832,000	$198,727.56	0	$0.00	$198,727.56

***Table D-3**: Energy Cost Summary for ARC-Archives & Library*

Month	Electricity		Gas		Total Cost
	KWh	Cost $	MCF	Cost	
September	373,484	$16,230.29	281	$708.22	$16,938.51
October	287,225	$11,523.91	443	$1,201.81	$12,725.72
November	307,303	$14,934.87	620	$1,964.87	$16,899.74
December	262,398	$12,487.17	977	$3,120.47	$15,607.64
January	287,616	$13,183.22	1,368	$3,985.73	$17,169.05
February	281,838	$11,462.29	1,009	$2,650.65	$14,112.94
March	297,829	$12,225.09	646	$1,575.34	$13,800.43
April	339,362	$18,522.35	581	$1,424.39	$19,946.74
May	387,828	$16,361.07	491	$1,208.73	$17,569.80
June	319,952	$14,202.26	199	$472.14	$14,674.40
July	299,915	$12,910.83	243	$535.95	$13,446.78
August	292,402	$11,853.57	221	$524.01	$12,337.58
Total	3,737,152	$165,857.02	7,079	$19,372.31	$185,229.33

***Table D-4**: Energy Cost Summary for JHR-John H. Reagan Building*

Month	Electricity		Gas		Total Cost
	kWh	Cost $	MCF	Cost	
September	501,000	$26,509.20	0	$0.00	$26,509.20
October	461,000	$24,077.06	0	$0.00	$24,077.06
November	536,500	$28,995.42	0	$0.00	$28,995.42
December	533,500	$28,441.20	0	$0.00	$28,441.20
January	584,500	$29,113.93	0	$0.00	$29,113.93
February	535,500	$23,052.53	0	$0.00	$23,052.53
March	534,500	$24,965.43	0	$0.00	$24,965.43
April	544,500	$30,779.59	0	$0.00	$30,779.59
May	602,000	$30,925.20	0	$0.00	$30,925.20
June	515,500	$27,587.22	0	$0.00	$27,587.22
July	551,500	$29,493.28	0	$0.00	$29,493.28
August	541,500	$27,364.74	0	$0.00	$27,364.74
Total	6,441,500	$331,304.80	0	$0.00	$331,304.80

Table D-5: Energy Cost Summary for WBT-William B. Travis Building

Month	Electricity		Gas		Total Cost
	kWh	Cost $	MCF	Cost	
September	672,000	$38,709.60	0	$0.00	$38,709.60
October	634,000	$36,314.84	0	$0.00	$36,314.84
November	713,000	$41,010.64	0	$0.00	$41,010.64
December	623,000	$36,858.00	0	$0.00	$36,858.00
January	693,000	$37,738.42	0	$0.00	$37,738.42
February	626,000	$31,906.90	0	$0.00	$31,906.90
March	627,000	$31,697.58	0	$0.00	$31,697.58
April	638,000	$39,114.94	0	$0.00	$39,114.94
May	670,000	$38,378.00	0	$0.00	$38,378.00
June	625,000	$36,421.25	0	$0.00	$36,421.25
July	663,000	$38,504.15	0	$0.00	$38,504.15
August	635,000	$37,336.60	0	$0.00	$37,336.60
Total	7,819,000	$443,990.92	0	$0.00	$443,990.92

Table D-6: Energy Cost Summary for LBJ-Lyndon B. Johnson Building

Month	Electricity		Gas		Total Cost
	kWh	Cost $	MCF	Cost	
September	1,299,000	$66,757.27	23	$67.33	$66,824.60
October	1,203,000	$61,890.91	324	$885.48	$62,776.39
November	1,406,000	$73,982.54	748	$2,375.03	$76,357.57
December	1,207,000	$59,631.43	1,671	$5,340.20	$64,971.63
January	1,331,000	$66,275.02	2,706	$7,882.85	$74,157.87
February	1,205,000	$56,878.19	1,189	$3,128.05	$60,006.24
March	1,208,000	$54,352.43	652	$1,595.83	$55,948.26
April	1,211,000	$66,665.32	67	$174.86	$66,840.18
May	1,309,000	$73,603.20	25	$70.59	$73,673.79
June	1,199,000	$61,707.52	15	$45.69	$61,753.21
July	1,156,000	$60,880.34	11	$33.69	$60,914.03
August	1,130,000	$58,062.93	15	$44.51	$58,107.44
Total	14,864,000	$760,687.10	7,446	$21,644.11	$782,331.21

Table D-7: Energy Cost Summary for SFA-Stephen F. Austin Building

Month	Electricity		Gas		Total Cost
	kWh	Cost $	MCF	Cost	
Sept.	2,138,400	$93,343.10	846	$2,166.42	$95,509.52
Oct	1,852,800	$87,571.78	2,541	$6,918.03	$94,489.81
Nov	2,078,400	$99,215.76	3,855	$12,232.21	$111,447.97
Dec	1,735,200	$85,478.45	5,346	$17,105.95	$102,584.40
Jan	1,843,200	$80,830.85	6,065	$17,698.29	$98,529.14
Feb	1,689,600	$71,817.60	4,304	$11,335.99	$83,153.59
Mar	1,720,800	$73,304.74	3,980	$9,727.34	$83,032.08
April	1,848,000	$88,975.68	2,114	$5,219.65	$94,195.33
May	1,839,160	$78,953.08	1,381	$3,435.23	$82,388.31
June	1,992,535	$87,482.33	840	$2,019.84	$89,502.17
July	2,105,255	$92,493.97	788	$1,774.61	$94,268.58
Aug	2,040,948	$86,185.80	959	$2,298.03	$88,483.83
Total	22,884,298	$1,025,653.14	33,019	$91,931.59	$1,117,584.73

Table D-8: Energy Cost Summary for INS-Insurance Building

Month	Electricity		Gas		Total Cost
	kWh	Cost $	MCF	Cost	
September	215,000	$11,692.20	0	$0.00	$11,692.20
October	202,000	$10,763.72	0	$0.00	$10,763.72
November	234,000	$12,763.92	0	$0.00	$12,763.92
December	204,000	$11,288.20	0	$0.00	$11,288.20
January	227,000	$11,613.98	0	$0.00	$11,613.98
February	208,000	$9,687.60	0	$0.00	$9,687.60
March	205,000	$9,686.10	0	$0.00	$9,686.10
April	200,000	$11,450.00	0	$0.00	$11,450.00
May	202,000	$10,504.40	0	$0.00	$10,504.40
June	171,000	$9,035.43	0	$0.00	$9,035.43
July	206,000	$10,673.50	0	$0.00	$10,673.50
August	211,000	$10,576.76	0	$0.00	$10,576.76
Total	2,485,000	$129,735.81	0	$0.00	$129,735.81

APPENDIX E: POWER SAVINGS ESTIMATION

This appendix discusses the power savings from lights and air handler unit shutdown at nights building by building.

E-1: Lyndon B. Johnson (LBJ) Building

Table E-1 lists the name, location , horsepower, feasibility of shutdown during the night, and power savings for each air handler. There are seventeen air handlers that can be shut down during unoccupied hours, which account for total power of 510 hp.

***Table E-1**: Power Savings From Air Handler at Nights for LBJ*

AHU No.	Location	HP	Shutdown (Y or N)	Power Savings at Night
AHU#1	12th floor	10	Y	10
AHU#2	12th floor	20	N	
AHU#6	Ground Floor	2	Y	2
AHU#7	6th floor	40	Y	40
AHU#8	5th floor	40	Y	40
AHU#9	4th floor	25	N	
AHU#10	3rd floor	40	Y	40
AHU#11	2nd floor	40	Y	40
AHU#12	1st floor	40	Y	40
AHU#13	1st floor	30	N	
AHU#14	Ground floor	30	Y	30
AHU#15	1st floor	3	Y	3
AHU#16	1st floor	30	Y	30
AHU#17	Ground floor	20	Y	20
AHU#18	4th floor	20	N	
AHU#19	7th floor	40	Y	40
AHU#20	8th floor	40	Y	40
AHU#21	9th floor	40	Y	40
AHU#23	10th floor	40	Y	40
AHU#25	Ground floor	5	Y	5
AHU#26	11th floor	50	Y	50
Total		605		510

Table E-2 lists the name, the location, horsepower, feasibility of shutdown during unoccupied hours and power savings, if shutdown is implemented. Three of four exhaust fans can be turned off during unoccupied hours, which account for 17.5 hp.

Table E-2: *Power Savings From Shutdown of Exhaust Fans During Unoccupied Hours*

Exhaust Fan	Location	HP	Shutdown at Night	Power Savings HP
Exh #1	12th floor	7.5	Y	7.5
Exh #2	12th floor	5	Y	5
Exh #3	1st floor	5	Y	5
Exh #4	Basement	5	N	
Total		22.5		17.5

The power savings of lighting was determined using LoanSTAR monitored electricity consumption data. Figure E-1 is a typical weekday electricity consumption profile for the LBJ building. It was found that the area enclosed by these two consumption profiles is about 2772 kWh/day. After evenly distributing it over a 7-hour period, it turns out to be 396 kW. It was found that the consumption does not go down after office hours as expected, because lights are still on after workers leave their offices. Therefore, an ideal consumption profile was generated (dashed lines), which assumes that lights are turned off after the workers leave their offices. The area enclosed by these two profiles was considered the potential savings from turning off lights.

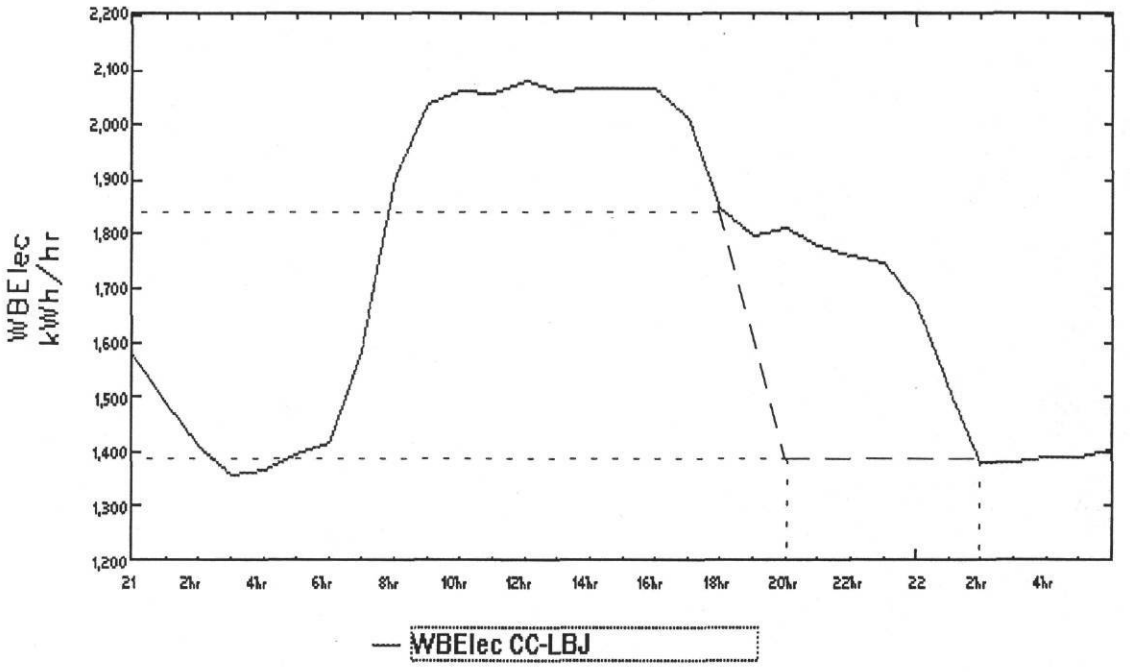

***Figure E-1**: Electricity Consumption Profiles for LBJ Building*

E-2: William B. Travis (WBT) Building

Table E-3 lists the name, location , horsepower, feasibility of shutdown during the night, and power savings for each air handler. There are twenty-five out of twenty-nine air handlers that can be shutdown during unoccupied hours, which account for total power of 345 hp.

Table E-4 lists the name, the location, horsepower, feasibility of shutdown during unoccupied hours and power savings, if shutdown is implemented. All exhaust fans can be turned off during unoccupied hours, which account for 30 hp.

Table E-3: Power Savings From Air Handler at Nights for WBT

AHU No.	Location	HP	Shutdown (Y or N)	Power Savings at Night
AHU-GFN	Grd floor N	7.5	Y	7.5
AHU-GFS	Grd floor S	10	Y	10
AHU-GFSB	Grd floor	7.5	Y	7.5
AHU-1N	1st floor N	15	Y	15
AHU-1S	1st floor S	10	Y	10
AHU-HR1	1st floor Hr Rm	2	N	
AHU-HR2	2nd floor Hr Rm	3	N	
AHU-2N	2nd floor N	15	Y	15
AHU-2S	2nd floor S	10	Y	10
AHU-3N	3rd floor N	15	Y	15
AHU-3S	3rd floor S	15	Y	15
AHU-4N	4th floor N	15	Y	15
AHU-4S	4th floor S	15	Y	15
AHU-5N	5th floor N	15	Y	15
AHU-5S	5th floor S	15	Y	15
AHU-6N	6th floor N	15	Y	15
AHU-6S	6th floor S	15	Y	15
AHU-7N	7th floor N	15	Y	15
AHU-7S	7th floor S	15	Y	15
AHU-8N	8th floor N	15	Y	15
AHU-8S	8th floor S	15	Y	15
AHU-9N	9th floor N	15	Y	15
AHU-9S	9th floor S	15	Y	15
AHU-10N	10th floor N	15	Y	15
AHU-10S	10th floor S	15	Y	15
AHU-11N	11th floor N	15	Y	15
AHU-11S	11th floor S	15	Y	15
AHU-12N	12th floor N	15	N	
AHU-12S	12th floor S	15	N	
Total		380		345

The power savings of lighting was determined using LoanSTAR monitored electricity consumption data. Figure E-2 is a typical weekday electricity consumption profile for the WBT building. It was found that the area enclosed by these two consumption profiles is about 2772 kWh/day. After evenly distributing it over a 7-hour period, it turns out to be

396 kW. It was found that the consumption does not go down after office hours as expected, because lights are still on after workers leave their offices. Therefore, an ideal consumption profile was generated (dashed lines), which assumes that lights are turned off after the workers leave their offices. The area enclosed by these two profiles was considered the potential savings from turning off lights.

***Table E-4**: Power Savings From Shutdown of Exhaust Fans During Unoccupied Hours*

Exhaust Fan	Location	HP	Shutdown at Night	Power Savings HP
Exh #A	Stairwell A	7.5	Y	7.5
Exh #B	Stairwell B	7.5	Y	7.5
Exh #C	Stairwell C	7.5	Y	7.5
Exh Toilet	Central Toilet	7.5	Y	7.5
Total		30		30

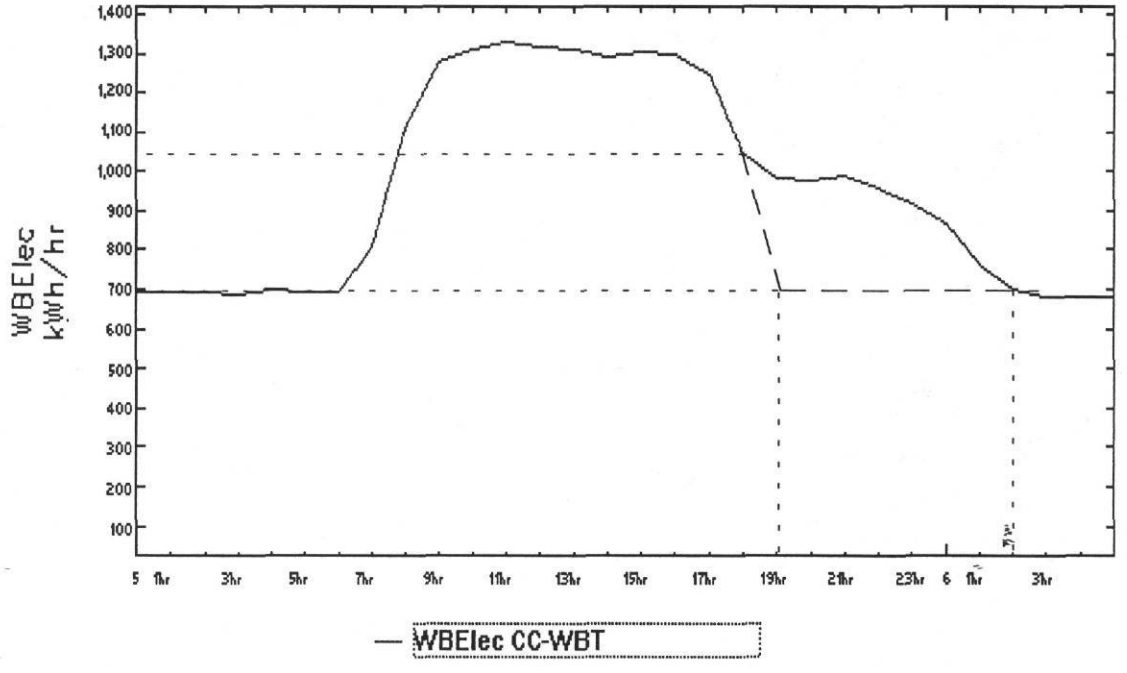

***Figure E-2**: Electricity Consumption Profiles for WBT Building*

E-3: Stephen F. Austin (SFA) Building

Table E-5 lists the name, location , horsepower, feasibility of shutdown during the night, and power savings for each air handler. There are seventeen air handlers that can be shutdown during unoccupied hours, which account for total power of 837 hp.

***Table E-5**: Power Savings From Air Handler at Nights for SFA*

AHU No.	Location	HP	Shutdown (Y or N)	Power Savings at Night
AHU#27	11th floor S	40	Y	40
AHU#26	11th floor N	40	Y	40
AHU#25	10th Floor S	40	Y	40
AHU#24	10th floor N	40	Y	40
AHU#23	9th floor S	40	Y	40
AHU#22	9th floor N	40	Y	40
AHU#21	8th floor S	40	N	
AHU#20	8th floor N	40	Y	40
AHU#19	7th floor S	40	Y	40
AHU#18	7th floor N	40	Y	40
AHU#17	6th floor S	40	Y	40
AHU#16	6th floor N	40	N	
AHU#15	5th floor S	40	Y	40
AHU#14	5th floor N	40	Y	40
AHU#13	4th floor S	40	Y	40
AHU#12	4th floor N	40	Y	40
AHU#11	3rd floor S	40	Y	40
AHU#10	3rd floor N	50	N	
AHU#9	2nd floor S	40	Y	40
AHU#8	2nd floor N	40	Y	40
AHU#7	Ground floor S	50	Y	50
AHU#6	Ground floor N	50	Y	50
AHU#5	Basement	40	Y	40
AHU#4	Kitchen	2	Y	2
AHU#3	7-11th floor	15	Y	15
Total		967		837

Table E-6 lists the name, the location, horsepower, feasibility of shutdown during unoccupied hours and power savings, if shutdown is implemented. Five out of six exhaust fans can be turned off during unoccupied hours, which account for 12 hp.

***Table E-6:** Power Savings From Shutdown of Exhaust Fans During Unoccupied Hours*

Exhaust Fan	Location	HP	Shutdown at Night	Power Savings HP
Exh #6		15	N	
Exh #5		3	Y	3
Exh #4		0.25	Y	0.25
Exh #3		3	Y	3
Exh #2		0.75	Y	0.75
Exh #1		5	Y	5
Total		27		12

The power savings of lighting was determined using LoanSTAR monitored electricity consumption data. Figure E-3 is a typical weekday electricity consumption profile for the SFA building. It was found that the area enclosed by these two consumption profiles is about 2345 kWh/day. After evenly distributing it over a 7-hour period, it turns out to be 335 kW. It was found that the consumption does not go down after office hours as expected, because lights are still on after workers leave their offices. Therefore, an ideal consumption profile was generated (dashed lines), which assumes that lights are turned off after the workers leave their offices. The area enclosed by these two profiles was considered the potential savings from turning off lights.

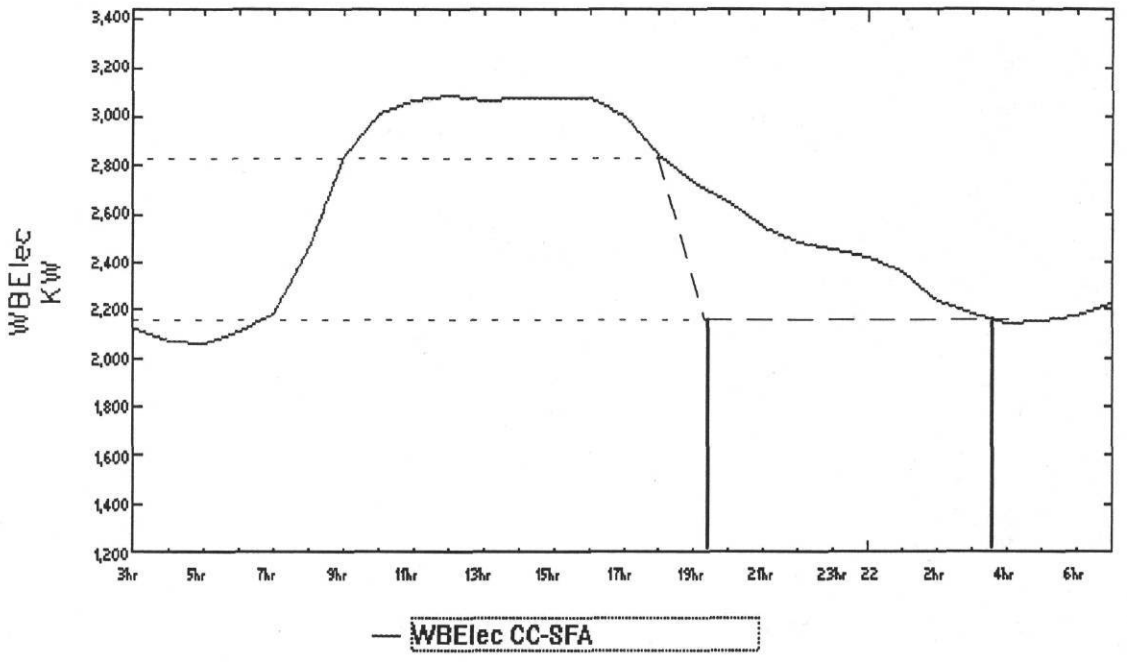

Figure E-3: Electricity Consumption Profiles for SFA Building

E-4: Lorenzo De Zavala Archive (ARC) Building

The power savings of lighting was determined using LoanSTAR monitored electricity consumption data. Figure E-4 is a typical weekday electricity consumption profile for the ARC building. It was found that the area enclosed by these two consumption profiles is about 280 kWh/day. After evenly distributing it over a 7-hour period, it turns out to be 40 kW. It was found that the consumption does not go down after office hours as expected, because lights are still on after workers leave their offices. Therefore, an ideal consumption profile was generated (dashed lines), which assumes that lights are turned off after the workers leave their offices. The area enclosed by these two profiles was considered the potential savings from turning off lights.

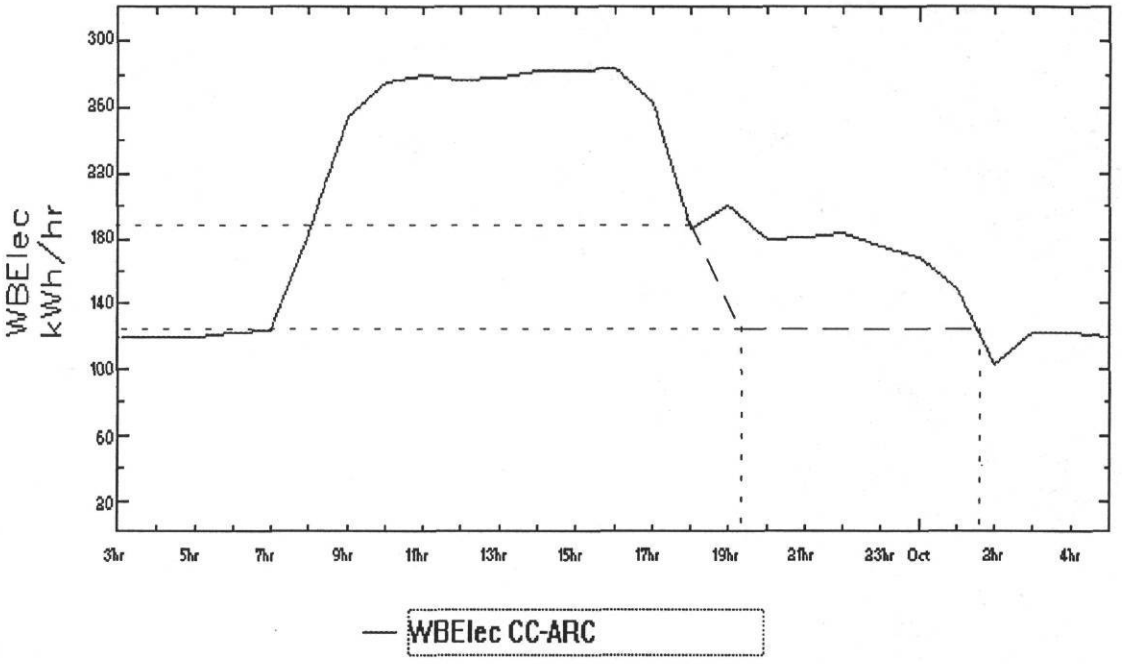

***Figure E-4**: Electricity Consumption Daily Profiles for ARC Building*

E-5: James E. Rudder (JER) Building

Table E-7 lists the name, location, horsepower, feasibility of shutdown during the night, and power savings for each air handler. All six air handlers can be shutdown during unoccupied hours, which account for total power of 80 hp.

***Table E-7**: Power Savings From Air Handler at Nights for JER*

AHU No.	Location	HP	Shutdown (Y or N)	Power Saving at Night
AHU-AC1	1st floor	15	Y	15
AHU-AC2	2nd floor	20	Y	20
AHU-AC3	3rd floor	7.5	Y	7.5
AHU-AC4	4th floor	15	Y	15
AHU-AC5	5th floor	7.5	Y	7.5
AHU-AC6	6th floor	15	Y	15
Total		80		80

The power savings of lighting was determined using LoanSTAR monitored electricity consumption data. Figure E-5 is a typical weekday electricity consumption profile for the JER building. It was found that the area enclosed by these two consumption profiles is about 420 kWh/day. After evenly distributing it over a 7-hour period, it turns out to be 60 kW. It was found that the consumption does not go down after office hours as expected, because lights are still on after workers leave their offices. Therefore, an ideal consumption profile was generated (dashed lines), which assumes that lights are turned off after the workers leave their offices. The area enclosed by these two profiles was considered the potential savings from turning off lights.

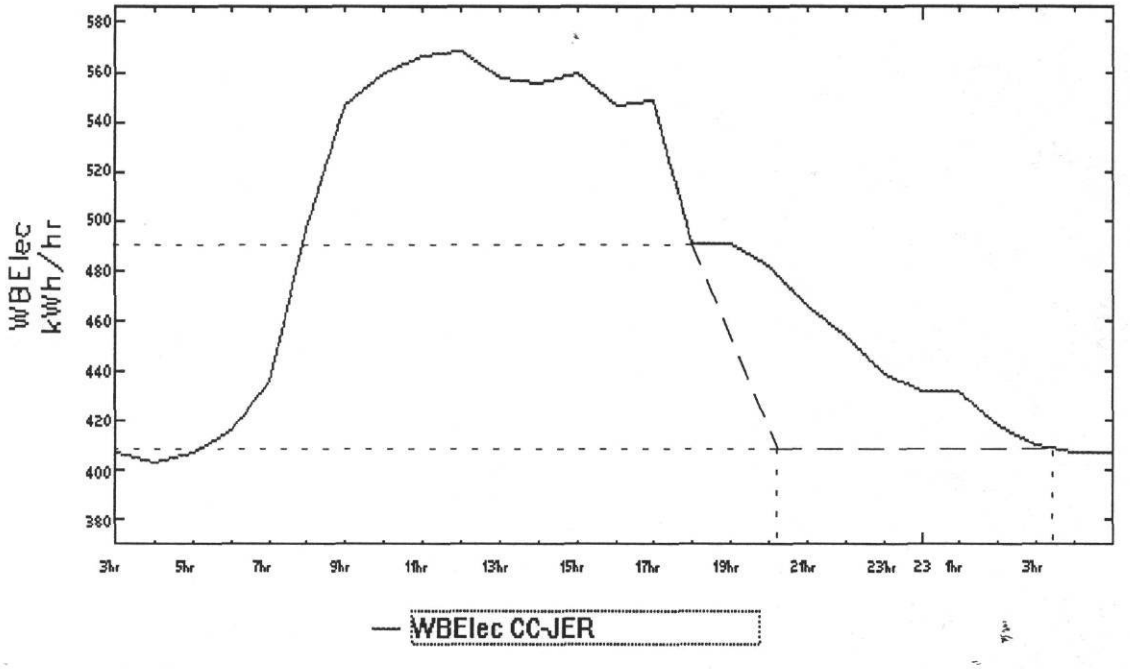

***Figure E-5**: Electricity Consumption Profiles for JER Building*

E-6: John H. Reagan (JHR) Building

The power savings of lighting was determined using LoanSTAR monitored electricity consumption data. Figure E-6 is a typical weekday electricity consumption profile for the JHR building. It was found that the area enclosed by these two consumption profiles is about 1057 kWh/day. After evenly distributing it over a 7-hour period, it turns out to be 151 kW. It was found that the consumption does not go down after office hours as expected, because lights are still on after workers leave their offices. Therefore, an ideal consumption profile was generated (dashed lines), which assumes that lights are turned off after the workers leave their offices. The area enclosed by these two profiles was considered the potential savings from turning off lights.

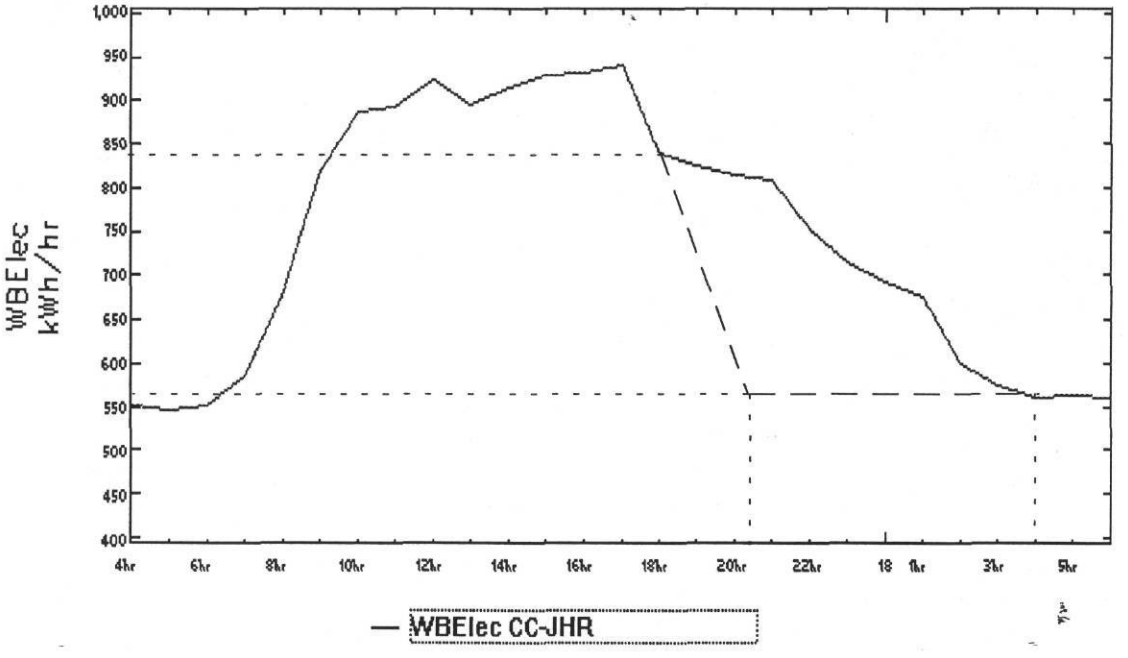

***Figure E-6**: Electricity Consumption Profiles for JHR Building*

E-7: State Insurance (INS) Building

The power savings of lighting was determined using LoanSTAR monitored electricity consumption data. Figure E-7 is a typical weekday electricity consumption profile for the INS building. It was found that the area enclosed by these two consumption profiles is about 490 kWh/day. After evenly distributing it over a 7-hour period, it turns out to be 70 kW. It was found that the consumption does not go down after office hours as expected, because lights are still on after workers leave their offices. Therefore, an ideal consumption profile was generated (dashed lines), which assumes that lights are turned off after the workers leave their offices. The area enclosed by these two profiles was considered the potential savings from turning off lights.

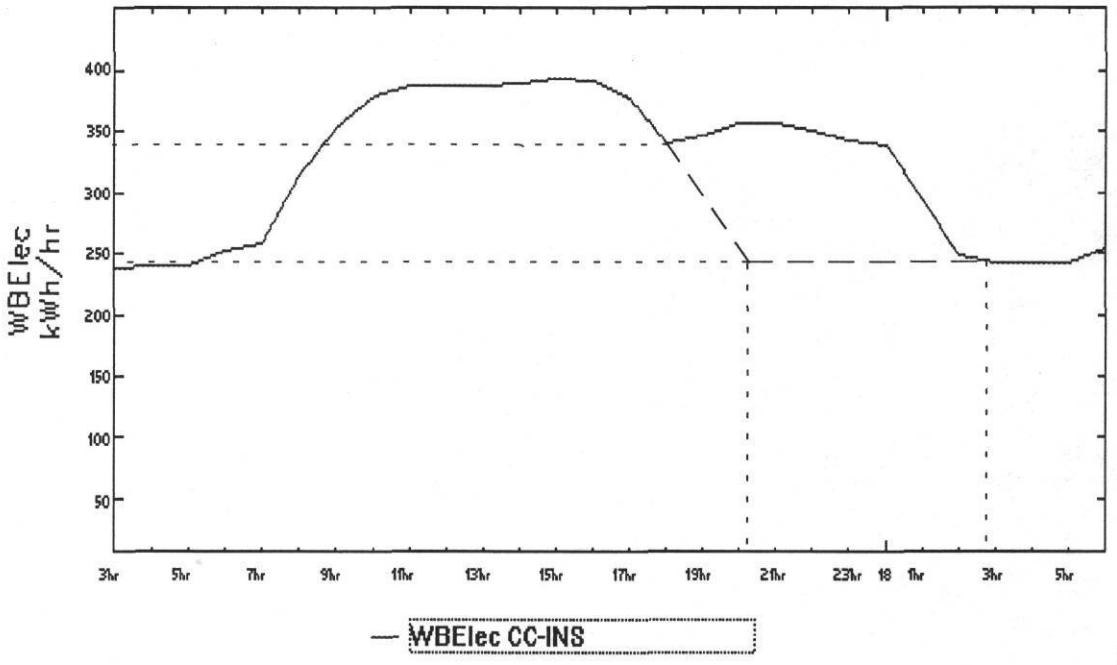

***Figure E-7**: Electricity Consumption Daily Profiles for INS Building*

E-8: John H. Winters (JHW) Building

The power savings of lighting was determined using LoanSTAR monitored electricity consumption data. Figure E-8 is a typical weekday electricity consumption profile for the JHW building. It was found that the area enclosed by these two consumption profiles is about 1008 kWh/day. After evenly distributing it over a 7-hour period, it turns out to be 144 kW. It was found that the consumption does not go down after office hours as expected, because lights are still on after workers leave their offices. Therefore, an ideal consumption profile was generated (dashed lines), which assumes that lights are turned off after the workers leave their offices. The area enclosed by these two profiles was considered the potential savings from turning off lights.

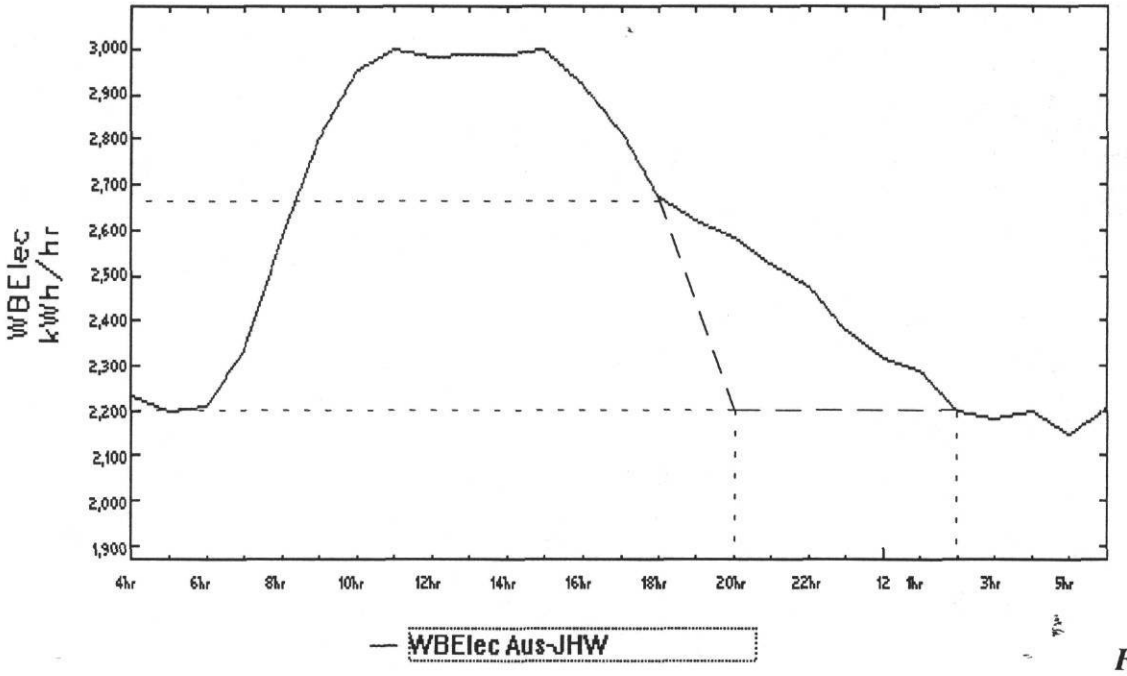

***Figure E-8**: Electricity Consumption Profiles for JHW Building*

APPENDIX F: ECRM DESCRIPTIONS AND CALCULATIONS FOR WBT BUILDING

This appendix was published in the ECRM report (October 1989) by ACR Engineering, Inc. Austin, Texas.

1. HVAC Modifications

a. Summary

kWh savings	1,881,700	kWh (577,300 kWh in WBT, 1,304,400 kWh in SFA)
Demand savings:	0	KW
MCF savings:	0	MCF
Cost savings:	$54,687	($20,107 in WBT, $16,054 in SFA)
Implementation cost:	$52,720	
Simple payback:	1.0 years	

b. Description

A Honeywell Excel direct digital control system now controls all air handlers in the WBT building. The Excel controls fan inlet vane position, supply air temperature, and hot and chilled water valves and measures various temperatures and pressures. The Excel is not programmed to turn air handlers on and off; the Honeywell EMS located in the Sam Houston Building does this. The units are set to come on between 5:00 and 5:30 AM and go off between 5:30 and 5:45 PM. However, all unit starters have been switched to the "Hand" setting, overriding the EMS.

We recommend the Honeywell Excel DDC controllers be programmed to turn the AHUs on and off according to a time schedule, with overrides being programmed into the controllers for maintaining minimum low and high interior temperatures.

However, there are several deficiencies in the WBT HVAC system that make it impossible to turn the air handlers off during unoccupied hours.

First, there are neither preheat nor tempering coils to the outside air intake unit in the penthouse. This creates problems in cold weather because the outside air adds considerably to the heating load, and in summer it creates high humidity-related condensation problems. These problems have been overcome by shutting off the outside air intake fan and all manual outside air dampers. However, this creates other problems - the violation of ventilation codes and the possibility for 'sick building' syndrome, and negative effects on the health of building occupants. We therefore recommend the installation of chilled and hot water coils to the outside air intake unit so that the building can be ventilated. Even though preheating and tempering outside air will increase energy consumption, we feel that the building should be ventilated. To do so will require that the coils be added before the AHUs can be turned off.

Second, each air handler has a 55°F night setback temperature programmed into its Excel control algorithm. Once interior temperatures have been allowed to fall to 55°F, it becomes impossible to reheat the building on a very cold morning or after a long, cold weekend. We recommend the controllers be reprogrammed to raise setback temperature according to outside air temperature (OAT). For example, if OAT falls to the 30s, Excel controllers should be programmed to allow only a 5°F setback.

Third, supply air temperature in the air handlers is statistically set at 55°F. On cold days, 55°F is lower than needed to cool the building. The result is that a certain amount of unnecessary simultaneous heating and cooling takes place in perimeter fan-coil units. There is some leakage of 55°F air through the VAV dampers even when they are closed. Also, when the heating setpoint has been met, the heating fan shuts off and the supply air dampers open again, supplying 55°F air to the occupied space. This makes it more difficult to heat the building. We recommend the Excel controllers be programmed to reset supply air temperature automatically according to actual load conditions. Currently,

the maintenance staff must reset the supply air temperature manually if it is going to get reset at all.

Fourth, the pumps supplying hot water to WBT are each sized at 5 HP, 155 GPM at 70 foot head. WBT blueprints indicate a design heating load of 3,100,000 Btuh with a 20 °F hot water temperature drop. Applying the formula Btuh = 500 * GPM * delta T (20 °F) gives 1,550,000 Btuh which is to be supplied by each pump, or exactly 50% of the design heating load. This indicates that, contrary to most heating or cooling pumping systems, both pumps must be operating simultaneously at design flow to provide the needed hot water to the building. However, with a single pump operating, we read a 69 foot pressure drop across the pump. In other words, one pump operating alone operated at design flow and head on a day when no heating was required, and when heating is called for head loss will likely increase rather than decrease. When both pumps operate simultaneously, the flow rate will not double, and the design heating load of 3,100,000 Btuh will not be supplied to the building. This becomes a problem because of items 1 through 3 listed above. During cold weather, the plant staff must open the steam bypass line directly to the steam converters to allow more steam into the converter.

We recommend the following HVAC system and operating modifications at WBT in order to allow the EMS to control air handling units:

1. Install preheat hot water coils for the fresh air intake air handler.
2. Install tempering chilled water coils for the fresh air intake air handler.
3. Add automatic dampers for the outside air intake coils to give freeze protection.
4. Open the manual outside air dampers in each air handler room. Allow the Excel to control these dampers as it is programmed to do. Reevaluate the control algorithms on the Excel to ensure minimum outside air intake whenever possible, unless the OA helps cool when the building needs cooling.

5. Reprogram the Excel controllers to implement a night setback temperature which varies with outside air temperature.

6. Reprogram the Excel controllers to reset supply air temperature according to outside air temperature.

7. Install larger steam valves and piping to the hot water converters.

8. Program the DDC controllers to turn all building air handlers on and off according to actual occupant need.

9. Add two additional temperature sensors per floor to aid in controller decision making.

10. Replace one of the 5 hp hot water pumps with a larger, higher flow pump.

Addition of the coils to the outside air unit will require physical modifications to the intake section of the fan, as there is virtually no space between the fan scroll and the permanent metal filters. The louvers will have to be moved and a wall extension constructed to hold them, and the filters will have to be moved as well.

Nearly all the air handling units can be turned off according to the current EMS schedule. Once the above modifications are made, place all air handlers under DDC control (with the same on/off schedule currently in the EMS), with the exception of units AHU-4N and AHU-8N, both of which serve critical computer areas, and the lobby AHU.

2. Implementation Cost

A. Equipment and Materials

hot water preheat coils	$7,500
chilled water coils	$8,500
piping and valves	$2,500
outside air dampers and actuators	$2,000
automatic filters including roll covers	$1,960
temperature sensors, 26 @ $60	$1,560

wall extension for coils & dampers	$600
add wiring for OA intake fan	$50
new converter steam valve and piping	$1,400
new hot water pump, 15 HP	$4,000
relay & EMS wiring to OA unit	$50
Subtotal Equipment and Materials	$30,120

B. Design $4,500

C. Labor

coils, filters, and damper installation	$4,600
construct wall extension for coils & dampers	$750
piping and valves	$1,000
Excel controller reprogramming- 29 pts x $200/pt	$5,800
temperature sensors, 26 @ $150	$3,900
power wiring of OA intake fan	$200
install new hot water pump, remove old pump	$950
DDC controls wiring	$200
new converter steam valve and piping	$700
Subtotal Labor	$18,100

D. Other $0

TOTAL COST	$52,720

Costs include contractor overhead & profit

Payback = $52,720 / $54,687

= 1.0 years