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LoanSTAR Monitoring and Analysis Program

Potential Operation and Maintenance (O&M) Savings at Dunbar Middle and Sims Elementary School

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

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EXECUTIVE SUMMARY

This report presents the results of a study of the potential cost savings which may be achieved by improving operational and maintenance (O&M) practices at Dunbar Middle School and Sims Elementary School in the Fort Worth Independent School District. This report discusses the methodology used to identify the O&M measures and summarizes the potential savings of these measures.

The O&M measures identified in these schools include turning off HVAC systems at night, turning off lights at night and installing motion sensors in the auditorium, gymnasium, and activity center.

Both Dunbar and Sims had lighting retrofits, which were funded by the LoanSTAR program, completed in November, 1991. As part of the LoanSTAR program, the lighting electricity use, whole-building electricity use and gas consumption have been measured since September 1991. The measured utility energy cost, measured savings due to the lighting retrofit and projected savings of O&M measures are summarized in the following table.

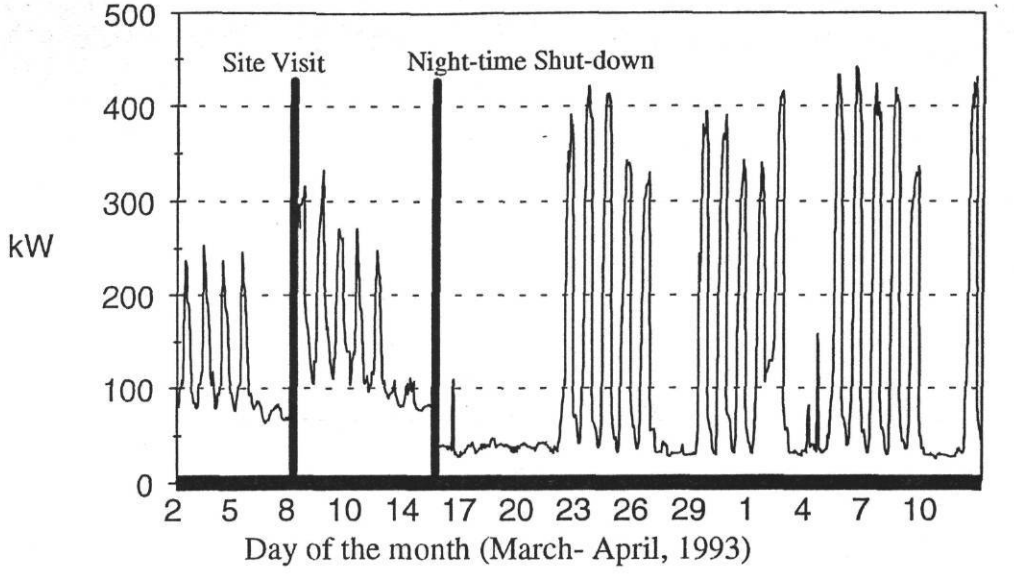
The results show lighting retrofit savings of $12,663 and potential annual O&M savings of $57,147 for these two schools, which accounts for 7% and 33%, respectively, of the total annual energy cost ($172,181) in 1992. Quite surprisingly, the O&M savings are about 5 times the LoanSTAR lighting retrofit savings in these two schools. Obviously, O&M measures should be given a high priority. However, it is recommended that the building operators carefully monitor comfort level and indoor air quality when the O&M measures are implemented to be sure that conditions are not compromised.

Summary of Measured Energy Cost, Retrofit Savings and Projected O&M Savings

Month	Total Energy Cost (Measured) $/month	Lighting Retrofit Savings (Measured) $/month	O&M Savings (Projected) $/month
1	$13,268	$1,179	$4,318
2	$10,998	$1,193	$3,424
3	$10,400	$1,079	$3,067
4	$13,065	$1,168	$3,967
5	$15,746	$1,170	$5,123
6	$15,968	$757	$5,966
7	$19,404	$623	$8,259
8	$17,316	$788	$6,888
9	$18,470	$1,177	$6,209
10	$14,982	$1,346	$4,499
11	$11,264	$1,138	$3,456
12	$11,299	$1,023	$3,660
Total	$172,181	$12,663	$57,147

Note: The values in this table are based on LoanSTAR measured data for the period 01/01/92 to 12/31/92 with a constant unit price of $0.0674/kWh for electricity and $4.6/MBtu for natural gas.

Shortly after the site visit on March 8, 1993 when the evening use of the HVAC systems was discovered, the Fort Worth Independent School district began turning off the HVAC system at night and on weekends at Dunbar Middle School. The following figure shows the LoanSTAR measured hourly whole-building electricity consumption before and after adopting the O&M measures. This figure clearly shows that the HVAC shut-down dropped the whole-building electricity consumption from 110 kW at night and on weekends to 35 kW, a savings of 75 kW. Although the current electricity consumption remains higher than an ideal nighttime consumption of 16 kW, the actual savings is larger than the estimated savings in this report due to the fact that the estimate was conservative and did not include daytime savings during weekends.



Measured Whole-building Electricity Consumption from March 2nd to April 12 1993 at Dunbar Middle School. Note: site visit was performed on March 8th, 1993; Shut-down started on March 15th, 1993.

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POTENTIAL OPERATION AND MAINTENANCE (O&M) SAVINGS AT DUNBAR MIDDLE AND SIMS ELEMENTARY SCHOOL

INTRODUCTION

O&M savings refers to energy savings due to improved operation and maintenance of building systems. It is expected that the improved operation of the building systems can result in substantial energy savings in school buildings since these buildings are unoccupied at night and contain a large amount of infrequently used space, such as in auditoriums, gymnasiums, and activity centers that often consume energy when not in use.

Two schools in the Fort Worth Independent School District, Dunbar Middle School and Sims Elementary School, were chosen to investigate the impact of O&M improvements on energy consumption and savings.

Dunbar Middle School encompasses 92,884 square feet of floor area, including a two-story main building, a separated activity center (17,745 square feet) and two portable buildings (3,100 square feet in total). The main building contains a gymnasium, an auditorium and a cafeteria, which have a combined floor area of 14,720 square feet. The remaining floor area is taken up by classrooms and offices. The classrooms and offices are used about 8 hours per day, Monday through Friday, and are closed on weekends, while the auditorium, gymnasium, activity center, and cafeteria (32,465 square feet, or 35% of the total floor area) are typically used just a few hours per day. Sims Elementary School encompasses 62,400 square feet of floor area, including a gymnasium (2,911 ft^2) and a cafeteria (3,380 ft^2), which are also used just a few hours per day.

Dunbar Middle School has four central air handling units, five rooftop HVAC units, two package HVAC units (portable building), four window A/C units (portable building), and a natural gas fired hot water boiler. Sims Elementary School has 41 rooftop HVAC units with economizer and gas-fired heaters. The lighting retrofit completed in November,

1991 as part of the LoanSTAR program reduced lighting demand 48.1 kW in Dunbar Middle School and 60 kW in Sims Elementary School according to the audit report. A Central Energy Management System (EMS) at the Fort Worth Independent School District can remotely control all the HVAC systems, excluding the lighting systems and the lighting and HVAC systems in the portable buildings. The hourly electricity and gas consumptions have been closely monitored by the LoanSTAR program since August, 1991 and have been reported in Monthly Energy Consumption Reports (MECR).

The annual utility bills for the period 07/01/91 to 07/01/92 totaled $146,863 ($1.58/ft^2) for Dunbar Middle School and $67,146 ($1.08/ft^2) for Sims Elementary Schools. These consumption levels are relatively high compared with a number of other schools in Texas [1, 2, 3, 4, and 5].

The utility bills (kWh and MBtu) are consistent with LoanSTAR measured data (See Figure A-1 in Appendix A). In the remaining sections of this report, all the analysis and calculations of potential O&M savings are based on LoanSTAR measured hourly data. Figures 1 and 2 were generated using LoanSTAR hourly data from 1992, which show the annual energy costs (electric plus gas) during daytime (7 a.m. to 5 p.m.) and nighttime hours (See Appendix B for detailed information). Figure 1 shows that the annual energy cost during nighttime unoccupied hours is about 43.9% of the total annual energy cost of $116,286 for Dunbar Middle School. Figure 2 shows that Sims Elementary School consumed 43.6% of its total annual energy cost of $55,895 during unoccupied hours in 1992. Clearly, the nighttime energy consumption can be substantially reduced in these two schools.

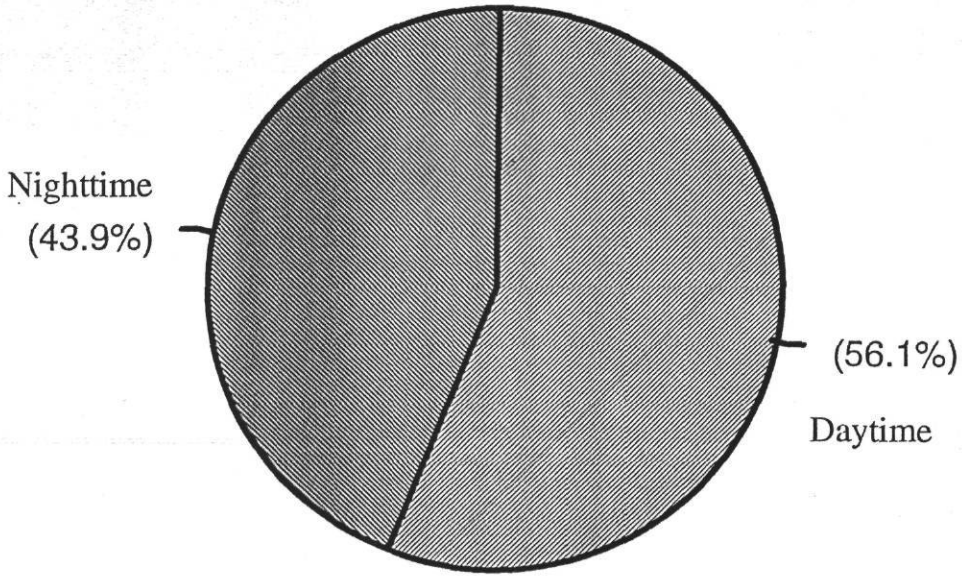

Figure 1: *Comparison of Daytime and Nighttime Annual Measured Energy Cost (1992) at Dunbar Middle School Using LoanSTAR Measured Data with Constant Electricity Price of $0.0674/kWh and Gas Price of $4.60/MBtu*

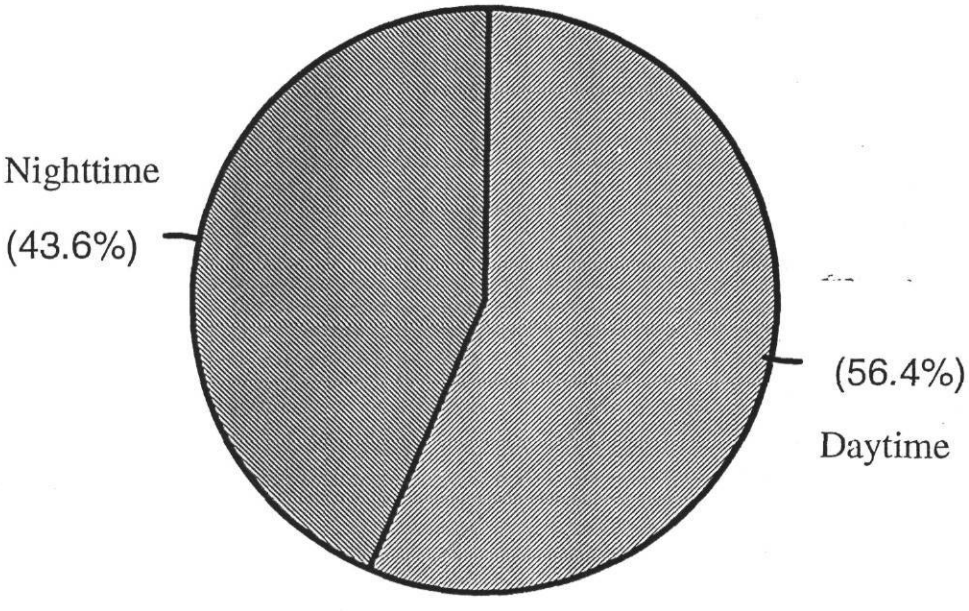

Figure 2: *Comparison of Daytime and Nighttime Annual Measured Energy Cost (1992) at Sims Elementary School Using LoanSTAR Measured Data with Constant Electricity Price of $0.0674/kWh and Gas Price of $4.60/MBtu*

The practical operating and maintenance measures in this report, identified from LoanSTAR data, site visits and short-term confirmation tests, can result in potential annual savings of $57,147 in these two schools, or 33% of the total operating cost. These measures, which require essentially no cost to implement, should not reduce the comfort level of the occupants. However, it is recommended that the building operators carefully monitor comfort levels and indoor air quality to confirm this.

This report describes the methodology used to identify these O&M opportunities, presents the O&M savings expected from each measure and provides more detailed information about calculations in the Appendix.

METHODOLOGY AND O&M OPPORTUNITIES

The steps used to identify and confirm practical O&M opportunities are outlined below.

1. *Investigate the operating patterns of each school's energy consuming system using LoanSTAR monitored hourly data.* To accomplish this, averaged daily profiles were calculated for typical weekdays and weekends to determine the time and amount of energy that could be saved by improved operation. In addition, the ratio of annual energy consumed during unoccupied hours to total annual energy consumption was calculated to find the saving potentials.

2. *Determine the nameplate rated power consumption of equipment which must remain on during unoccupied hours.* Estimate the consumption of the equipment during unoccupied hours using the information from the survey.

3. *Investigate the schools' schedules and operation patterns by interviewing school principals, teachers, and custodial staffs.* Daytime and nighttime walk-throughs were used to confirm the equipment operation. The results provided a typical profile of how the

school is used during the weekdays and evenings, including how the auditorium, activity center, and cafeteria are used.

4. Determine O&M opportunities and savings potential based on the results from steps 1 through 3. Using the measured unoccupied consumption and the observed/estimated consumption (step 3) calculate savings potential.

5. Perform short-term tests at night to confirm savings of major O&M measures. A short-term test was performed which included the following procedures: (1) turn off all the air-handling units, pumps, and chillers, (2) turn off all the lights except security lights. The resulting total measured electricity consumption represents minimum baseload energy consumption at night.

These procedures were carried out in each school. Figures 3 to 6 show averaged daily lighting and HVAC electricity consumption patterns during weekdays for Dunbar Middle School and Sims Elementary School (The data used are from September and October 1992).

Figure 3 shows that the lighting electricity consumption in Sims Elementary School is about 7 kW from 1 a.m. to 6 a.m. each day, and 30 kW from 7 p.m. to midnight when the custodians are working. The security and exit sign lighting are only 3 kW, while the installed corridors, activity center, cafeteria, and kitchen power account for 27 kW(according to fixture count observed during the site visit). Figure 4 shows that the HVAC electricity consumption (total electricity consumption minus lighting electricity consumption) varies from 20 kW to 80 kW from 4 p.m. to 4 a.m., while the estimated uninterruptible equipment totaled 5 kW in this school.

Figures 5 and 6 show similar results for Dunbar Middle School, which consumes 30 to 40 kW for lighting from 7 p.m. to 7 a.m., and 50 to 60 kW from 4 p.m. to 7 p.m., a figure that is high when compared to the total security and sign lighting of 3 kW and the installed corridor, gymnasium, activity center, cafeteria, and auditorium lighting load of 22

kW. The other-than-lighting electricity consumption is about 90 to 120 kW from 5 p.m. to 4 a.m., while the estimated uninterruptible equipment have a total capacity of 7 kW. See Appendix C for detailed lighting fixture and other equipment information, and Appendix D for additional profiles of the electricity consumption.

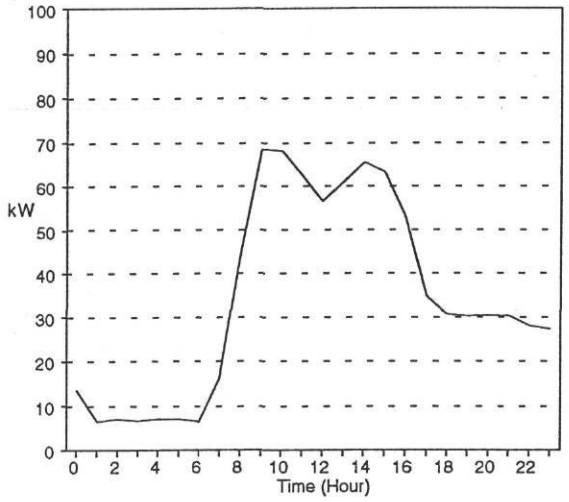

Figure 3: *Averaged Lighting Electricity Consumption Profile during Weekdays (Sims Elementary School)*

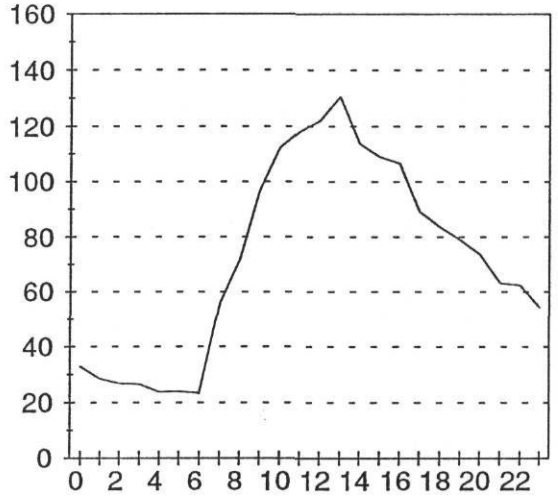

Figure 4: *Averaged HVAC Electricity Consumption Profile during Weekdays (Sims Elementary School*

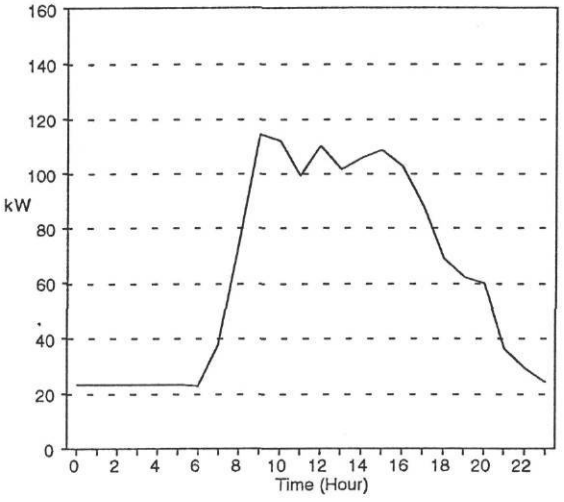

Figure 5: *Averaged Lighting Electricity Consumption Profile during Weekdays (Dunbar Middle School)*

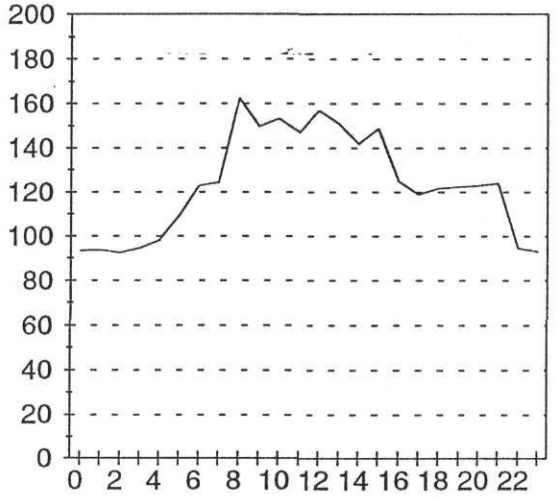

Figure 6: *Averaged HVAC Electricity Consumption Profile during Weekdays (Dunbar Middle School))*

The short-term test performed at Dunbar Middle School demonstrated that lighting consumption can be reduced to 4.5 kW during unoccupied hours, even with the interior and exterior security lights and exit sign lights remaining on. The electricity consumption for loads other-than-lighting can be reduced to 11 kW when all the air-handling units are turned off. See Appendix E for detailed short-term test information.

The daytime walk-through found that the lights were on in the activity center, auditorium, gymnasium, and cafeterias in both schools whether in use or not. The nighttime walk-through found that all the air-handling units, rooftops, pumps and chillers were on at 11 p.m., even though they were presumably turned off by the remote energy management system at 5 p.m.

Clearly, O&M savings can be expected from: (1) turning off lights at night; (2) improving custodial operations; (3) installing motion sensors in auditoriums, gymnasiums, book rooms and activity centers; (4) turning off air-handling units and/or heaters at night. The exception would be for any period when extreme freezing conditions exist. Precautions would need to be taken to avoid freezing pipes. Also, the Dunbar operators should take the necessary precautions to make sure that comfort and indoor air quality are maintained.

RESULTS AND DISCUSSION

The potential O&M savings for each school is summarized in Figure 7 by measure. The estimated combined annual savings is $57,147 for Dunbar Middle School and Sims Elementary School. Turning off the HVAC systems from 6:00 p.m. to 7:00 a.m. accounts for $48,015 in savings (84.1% of the total), which includes $4,952 in gas savings and $43,063 in electricity savings. Turning off lights at night (11 p.m. to 6 a.m. for Dunbar Middle School, and midnight to 6 a.m. for Sims Elementary School) can save $3,723 annually, which accounts for 6.5% of the total savings. Turning off lights at night, where

the custodians are not working, during custodial hours (6 p.m. to 10 p.m. for Dunbar Middle School, and 6 p.m. to 11 p.m. for Sims Elementary School) can save $4,728 per year or 8.3% of the total savings, leaving one half of the remaining lights on in the corridors, gymnasium, activity center, and cafeteria. Turning off lights with motion sensors in the activity center, gymnasium, and auditorium can save a total of $681 per year during unoccupied hours on weekdays, which accounts for 1.2% of the total savings.

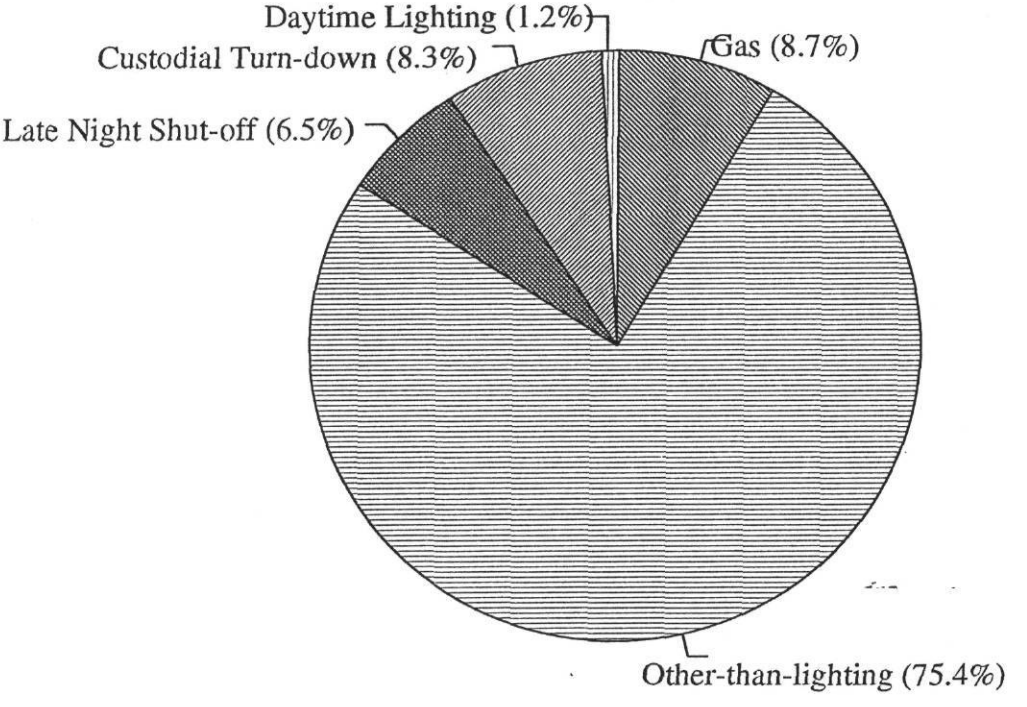

Figure 7: *Estimated Annual O&M Savings of Each Measure for Both Sims Elementary and Dunbar Middle Schools. Total Savings is $57,147*

Most of these savings, except for lighting, can be achieved by using the Central Energy Management System in the Fort Worth Independent School District, provided this system is properly maintained and operated. However, time clocks should be installed on the package air conditioning units and window units in portable buildings, and motion

sensors would be required for the gymnasium, activity center, and auditorium. Some security lights need to be kept on during daytime in these areas.

O&M savings for both schools are listed in Table 1. The third column describes the actions needed.

Table 1: *Summary of O&M Savings for Both Dunbar Middle School and Sims Elementary School*

Item	Savings:	Note:
Gas	$4,952	Turn off HVAC System by EMS
Other-than-lighting Electricity	$43,063	Turn off HVAC System by EMS, Install Time Clock on Compact and Window Units
Daytime Lighting	$681	Install Motion Sensors in Auditorium, Gymnasium, and Activity Center
Evening Lighting	$4,728	Turn off Lights Where Custodians Are not Working
Night Lighting	$3,723	Turn off Lights When Custodians Leave
Total	$57,147	

Figure 8 shows O&M savings for each measure in Dunbar Middle School. Turning off the HVAC system at (6 p.m. to 6 a.m.) can save $32,248 in electricity and $2,437 in gas costs annually, which accounts for 85.7% of total savings ($40,457). The annual lighting savings is $5,772, including $2,839 from improving custodial operation in the evenings, $2,452 from turning off lights when custodians leave, and $481 from motion sensor controls in the auditorium and activity center lighting.

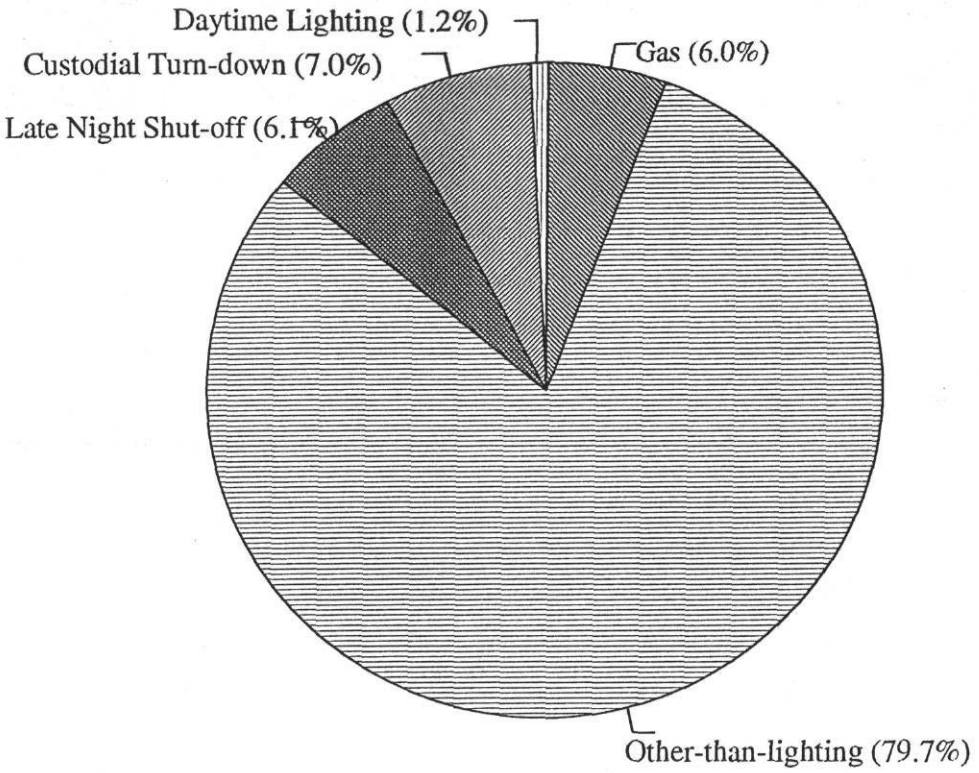

Figure 8: *Annual O&M Savings of Each Measure for Dunbar Middle School. The Total Savings is* ***$40,457***

Figure 9 shows O&M savings by measure for Sims Elementary School. Turning off the HVAC system at night (6 p.m. to 6 a.m.) can save a total of $13,330, including $10,815 in electricity reductions and $2,515 in gas reductions, accounting for 79.9% of the annual savings. The lighting savings is $3,360, including $1,889 in savings from improving the custodial operation in the evenings, $1,271 in annual savings from turning lights off when the custodians leave, and $200 in savings from installing motion sensors in the gymnasium hall way. The lighting savings accounts for 17% of the annual savings.

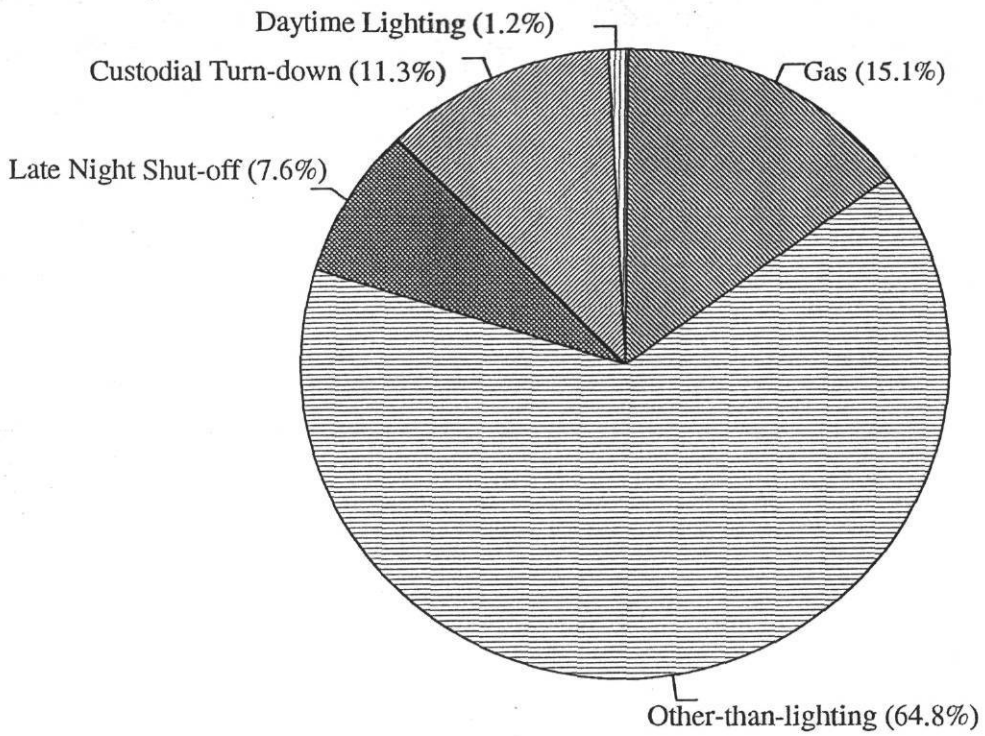

Figure 9: *Annual O&M Savings of Each Measure for Sims Elementary School. The Total Savings is* ***$16,690***

Figure 10 shows the total annual savings for both schools. The projected savings for Dunbar Middle School amounts to $40,457 per year, which accounts for 70.8% of the total annual savings for both schools, while Sims Elementary School is projected to save $16,690, or 29.2% of the total. In terms of unit floor area, Dunbar Middle School has an annual savings of $0.44/ft^2, while Sims Elementary School has an annual savings of $0.27/ft^2. If all O&M measures are implemented as suggested, the resultant EUI for Dunbar will be 0.82$/ft^{2}yr and 0.63$/ft^{2}yr. This difference in annual savings per unit floor area may be due to several facts: 1) Dunbar Middle School has a separated activity center building and two portable buildings while Sims Elementary School consists of only one building; and 2) Dunbar Middle School has central HVAC systems and Sims Elementary

School uses rooftop systems. The separated activity center and portable buildings increase the ratio of envelope area to floor area, which probably contributes to the increased HVAC energy consumption.

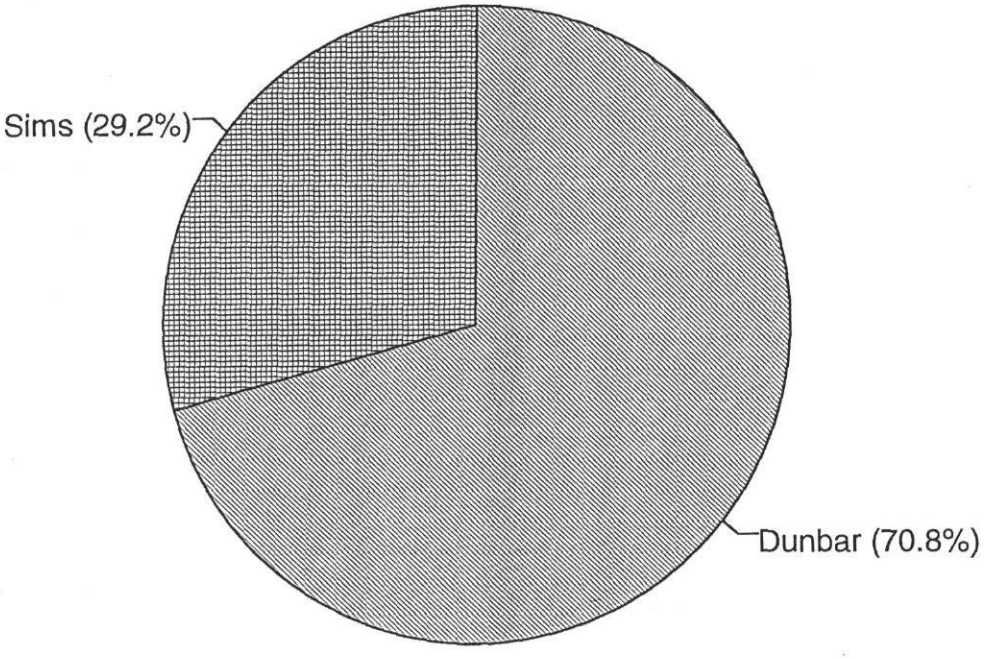

Figure 10: *Comparison of Annual Savings for Dunbar Middle and Sims Elementary Schools*

Table 2 summarizes the annual energy cost, projected energy savings, and the savings/cost ratio. According to LoanSTAR measured data, the annual gas and electricity costs are $117,280 for Dunbar Middle School and $55,894 for Sims Elementary School. If the O&M measures identified in this report had been fully implemented in 1992, they could have saved $40,457 at Dunbar Middle School and $16,690 at Sims Elementary School, or 34.5% and 29.9%, respectively, of the 1992 total energy costs. If these O&M

measures are fully implemented, they will save similar energy costs annually in the following years.

Table 2 shows that the majority of savings is from HVAC system shut-down which can be achieved by using the central energy management system. However, the lighting savings, which can be achieved through the custodial staff, is also important.

Table 2: *Summary of Annual Consumption and Annual O&M Savings in Dunbar Middle School and Sims Elementary School*

		Dunbar			Sims		
		Utility Cost $/year	Savings $/year	% Savings	Utility Cost $/year	Savings $/year	% Savings
HVAC	Electricity	$85,510	$32,248	37.7	$35,697	$10,815	30.3
	Gas	$9,591	$2,437	25.4	$5,803	$2,515	43.3
Lighting	Late Night		$2452	11.1		$1,271	8.8
	Evening	$22,185	$2,839	12.8	$14,394	$1,889	13.1
	Day-time		$481	2.17		$200	1.4
Total		$117,280	$40,457	34.49	$55,894	$16,690	29.9

Figures 11 and 12 show the measured savings due to the lighting retrofit (top block), the projected savings due to the O&M measures (middle block), and the projected remaining monthly energy cost (bottom block) at Dunbar Middle School and Sims Elementary School. Note that both projected O&M savings and monthly cost were estimated using LoanSTAR measured energy consumption in 1992.

Figures 11 and 12 show that the O&M savings are much larger than the lighting retrofit savings. Tables 3 and 4 list the measured monthly energy use and the measured savings in 1992 due to the lighting retrofit, and the projected O&M savings.

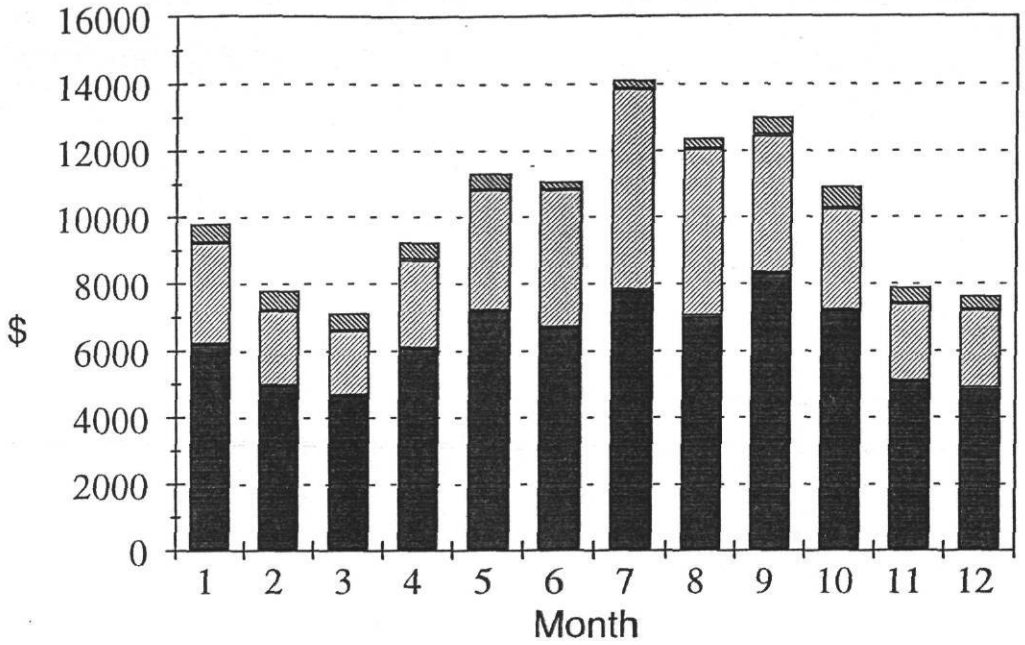

Figure 11: *Measured Savings due to the Lighting Retrofit (Top Block), Projected Savings due to O&M Measures (Middle Block) and Projected Monthly Energy Costs (Bottom Block) at Dunbar Middle School*

Table 3: *Measured Energy Use and Savings due to the Lighting Retrofit and Projected O&M Savings at Dunbar Middle School in 1992*

Month	Total Cost (Measured 1992) $/month	Lighting Retrofit Savings (Measured) $/month	O&M Savings (Projected) $/month
1	$9,221	$581	$3,040
2	$7,183	$587	$2,234
3	$6,578	$532	$1,921
4	$8,673	$535	$2,621
5	$10,788	$523	$3,607
6	$10,796	$251	$4,122
7	$13,826	$291	$6,073
8	$12,024	$327	$5,051
9	$12,439	$551	$4,143
10	$10,235	$651	$3,063
11	$7,353	$521	$2,269
12	$7,171	$421	$2,313
Total	$116,286	$5,771	$40,457

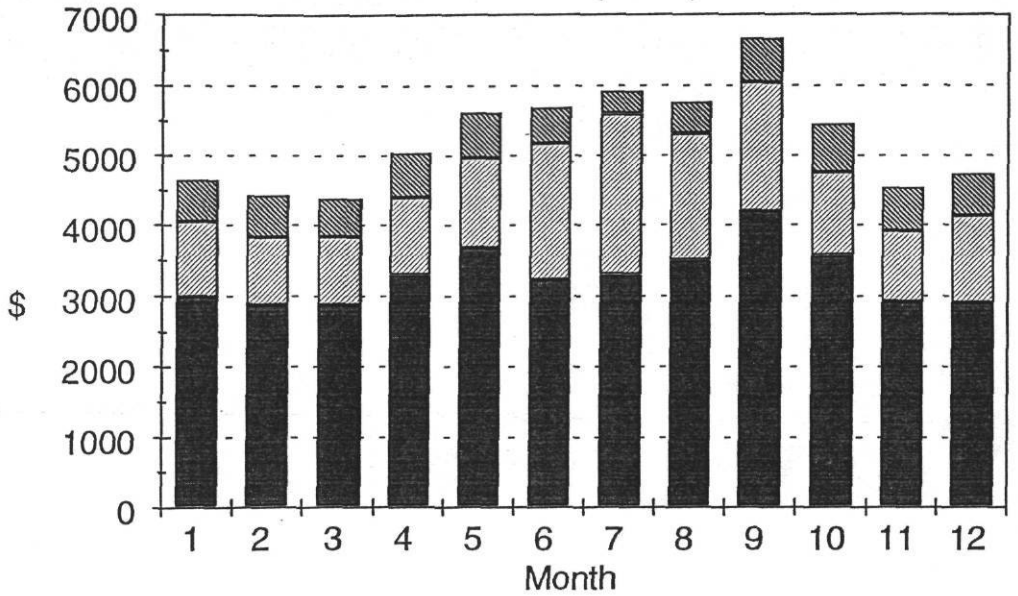

Figure 12: Measured Savings due to the Lighting Retrofit (Top Block), Projected Savings due to O&M Measures (Middle Block) and Projected Monthly Energy Costs (Bottom Block) at Sims Elementary School

Table 4: Measured Energy Use and Savings due to the Lighting Retrofit and Projected O&M Savings at Sims Elementary School in 1992

Month	Total Cost (Measured 1992) $/month	Retrofit Savings (Measured) $/month	O&M Savings (Projected) $/month
1	$4,047	$598	$1,064
2	$3,815	$606	$949
3	$3,822	$547	$957
4	$4,393	$633	$1,109
5	$4,958	$647	$1,288
6	$5,172	$506	$1,956
7	$5,578	$332	$2,292
8	$5,292	$461	$1,802
9	$6,031	$626	$1,838
10	$4,747	$695	$1,197
11	$3,911	$617	$1,000
12	$4,129	$602	$1,240
Total	$55,895	$6,870	$16,691

CONCLUSIONS

Potential O&M measures have been investigated for Dunbar Middle School and Sims Elementary School in the Fort Worth Independent School District. The measures identified from LoanSTAR data were verified using a daytime walk-through and short-term tests performed at night. The potential annual energy savings of O&M measures were estimated using LoanSTAR measured data (from January 1st, 1992 to December 31st, 1992), short-term measured results, and the type and number of lighting fixtures counted during the daytime walk-through.

The study has found that both schools should shut down the HVAC system and turn off the lights (except security and sign lights) from 6 p.m. to 6 a.m. It is also possible to turn off part of the corridor, auditorium, gymnasium and cafeteria lights during custodial working hours when these spaces are not being cleaned. These O&M measures can be implemented by using the existing Central Energy Measurement System and by improving the custodial schedules. Consequently, substantial energy savings can be achieved with only a minimum cost. It is also recommended that the service staffs examine the EMS system operation periodically.

The potential savings has been estimated for each O&M measure for these two schools. The results show total annual savings of $57,147 for these two schools, which accounts for 33% of the total annual energy cost ($173,174) in 1992. The majority of savings (85.7% for Dunbar, 79.9% for Sims) is from turning off HVAC systems during unoccupied hours, while the rest of the savings is from turning off lights at night and improving lighting management during custodial working hours.

We are fortunate to have had a very quick response from the Fort Worth Independent School District. Following our visit on March 8, 1993, the FWISD management immediately began implementing the nighttime shut-down. Figure 13 shows the recently

measured whole-school electricity consumption. The figure clearly shows that the whole-building electricity consumption was about 110 kW during evenings and weekends when the HVAC system was not shut down, and dropped by 75 kW to 35 kW on March 15, 1993. Although the current electricity consumption is slightly higher than the projected 16 kW consumption at night, the actual savings is larger than the estimated savings in this report due to the fact that our estimation did not include daytime savings during weekends. See Appendix G for details.

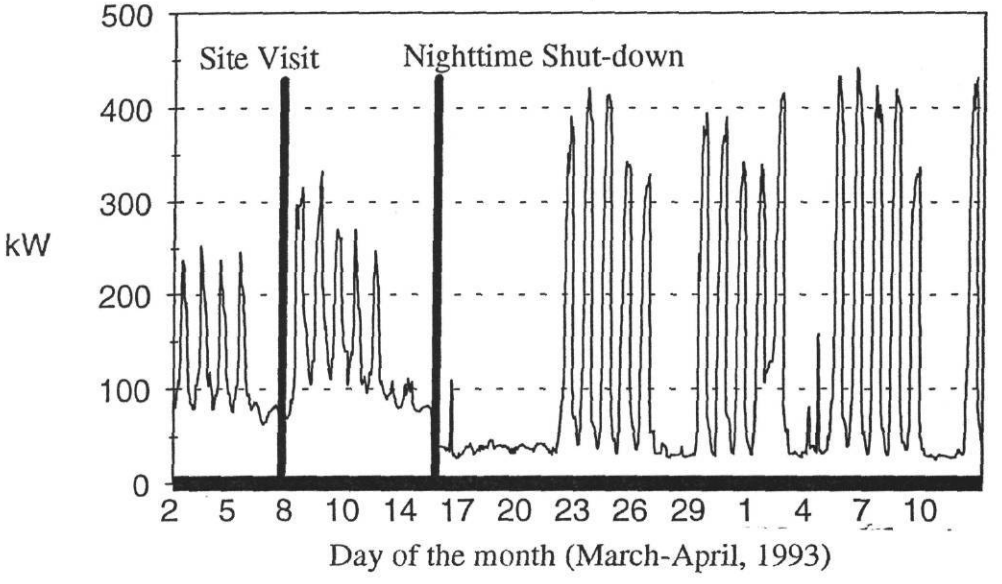

Figure 13: Measured Whole-Building Electricity Consumption from March 2nd to April 12th at Dunbar Middle School. Note: Site visit was performed on March 8th, 1993; Shut-down started on March 15th, 1993.

It is important to point out that the O&M savings is about 4.7 times higher than the lighting retrofit savings in these two schools. Clearly, O&M measures should be given a high priority.

The 2:1 annual savings difference between Dunbar Middle School and Sims Elementary School reflects the 1.5:1 difference in floor area between Dunbar Middle

school and Sims Elementary school. It is suspected that the central systems and the separated buildings at Dunbar Middle school also contribute to this difference.

Since both Sims Elementary School and Dunbar Middle School are typical of their respective types of schools in terms of size and operation patterns it is highly possible that similar O&M savings can be achieved in other schools in the Fort Worth Independent School District.

REFERENCES

1. McClure, J. D. and Estes, J., 1985, "Building energy efficient schools," Proceedings of the Second Annual Symposium on Improved Building Energy Efficiency in Hot and Humid Climates, Energy System Laboratory, Texas A&M University, pp. 104-110.

2. Utesch, A. L., 1988, "Thermal storage for energy efficient structure," Proceedings of the Fifth Annual Symposium on Improved Building Energy Efficiency in Hot and Humid Climates, Energy System Laboratory, Texas A&M University, pp. 36-39.

3. Maxwell, C. L., 1988, "Energy efficient design concept for Mesquite independent school district," Proceedings of the Fifth Annual Symposium on Improved Building Energy Efficiency in Hot and Humid Climates, Energy System Laboratory, Texas A&M University, pp. 267-275

4. McClure, J. D. Bicknell, K. N. and et al., 1988, "Guidelines for energy efficient schools," Proceedings of the Fifth Annual Symposium on Improved Building Energy Efficiency in Hot and Humid Climates, Energy System Laboratory, Texas A&M University, pp.276-283

5. McClure J. D., Estes, J. M., and et al., 1986, "Maintenance and operation of schools for energy efficiency," Proceedings of the Third Annual Symposium on Improved Building Energy Efficiency in Hot and Humid Climates, Energy System Laboratory, Texas A&M University, pp. 96-101.

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Aamer Athar	LoanSTAR Program Staff
Susan Swanson	LoanSTAR Program Staff

APPENDIX A

This appendix contains the utility bills from the Fort Worth Independent School District for Dunbar Middle School and Sims Elementary School from May, 1991 through April, 1992. These data are compared with LoanSTAR measured energy consumption over the period of January 1st, 1992 through December 31st, 1992.

Table A-1 lists the monthly utility bills at Dunbar Middle School and Sims Elementary School. It shows total annual energy costs of $146,863 and $67,146 for Dunbar and Sims, respectively. These costs correspond to the annual unit cost of $1.58/ft^2 and $1.08/ft^2, respectively, for Dunbar and Sims.

***Table A-1:** Summary of Utility Bills at Dunbar Middle School and Sims Elementary School*

	Dunbar			Sims		
Month	Elect.	Gas	Total	Elect.	Gas	Total
5/91	$9,885	$200	$10,885	$4,843	$128	$4,971
6/91	$12,952	$96	$13,057	$6,088	$25	$6,113
7/91	$15,722	$78	$15,800	$6,262	$25	$6,287
8/91	$15,844	$98	$15942	$7,010	$38	$7,048
9/91	$15,026	$1236	$16,262	$7,630	$502	$8,132
10/91	$14,312	$1395	$15,707	$6,580	$888	$7,468
11/91	$9,631	$2193	$11,824	$4,617	$1,158	$5,775
12/91	$6,490	$2554	$9,044	$3,207	$1,440	$4,647
1/92	$8,051	$2,755	$10,806	$2,919	$1,609	$4,528
2/92	$7,811	$2,675	$10,486	$2,794	$1,609*	$4,403
3/92	$8,063	$341	$8,404	$3,162	$483	$3,645
4/92	$8,800	$655	$9,455	$3,387	$742	$4,129
Total	$132,587	$14,276	$146,863	$58,499	$8,647	$67,146

* Gas consumption was assumed to be the same as January because of missing data.

Figure A-1 compares the average daily whole-building electricity use from the utility bills with the LoanSTAR measured data for Feburary-December, 1992. Hence, the data are directly compared only for January through April and for October through December where the agreement is good. The data for May, June, July, and August are substantially

different. The lighting retrofits were performed at Dunbar and Sims in September, so the differences shown in the figure represent the savings due to the lighting retrofits. Based on the October, 1991 through April, 1992 comparison, it is concluded that the LoanSTAR measured whole-building electricity use is consistent with the utility bills. The energy saving analysis in this report uses LoanSTAR measured hourly data since the hourly data show the building energy operational characteristics in greater detail.

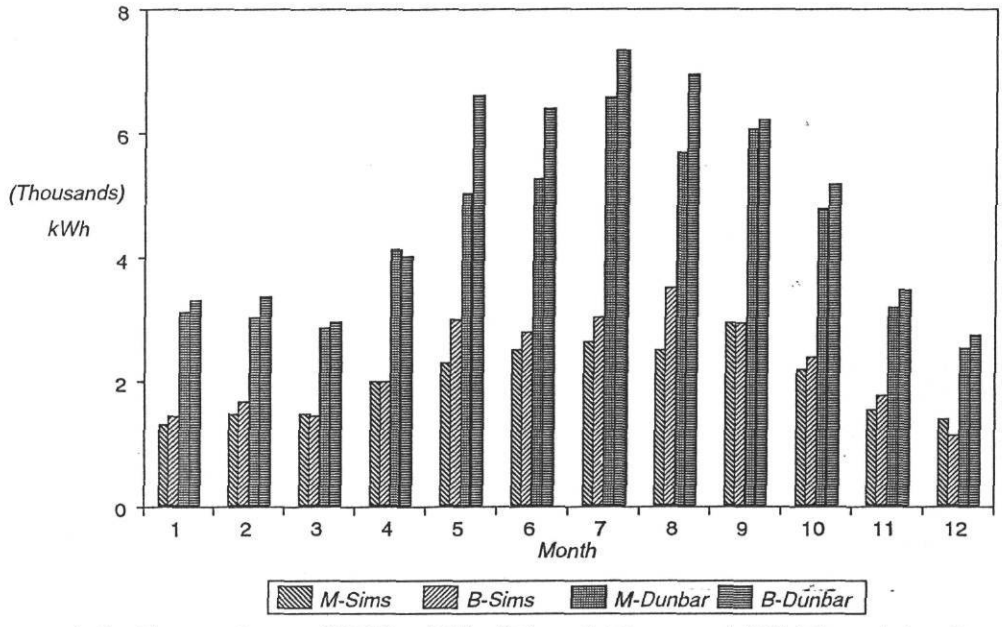

Figure A-1: *Comparison of Utility Bills (B) and Measured (M) Electricity Cost ($/month) by LoanSTAR Program (Note: Both Dunbar and Sims used the TU (Texas Utility) MS charge rate. The measured energy cost was calculated using a constant price of $0.0674/kWh for electricity and $4.6/MBtu for gas.)*

APPENDIX B

This appendix provides hourly and monthly electricity and gas consumption from December, 1991 through November, 1992 at Sims Elementary and Dunbar Middle School.

Figure B-1 shows hourly whole-building electricity consumption at Dunbar Middle School. It shows that the electricity consumption rarely dropped below 70 kW at night and that the HVAC systems were mostly operated 24 hours a day during most of the summer vacation period.

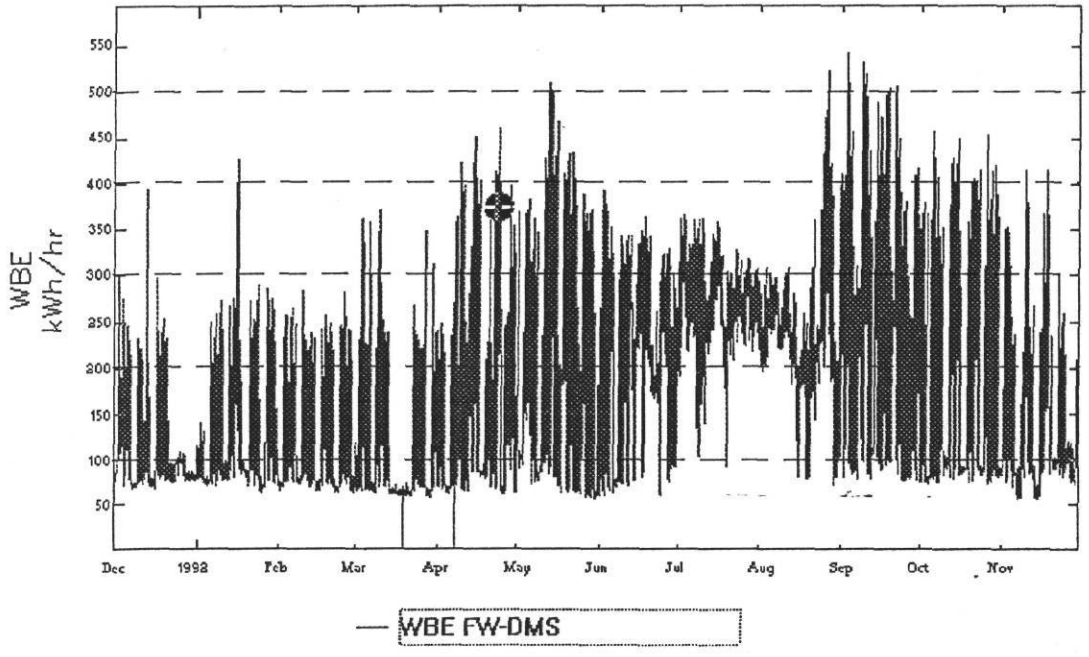

Figure B-1: LoanSTAR Measured Hourly Whole-Building Electricity Use at Dunbar Middle School

Figure B-2 shows LoanSTAR measured hourly lighting electricity use at Dunbar Middle School. It shows that the lighting electricity use was occasionally as low as 2 kW at night. However, it was generally higher than 10 kW.

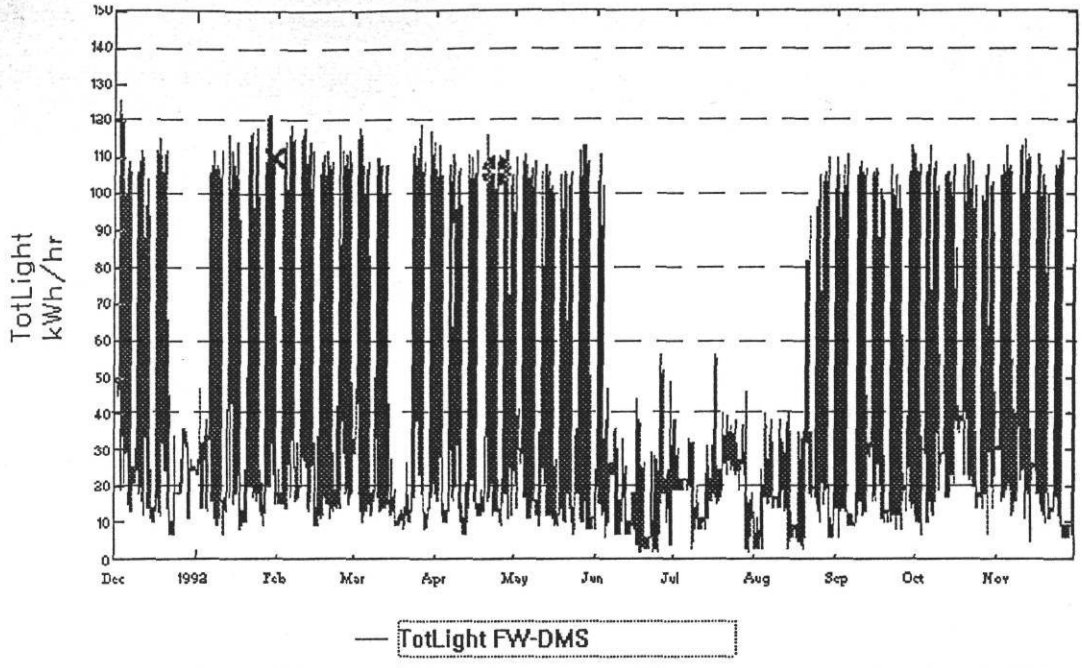

Figure B-2: *LoanSTAR Measured Hourly Lighting Electricity Use at Dunbar Middle School*

Figure B-3 shows LoanSTAR measured hourly gas consumption at Dunbar Middle School. Although the consumption should essentially be zero at night if the HVAC system is off for most of the heating season, it always remains above 200,000 Btu/hr, which also indicates constant use.

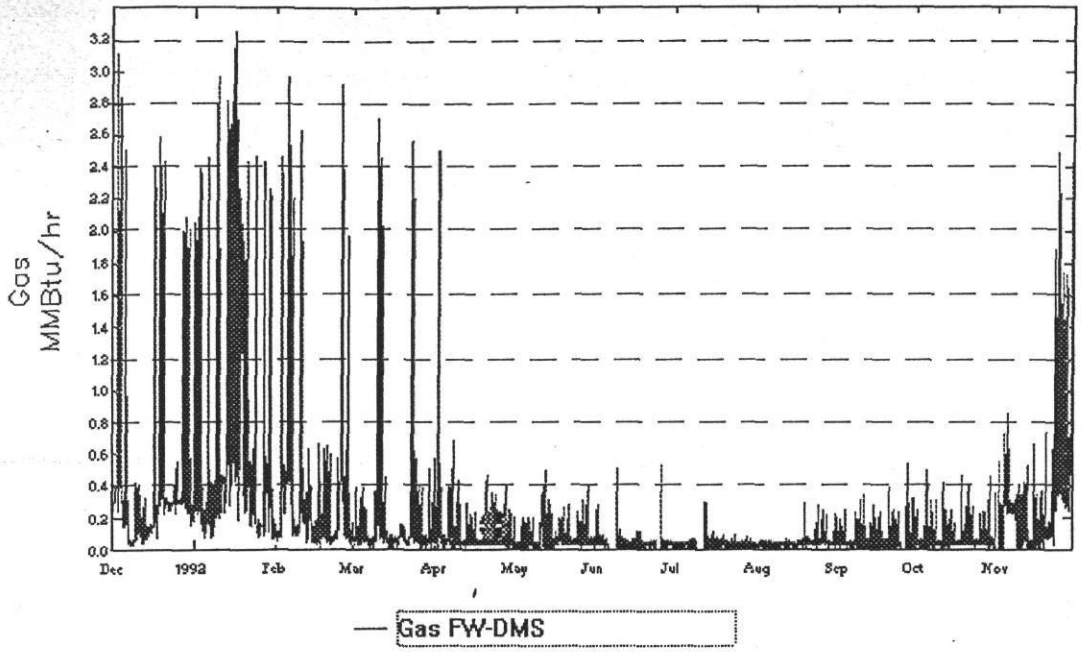

Figure B-3: *LoanSTAR Measured Hourly Gas Consumption at Dunbar Middle School*

Figure B-4 shows LoanSTAR measured hourly whole-building electricity consumption at Sims Elementary School. The electricity consumption was often as high as 30 kW at night when only the security lights, exit lights, and a few refrigerators need to be on. The high electricity consumption (50kW) during summer vacation shows that the HVAC systems were on during this period, which presents a substantial energy conservation opportunity.

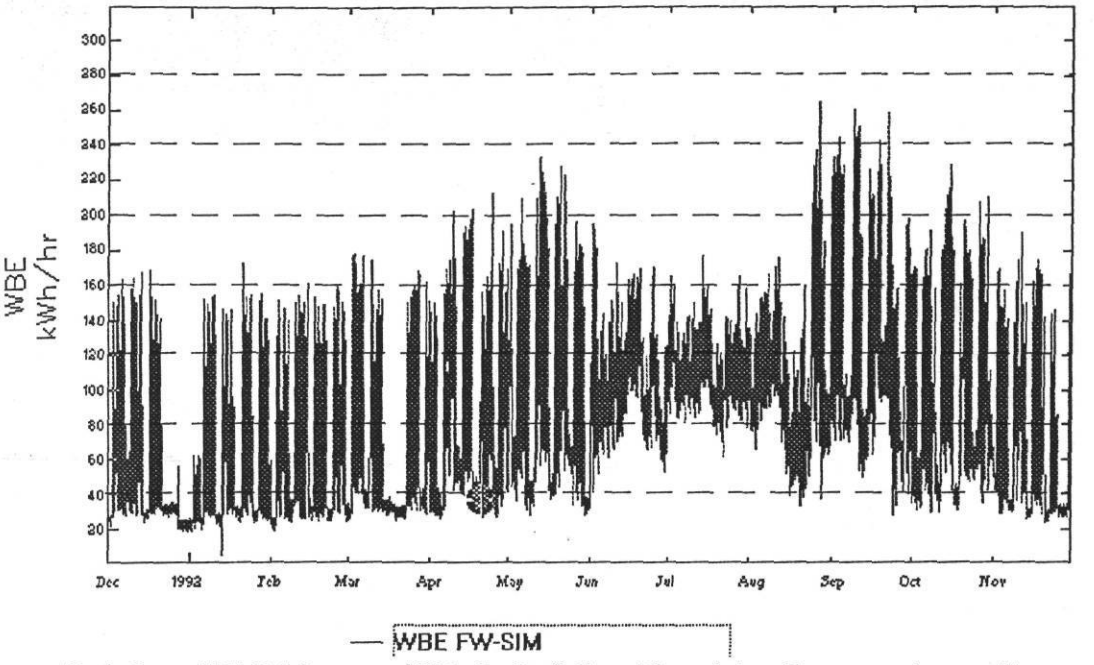

Figure B-4: *LoanSTAR Measured Whole-Building Electricity Consumption at Sims Elementary School*

Figure B-5 shows LoanSTAR measured hourly lighting electricity consumption at Sims Elementary School. The figure shows that the lighting consumption was often as high as 7 kW at night while 3 kW is generally enough for the security and exit lights.

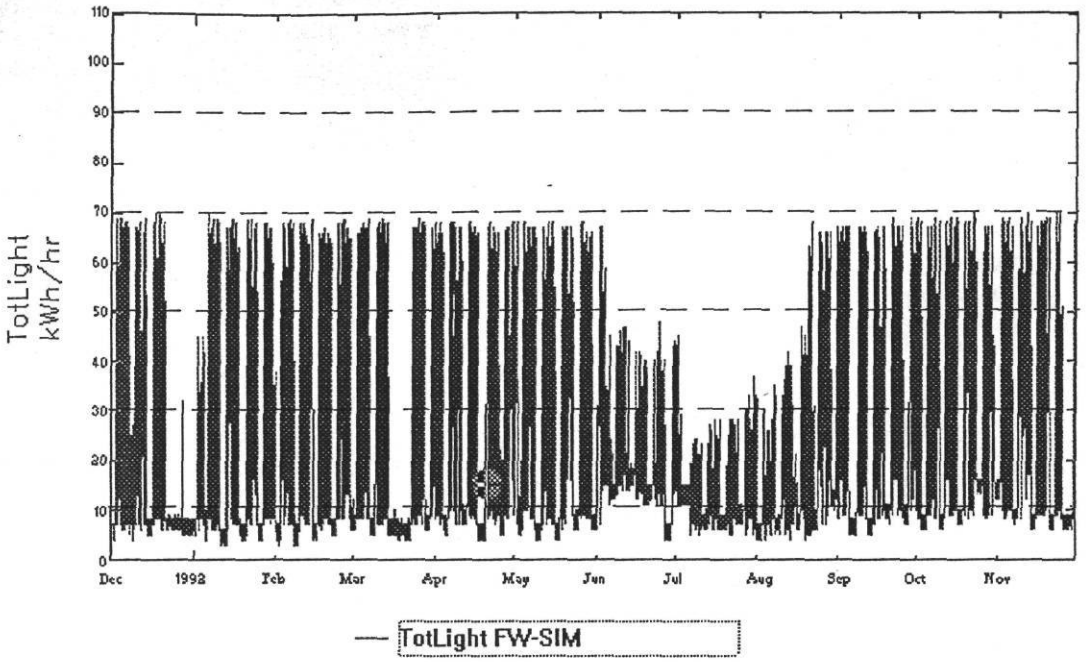

Figure B-5: *LoanSTAR Measured Hourly Lighting Electricity Consumption at Sims Elementary School*

Figure B-6 shows LoanSTAR measured hourly natural gas consumption at Sims Elementary School. Figure B-6 shows no zero consumption at night during the winter. It appears that the heating systems were on at night during the winter months.

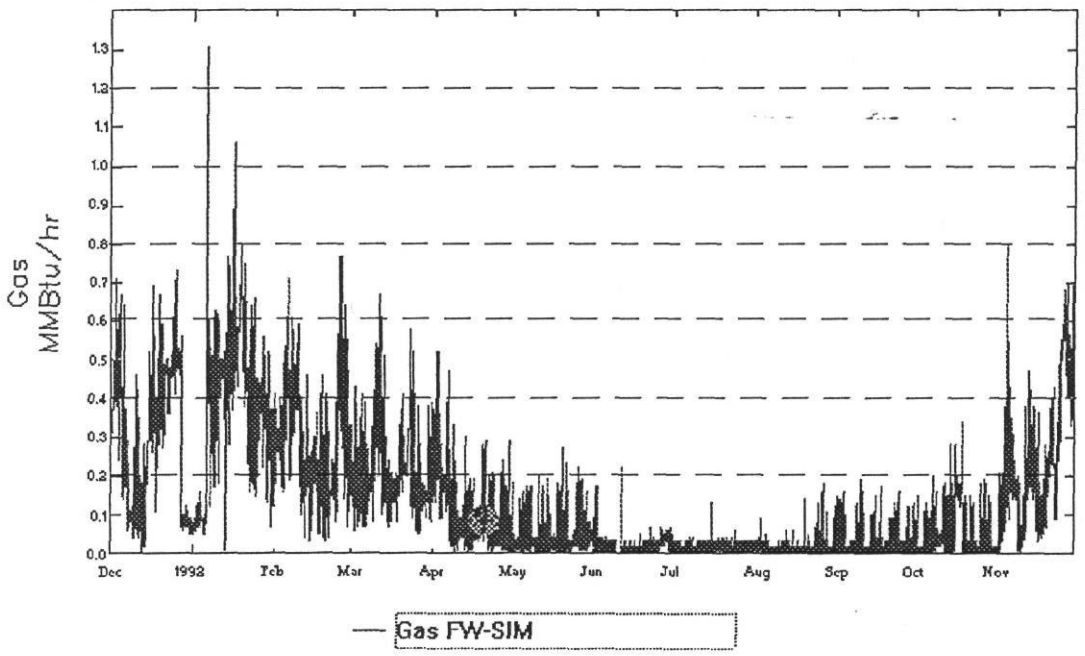

Figure B-6: *LoanSTAR Measured Hourly Natural Gas Consumption at Sims Elementary School*

The monthly electricity and lighting consumptions were totaled from LoanSTAR measured hourly data. The monthly consumptions were also totaled from 7:00 a.m. to 6:00 p.m. and from 6:00 p.m. to 7:00 a.m., which are defined as daytime and nighttime respectively. Tables B-1 to B-6 give the measured monthly consumption results.

Table B-1: *The Measured 1992 Monthly Energy Consumption at Dunbar Middle School*

Month	Whole-Building Electricity (kWh/month)	Lighting (kWh/month)	Gas (ft^3/month)	Gas (MBtu/month)	Temperature (°F)	Hours
1	96,901	33,637	567,261	585	50	744
2	87,802	33,739	266,707	275	57	696
3	88,656	29,659	127,144	131	63	744
4	124,215	31,597	63,423	65	69	720
5	156,550	29,908	49,830	51	74	744
6	158,458	13,721	24,485	25	79	720
7	203,695	15,626	20,393	21	82	744
8	176,543	18,952	26,338	27	79	744
9	181,918	31,789	37,449	39	68	720
10	148,676	36,748	45,070	46	64	744
11	95,645	29,532	191,241	197	47	720
12	78,789	24,252	392,334	404	49	744
Total	1,597,848	329,160	1,811,672	1,868	65	8,784

Note: Column 1 lists the month, column 2 the whole-building electricity consumption, column 3 the lighting electricity consumption, column 4 the gas consumption (in units of cubic feet), column 5 the gas (in units of MBtu), column 6 the average ambient temperature during each month, and column 7 the total hours of each month.

Table B-2: *The Measured Monthly Energy Consumption from 7:00 a.m. to 6:00 p.m (Daytime) at Dunbar Middle School*

Month	Whole-Building Electricity (kWh/month)	Lighting (kWh/month)	Gas (ft^3/month)	Gas (MBtu/month)	Temperature (°F)	Hours
1	55,428	22,776	329,209	339	53	341
2	51,545	22,972	171,219	177	59	319
3	52,327	19,649	88,583	91	67	341
4	74,240	21,971	46,222	48	71	330
5	90,107	21,508	32,668	34	77	341
6	83,651	8,846	13,626	14	80	330
7	98,150	8,144	10,779	11	83	341
8	87,692	12,403	14,950	15	80	341
9	105,815	22,470	26,736	28	66	330
10	90,250	24,212	32,456	33	63	341
11	56,654	20,177	113,497	117	48	330
12	43,698	15,777	234,754	242	50	341
Total	889,556	220,905	1,114,699	1,149		4,026

Note: Column 1 lists the month, column 2 the whole-building electricity consumption, column 3 the lighting electricity consumption, column 4 the gas consumption (in units of cubic feet), column 5 the gas (in units of MBtu), column 6 the average daytime ambient temperature during each month, and column 7 the total hours of each month.

Table B-3: *The Measured Monthly Energy Consumption at Night (6:00 p.m to 7:00 a.m.) at Dunbar Middle School*

Month	Whole Building Electricity (kWh/month)	Lighting (kWh/month)	Gas (ft^3/month)	Gas (MBtu/month)	Temperature (°F)	Hours
1	41,473	10,861	238,051	245	47	403
2	36,256	10,767	95,488	98	54	377
3	36,330	10,010	38,561	40	59	403
4	49,975	9,626	17,202	18	67	390
5	66,443	8,400	17,162	18	71	403
6	74,806	4,875	10,859	11	78	390
7	105,545	7,482	9,614	10	82	403
8	88,851	6,549	11,388	12	78	403
9	76,103	9,319	10,713	11	69	390
10	58,426	12,536	12,614	13	65	403
11	38,991	9,355	77,744	80	45	390
12	35,091	8,475	157,580	162	48	403
Total	708,292	108,255	696,973	719		4,758

Note: Column 1 lists the month, column 2 the whole-building electricity consumption, column 3 the lighting electricity consumption, column 4 the gas consumption (in units of cubic feet), column 5 the gas (in units of MBtu), column 6 the average nighttime ambient temperature during each month, and column 7 the total hours of each month.

Table B-4: *The Measured Monthly Energy Consumption at Sims Elementary School*

Month	Lighting (kWh/month)	Whole-Building Electricity (kWh/month)	Gas (ft^3/month)	Gas (MBtu/month)	Temperature (°F)	Hours
1	19,072	40,865	272,510	281	50	744
2	19,463	43,216	190,280	196	57	696
3	17,250	45,895	153,570	158	63	744
4	20,222	60,004	73,431	76	69	720
5	20,348	71,339	31,670	33	74	744
6	14,853	75,791	13,350	14	79	720
7	9,536	82,092	9,570	10	82	744
8	13,810	77,690	11,720	12	79	744
9	19,932	88,242	17,690	18	68	720
10	21,550	68,049	33,921	35	64	744
11	19,362	46,415	165,060	170	47	720
12	18,171	43,597	250,950	259	49	744
Total	213,568	743,195	1,223,722	1,262		8,784

Note: Column 1 lists the month, column 2 the whole-building electricity consumption, column 3 the lighting electricity consumption, column 4 the gas consumption (in units of cubic feet), column 5 the gas (in units of MBtu), column 6 the average ambient temperature during each month, and column 7 the total hours of each month.

Table B-5: *The Measured Monthly Energy Consumption Over 7:00 a.m. to 6:00 p.m (Daytime) at Sims Elementary School*

Month	Lighting (kWh/month)	Whole-Building Electricity (kWh/month)	Gas (ft^3/month)	Gas (MBtu/month)	Temperature (°F)	Hours
1	12,543	25,645	129,880	134	53	341
2	12,553	27,458	92,960	96	59	319
3	11,047	28,165	77,330	80	67	341
4	13,037	36,217	41,131	42	71	330
5	13,048	42,504	21,860	23	77	341
6	9,020	38,285	7,490	8	80	330
7	5,811	39,148	4,960	5	83	341
8	9,456	41,529	7,440	8	80	341
9	12,948	50,233	13,770	14	66	330
10	13,531	40,793	23,050	24	63	341
11	11,986	28,562	82,990	86	48	330
12	10,743	25,206	118,590	122	50	341
Total	135,723	423,744	621,451	641		4,026

Note: Column 1 lists the month, column 2 the whole-building electricity consumption, column 3 the lighting electricity consumption, column 4 the gas consumption (in units of cubic feet), column 5 the gas (in units of MBtu), column 6 the average daytime ambient temperature during each month, and column 7 the total hours of each month.

Table B-6: *The Measured Monthly Energy Consumption Over 6:00 p.m. to 7:00 a.m. (Nighttime) at Sims Elementary School*

Month	Lighting (kWh/month)	Whole-Building Electricity (kWh/month)	Gas (ft^3/month)	Gas (MBtu/month)	Temperature (°F)	Hour
1	6,529	15,220	142,630	147	47	403
2	6,910	15,758	97,320	100	54	377
3	6,202	17,730	76,240	79	59	403
4	7,185	23,787	32,300	33	67	390
5	7,301	28,835	9,810	10	71	403
6	5,833	37,506	5,860	6	78	390
7	3,725	42,943	4,610	5	82	403
8	4,354	36,161	4,280	4	78	403
9	6,984	38,009	3,920	4	69	390
10	8,019	27,257	10,871	11	65	403
11	7,376	17,853	82,070	85	45	390
12	7,428	18,391	132,360	136	48	403
Total	77,845	319,451	602,271	621		4,758

Note: Column 1 lists the month, column 2 the whole-building electricity consumption, column 3 the lighting electricity consumption, column 4 the gas consumption (in units of cubic feet), column 5 the gas (in units of MBtu), column 6 the average nighttime ambient temperature during each month, and column 7 the total hours of each month.

Tables B-7 and B-8 summarize the annual energy consumption and cost index, e. g. annual energy consumption or cost per square foot. The energy consumption was calculated as the ratio of annual consumption to the floor area for each school. The cost indexes were calculated using a constant electricity price of $0.0674/kWh, and a gas price of $4.6/MBtu. Both Dunbar Middle and Sims Elementary Schools have about the same lighting and gas index, (3.54 and 3.42 kWh/ft^{2}yr for lighting, and 19.50 and 19.61 ft^3/ft^{2}yr for gas). However, the electricity indexes (other-than-lighting) are 13.66 kWh/ft^{2}yr for Dunbar Middle and 8.49 kWh/ft^{2}yr for Sims Elementary School. Since this electricity consumption is mainly due to HVAC systems, it appears that the HVAC system at Dunbar Middle School consumed 1.6 times more energy than that at Sims Elementary school. This high HVAC system energy consumption may be due to the following reasons: (1) Dunbar Middle School has a gymnasium, an auditorium, and an activity center, which have a smaller ratio of floor area to space volume than that of normal class rooms; (2) Dunbar has two portable buildings and an activity center, which increase the ratio of exterior envelope to the floor area; (3) Dunbar is conditioned by three central systems while Sims is conditioned by rooftops; and (4) there is possible system degradation at Dunbar Middle School, which may require commissioning the HVAC systems.

Table B-7: *Summary of Energy and Cost Indices at Dunbar Middle and Sims Elementary School Before Implementing O&M Measures*

	Lighting	Index	Other Ele.	Index	Gas	Index	Total
	kWh/ft^{2}yr	$/ft^{2}yr	kWh/ft^{2}yr	$/ft^{2}yr	ft^3/ft^{2}yr	$/ft^{2}yr	$/ft^{2}yr
Dunbar	3.54	$0.24	13.66	$0.92	19.50	$0.09	$1.25
Sims	3.42	$0.23	8.49	$0.57	19.61	$0.09	$0.89

The annual energy consumption and cost indices after implementing O&M measures are substantially smaller than those in Table 7. However, Dunbar middle school still has

higher indices than Sims, which may reflect the impact of the system type and system efficiency.

Table B-8: *Summary of Projected Energy and Cost Indices at Dunbar Middle and Sims Elementary School After Implementing O&M Measures*

	Lighting	Index	Other Ele.	Index	Gas	Index	Total
	kWh/ft²yr	$/ft²yr	kWh/ft²yr	$/ft²yr	ft³/ft²yr	$/ft²yr	$/ft²yr
Dunbar	2.62	$0.18	8.5	$0.57	14.5	$0.08	$0.83
Sims	2.62	$0.18	5.9	$0.40	11.1	$0.05	$0.63

Figures B-7 and B-8 show the ratio of the night energy consumption to the total energy consumption on a monthly basis for Dunbar Middle and Sims Elementary Schools, respectively. Note that the annual data were calculated as the ratio of annual night consumption to the annual consumption instead of the average ratio of each month.

Figure B-7 shows that the nighttime lighting consumption ratio varied from 0.28 (May) to 0.48 (July), the other-than-lighting electricity consumption ratio varied from 0.41 (October) to 0.52 (July), and the gas consumption ratio varied from 0.27 (April) to 0.47 (July) at Dunbar Middle School. It also shows that the annual nighttime lighting consumption is about 32% of the total lighting consumption, other-than-lighting electricity consumption at night is about 47% of the total consumption, and annual gas consumption at night is about 38% of the total annual gas consumption at Dunbar Middle School. The energy consumption at night contributes significantly to the total energy consumption, even when the school is closed.

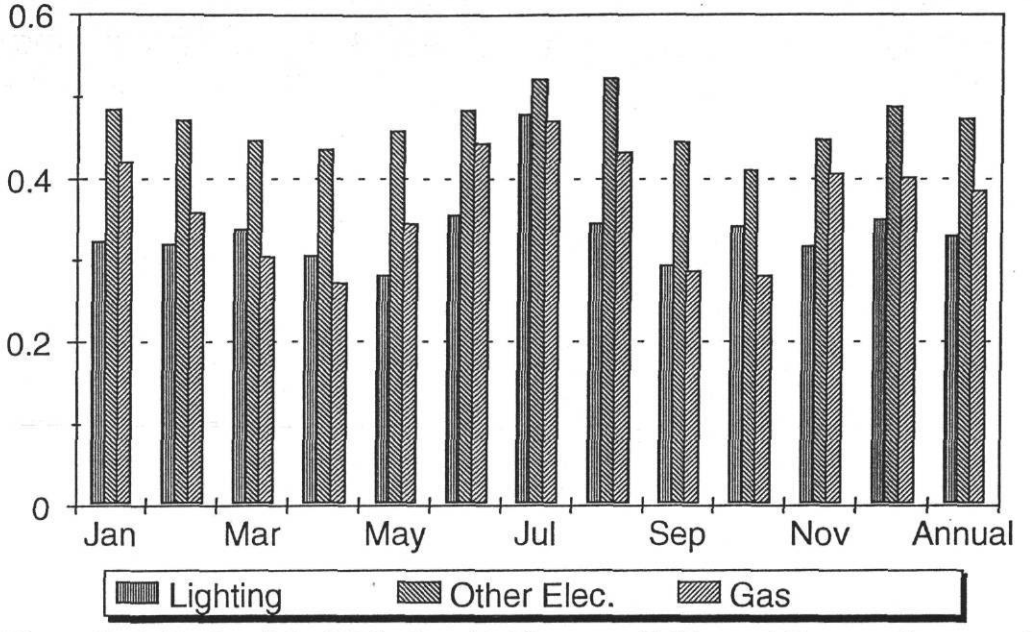

Figure B-7: *Ratio of the Nighttime (6:00 p.m. to 7:00 a.m.) Energy Consumption to the Total Energy Consumption for Dunbar Middle School (According to LoanSTAR Measured Data)*

Figure B-8 shows that the nighttime lighting consumption ratio varied from 0.32 (August) to 0.41 (December), the other-than-lighting electricity consumption ratio varied from 0.37 (February) to 0.54 (July), and the gas consumption ratio varied from 0.22 (September) to 0.53 (December) at Sims Elementary School. It also shows that the annual nighttime lighting consumption is about 36% of the total lighting consumption, other-than-lighting electricity consumption at night is about 46% of the total consumption, and annual gas consumption at night is about 49% of the total annual gas consumption at Sims Elementary School. The energy consumption at night contributes significantly to the total energy consumption, even when the school is closed.

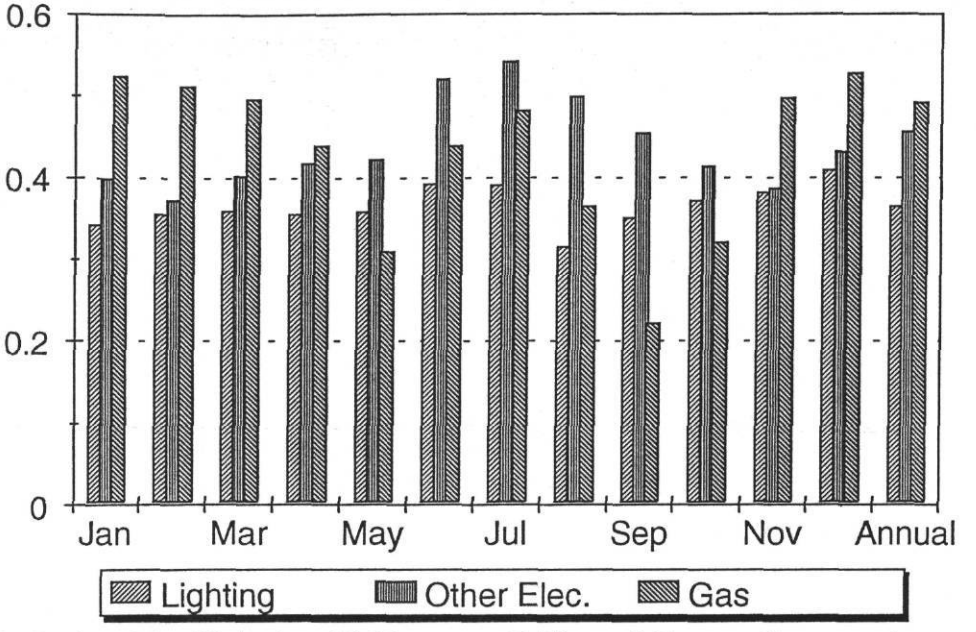

Figure B-8: *Ratio of the Nighttime (6:00 p.m. to 7:00 a.m.) Energy Consumption to the Total energy Consumption for Sims Elementary School (According to LoanSTAR Measured Data)*

Figure B-9 shows ratios of night lighting consumption to the total lighting consumption for Dunbar Middle School and Sims Elementary School. It shows that Sims Elementary School has a slightly higher ratio than Dunbar most of the time except during summer vacation (July and August). It appears that these two schools are operated using similar lighting patterns.

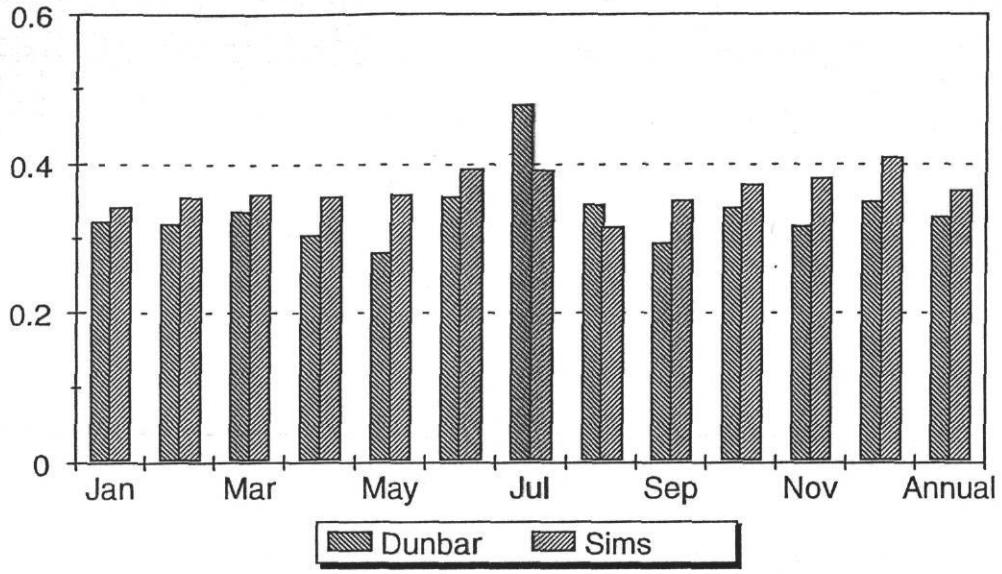

Figure B-9: *Ratios of Nighttime (6:00 p.m. to 7:00 a.m.) Lighting Consumption to Total Lighting Consumption for Dunbar Middle and Sims Elementary School*

Figure B-10 shows the ratios of other-than-lighting electricity consumption at night to the total other-than-lighting electricity consumption for both Dunbar Middle and Sims Elementary Schools. It shows that Dunbar Middle School has a higher ratio than that of Sims during most months, except for June, July, September and October.

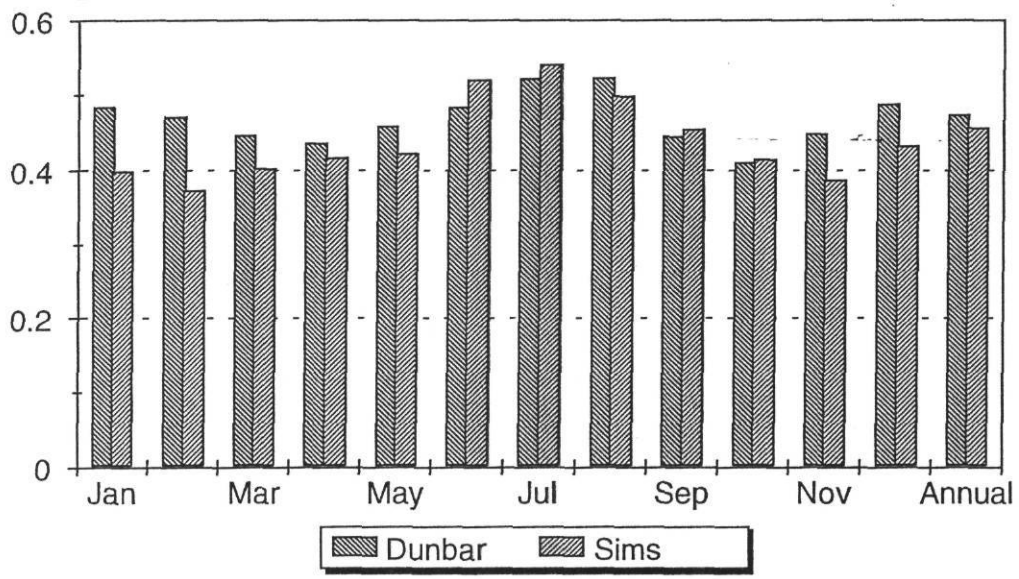

Figure B-10: *Comparison of ratio of Nighttime (6:00 p.m. to 7:00 a.m.) Other Than Lighting Consumption to Total Other Than Lighting Consumption for Dunbar Middle and Sims Elementary School*

Figure B-11 shows the ratio of nighttime gas consumption to the total gas consumption. It shows that Sims Elementary School has a higher ratio than Dunbar Middle School for most months.

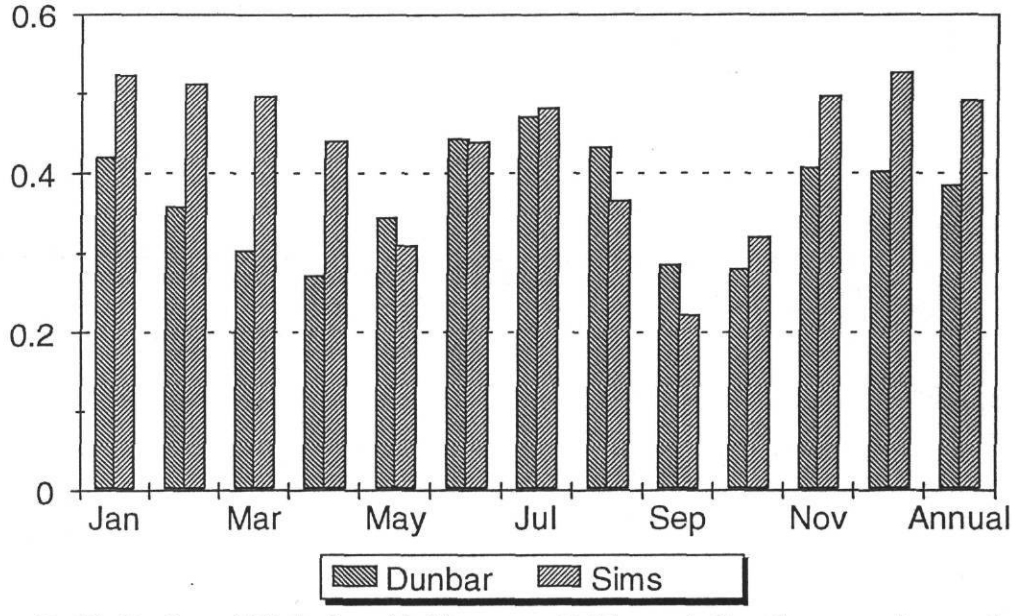

Figure B-11: *Ratios of Nighttime (6:00 p.m. to 7:00 a.m.) Gas Consumption to the Total Gas Consumption at Dunbar Middle and Sims Elementary School*

APPENDIX C

A site visit to Sims Elementary School was performed on 8 March, 1993. The lighting fixtures were counted room by room. The total installed fixture count is 824, including 606 88-watt two-lamp fixtures (Type A), 16 40-watt single-lamp fixtures (Type B), 141 80-watt two-lamp fixtures (Type C), one 20-watt lamp (Type D), eight 30-watt lamps (Type E), 20 18-watt lamps (Type F), 22 250-watt lamps (Type G), and 10 100-watt lamps (Type H). The lighting fixtures have a total installed wattage of 72,368. The lighting fixture counts are summarized in Table C-1.

Table C-1: *Results of Lighting Fixture Count During Site Visit (03/08/93) at Sims Elementary School*

Room	A	B	C	D	E	G	H	I	Watts
	88	40	80	20	30	18	250	100	
100	12								1056
101	12	2			2				1196
102	12								1056
103	12								1056
104	12	2			2				1196
105	11	2			2	5			1198
106	11					5			1058
107	11	2			2	5			1198
108	11					5			1058
109	9								792
110	9								792
111	9								792
112	9								792
113	9								792
114	9								792
115	9								792
116	9								792
117	9								792
118	9								792
119	9								792
120	9								792
121	9								792
122	9								792
123	9								792

124	9								792
125	6								528
126	6								528
127	9								792
128	9								792
129	9								792
130	9								792
131	9								792
132	9								792
133	9								792
134	9								792
135	9								792
136	9								792
137	9								792
138	9								792
139	9								792
140	9								792
141	9								792
142	9								792
143	9								792
144	12								1056
Office	26	1							2328
Corridor	68	4	100						14144
Entry Hall	22		18						3376
Mechanical			4						320
Smoker		1		1					60
Book Room	6								528
Custodian			1						80
Bath Room	12								1056
Median	17								1496
Gymnasium	6	2	5				16		5008
Kitchen	24		5				6		4012
Exterior			8					10	1640
Total	606	16	141	1	8	20	22	10	72368

Note: The watts include both lamp and ballasts.

Table C-2 groups the fixtures into class-room and office room lights, service room lights, kitchen and gymnasium room lights, and exterior lights. The security lighting was defined as the sum of exterior lights plus 1.4 kW, which serves the four entries to the building and generally remians on at night. The maximum custodial lighting was defined as the sum of corridor, kitchen and gymnasium, exterior, and service room lighting since all of these lights could occasionally be on at same time.

Table C-2: *Installed Lighting Wattage for Different Purposes at Sims Elementary School*

Type	Watts
Class-Room and Office	42672
Service Room	1516
Kitchen and Gymnasium	9020
Corridor	17520
Exterior	1640
Security Lighting	3040
Custodial Lighting	29700

A site visit to Dunbar Middle School was performed on 31 March, 1993. The lighting fixtures were counted room by room. The total installed fixture count is 1130, including 702 88-watt fixtures (Type A, 2×4, 2-lamp), 57 45-watt fixtures (Type B, 2×2, 2-lamp)-which were retrofitted from Type B1, 74 88-watt fixtures (Type B1, 2×2, 2-lamp), 103 88-watt fixtures (Type C, 2-lamp, 4 feet strip), 43 88-watt fixtures (Type D, 1×4, 2-lamp), one 66-watt fixture (Type E, 2-lamp, 3 feet strip), 106 88-watt fixtures (Type F), 12 150-watt lamps (Type G), and 32 150-watt fixture s(Type H, 2×4, 4-lamp). The lighting fixtures have a total wattage of 99.5 kW. The results of the fixture count are summarized in Table C-3.

***Table C-3:** Results of Lighting Fixture Count During the Site Visit at Dunbar Middle School*

Room	Type A	Type B	Type B (non)	Type C	Type D	Type E	Type F	Type H	Type G	Watts
	88	45	88	88	88	66	88	100	150	
101	16									1408
102	12									1056
106	22	2								2026
107	24	1					3			2421
108	6									528
109	12									1056
110	6									528
111	20									1760
112	12									1056
113	12									1056
114	20									1760
115	15									1320
116	12									1056
117	22						1			2024
118	27			2			1			2640
120				40						3520
122	12									1056
124	4									352
Auditorium			47							4136
Stage								12		1800
Corridor							91			8008
Storage	8									704
Faculty					14					1056
Mechanical	12									1056
Faculty work	4									352
Magnet					6					528
Library	4	30								1702
Offices	35	5		2						3481
Resource		2								90
Bathrooms			27	4						2728
Cafeteria	48									4224
Kitchen				17						1496
Gymnasium									20	3000
Locker rooms	4			26	19	1				4378
Activity bldg					4		5		12	2592
Portable 301	10									880
Portable 302	10									880
Portable 303	6									528
Portable 304	6									528
201	19	1								1717

202	12									1056
204	11	1								1013
206	11	1								1013
207	6									528
208	6									528
209	5	1								485
210	5	1								485
211	11	1								1013
212	11	1								1013
213	15									1320
14	15									1320
215	15									1320
216	15									1320
217	20									1760
218	12									1056
219	18	2								1674
220	10	2								970
221	11	1								1013
222	12									1056
223	11	1								1013
224	11	1								1013
226	11	1								1013
228	11	1								1013
230	11	1								1013
Office							1			88
Storage	6						4			880
Mechanical				12						1056
TOTAL	702	57	74	103	43	1	106	12	32	99519

Table C-4 groups the fixtures into class-room and office room lights, service room lights, kitchen and gymnasium room lights, and exterior lights. The security lighting was defined as the exterior lights plus entry lights to the building. The maximum custodial lighting was defined as the sum of corridor, kitchen, gymnasium, activity center, exterior, and service room lighting.

Table C-4: *Installed Lighting Wattage for Different Purposes at Dunbar Middle School*

Type	Watts
Class-Room and Office	60645
Service Room	6314
Kitchen and Gymnasium	19004
Corridors	8008
Security	4500
Custodial lighting	20860

Table: C-5 lists the kitchen equipment at Dunbar Middle School. This information came from the initial blue print of the school design. Note that the site visits found that this information is accurate. Sims Elementary School has the same equipment.

Table C-5: Installed Kitchen Power Devices at Dunbar Middle School

Item	Power on Name Plate	Remain On at night
1. Compressor 208 Volt, 3 phase	1 hp	1 hp
2. Compressor 208 Volt, 3 phase	2 hp	2 hp
3. Freezer 208 Volt, 1 phase, 10.9 FLA	2.23 kW	2.23 kW
4. Door Jamb heater and lights, 120 Volt, 1 phase	750 Watts	750 Watts
5. Disposal, 208 Volt, 3 phase	2 hp	
6. Mixer, 208 Volt, 3 phase	1 hp	
7. Cooler, 120 volt, 1 phase	0.66 hp	0.66 hp
8. Flake ice machine, 208 Volt, 1 phase	1 hp	1 hp
9. Convection oven, 208 volt, 3 phase	11 kW	
10. Convection steamer, 208 volt, 3 phase	24 kW	
11. Kettle, 208 volt, 3 phase	24 kW	
12. Fryer, 120/208 Volt, 3 phase	18 kW	
13. Fry Pan, 208 volt, 3 phase	24 kW	
14. Range with oven, 208 volt, 3 phase,	22.2 kW	
15. Slicer, 120 Volt, 1 phase	0.25 hp	
16. Domestic clothes washer 120 volt, 1 phase	0.33 hp	
17. Booster heater, 208 volt, 3 phase	45 kW	
18. Detergent dispenser, 120 volt, 1 phase	1.8 kW	
19. Dishwasher, 208 volt, 3 phase	1.5 hp	
20. Dishwasher tank heater, 208 volt, 3 phase	15 kW	
21. Disposal, 208 volt, 3 phase	3 hp	
22. refrigerator, 120 volt, 1 phase	0.333 hp	0.333 hp
Total	197.66 kW	6.74 kW

Note that Dunbar Middle School has three free-standing cola vendors, each with a designed electricity load of 1.2 kW or total of 3.6kW. Hence, Dunbar Middle School has a total cycling load of 10.34 kW.

APPENDIX D

An average weekly electricity profile was generated by averaging the electricity consumption at the same time of day and the same day of the week from nine weeks of data (September and October), which were avilable at the time of analysis. The averaged daily profile was generated by averaging the electricity consumption at the same time during the five week-days in the averaged weekly profile. These averaged profiles are helpful in finding how the lights and HVAC system were operated.

Figure D-1 indicates lighting consumption of 20 kW at night, which is much higher than the total installed security and sign lights of 4.5 kW. Note that the short-term measurement proved that the lighting electricity consumption is 4.5 kW at night when all the security and sign lights were on. Therefore, lighting consumption can be reduced by a substantial amount at night.

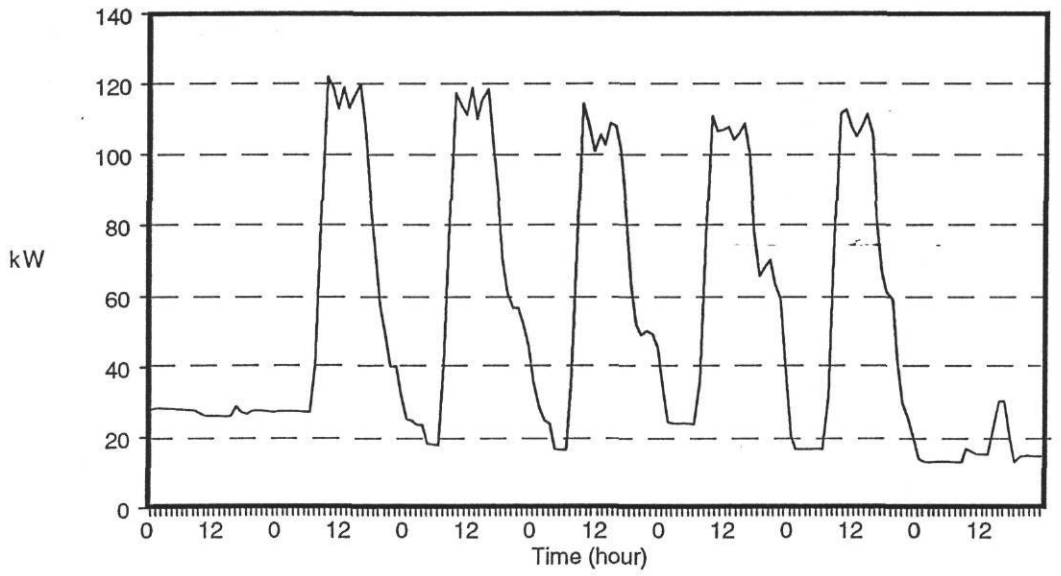

Figure D-1: *The Averaged Weekly Lighting Electricity Consumption Profile for Dunbar Middle School (12 indicates noon, 0 indicates midnight)*

Figure D-2 shows the averaged weekday lighting electricity consumption profile. The lighting electricity consumption varied from 80 kW to 40 kW during the period from 5 p.m. to 11 p.m when the custodians were working. However, the maximum custodial lighting was about 20.86 kW, which assumed that all the lights in the auditorium, kitchen, and corridors were on. If the custodial staff can keep the lights on only in the immediate working areas, the lighting electricity consumption can be easily controlled to as low as 10 kW during this period.

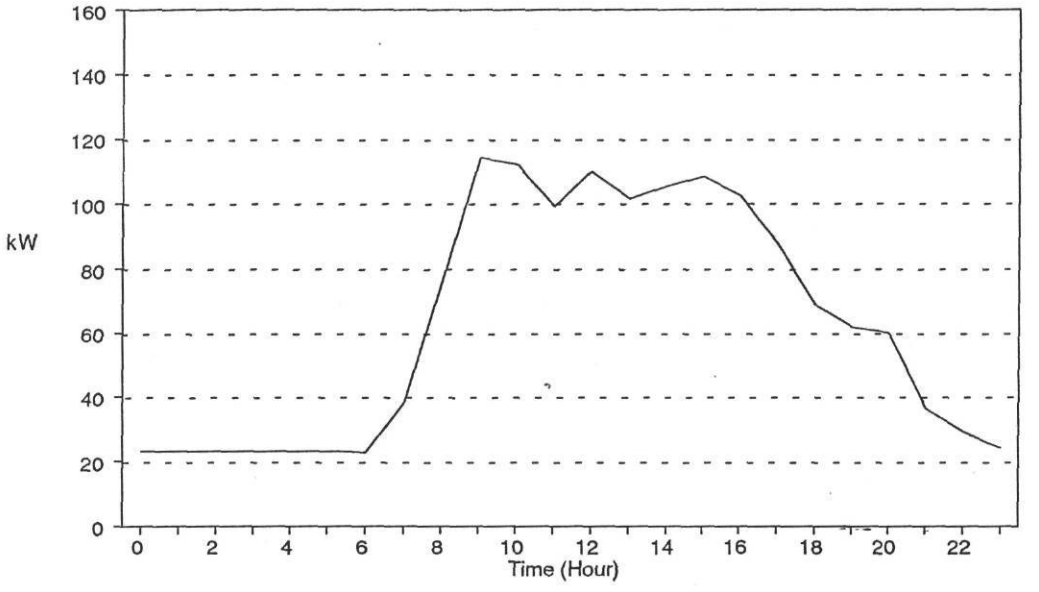

Figure D-2: *The Averaged Week Day Lighting Electricity Consumption Profile for Dunbar Middle School*

Figure D-3 shows the averaged daily other-than-lighting electricity consumption profile, which is defined as the difference between the whole-building electricity consumption and the whole-building lighting consumption. This electricity consumption was mainly due to the operation of the HVAC system. Consequently, the profile suggests that the HVAC system consumed 90 to 120 kW on the average at night when the HVAC

system was allowed to be turned off. Since the compressors, refrigerators, and cola vendors had a total installed power demand of 10.34 kW(See Appendix C), this high nighttime electricity consumption was mainly due to the operation of the HVAC system. The figure shows a sudden change between 23:00 to 0:00 which may be caused by the limited data (five weeks) and cycling loads at night.

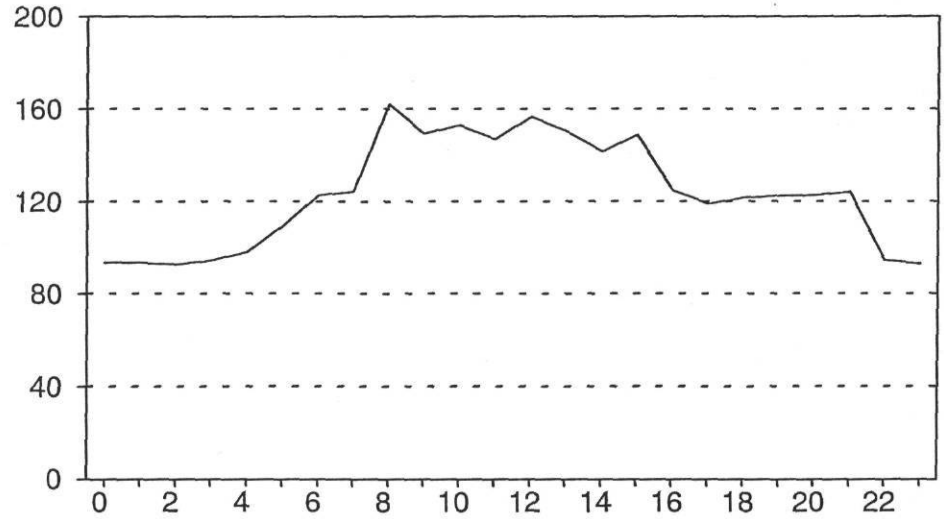

Figure D-3: *The Average Daily HVAC System Electricity Consumption at Dunbar Middle School*

Figure D-4 shows approximately 7 kW lighting consumption at night at Sims Elementary School. Since the total installed security and sign lights were 3.04 kW, some lights should be turned off.

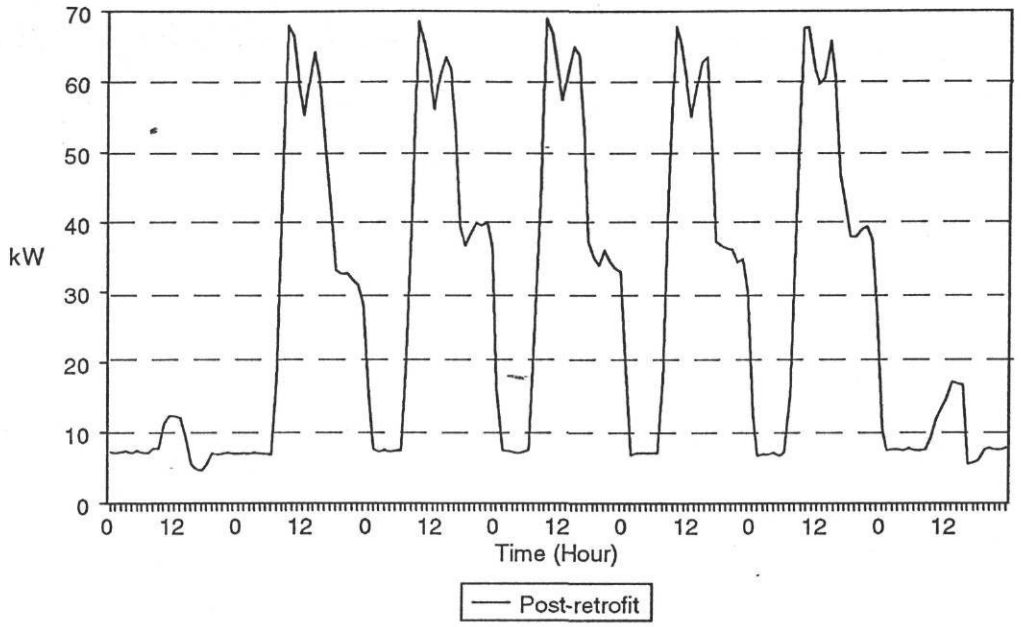

Figure D-4: *The Averaged Weekly Lighting Electricity Consumption Profile for Sims Elementary School (12 indicates noon and 0 indicates midnight)*

Figure D-5 shows the averaged weekday lighting electricity consumption profile at Sims Elementary School. This indicates an average consumption of 35 kW from 5 p.m. to midnight. However, the site visits have proved that the maximum designed custodial lighting was 29.7 kW at this school, which assumed that all lights in the corridors, kitchen, gymnasium, and service rooms were on. If the custodial staff can keep the lights on only in immediate working areas, the lighting consumption during this period can be easily controlled to as low as 20 kW (2/3 of the maximum lighting consumption). Consequently, a substantial amount of electricity energy can be saved.

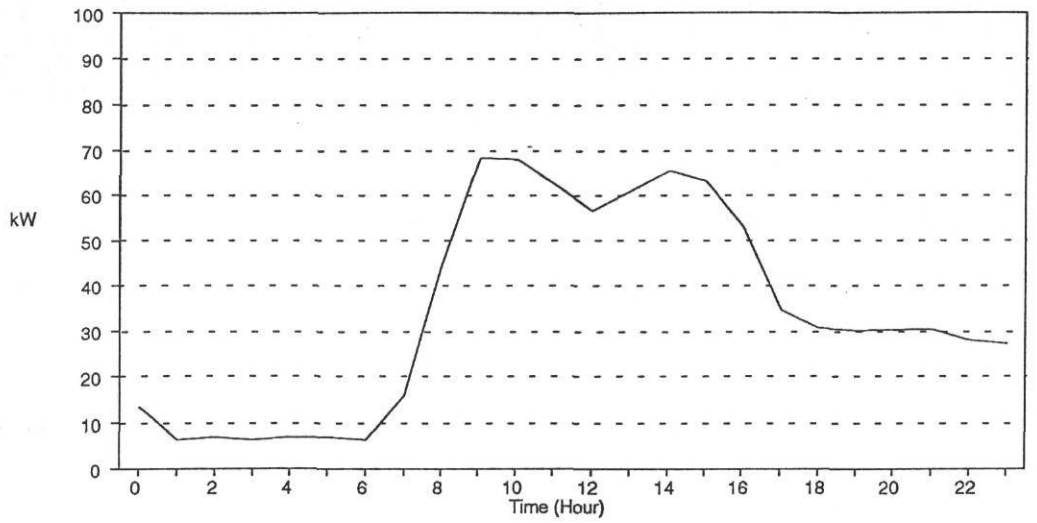

Figure D-5: *The Averaged Week-Day Lighting Consumption Profile for Sims Elementary School*

Figure D-6 shows the averaged HVAC system electricity consumption profile for Sims Elementary School. It shows an electricity consumption of 20 to 80 kW at night when the HVAC system was presumed to be turned off. Note that the maximum cycling load was about 6.5 kW at night. Consequently, it appears that the HVAC system was on at night.

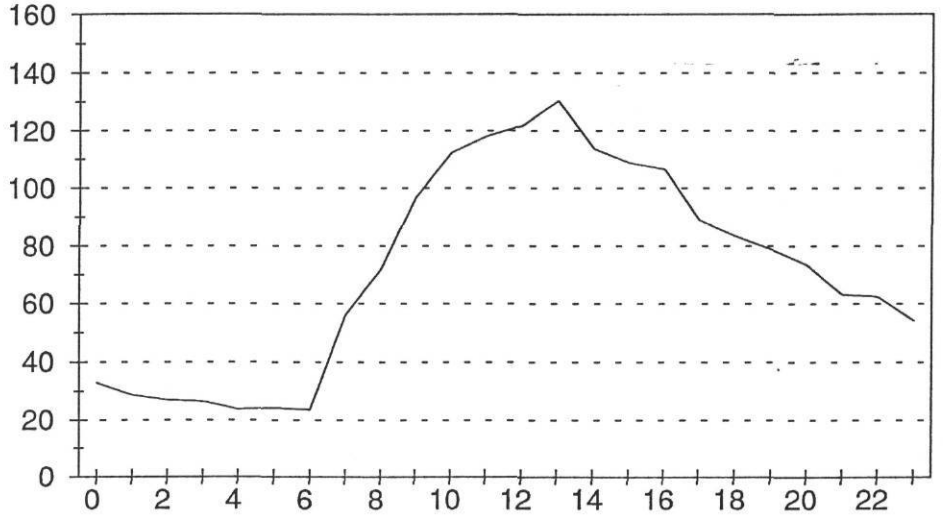

Figure D-6: *The Averaged Daily HVAC System Electricity Consumption Profile for Sims Elementary School*

From these averaged profiles, we can see the following energy savings opportunities: (1) shut-down HVAC systems at night; (2) turn off unnecessary lighting at night; and (3) have the custodians use only necessary lighting while working.

APPENDIX E

This appendix summarizes the short-term tests performed at Dunbar Middle School and Sims Elementary School.

The short-term test was performed from 11 p.m to 3 a.m. at Dunbar Middle School on 8 March, 1993. The test consisted of turning off light switches panel-by-panel, then other equipment panel-by-panel. The electricity consumption data were recorded at one-minute intervals. The test results are shown in Figures E-1 and E-2. The x axis is time, the y axis is the measured electricity consumption in units of kW.

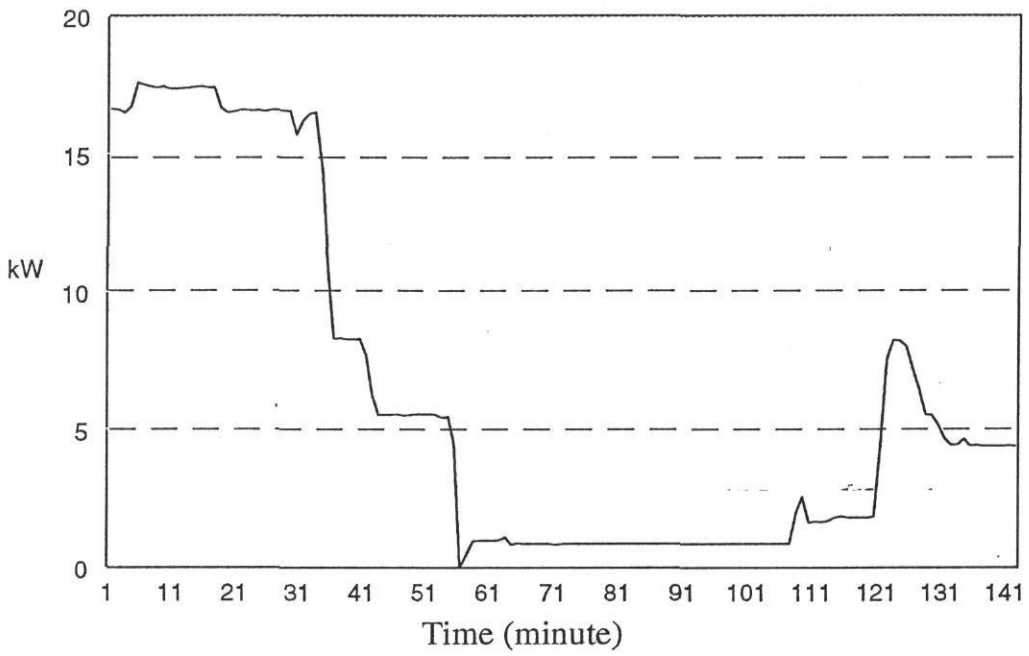

Figure E-1: *The Measured Lighting Electricity Consumption during the Short-Term Test on 8 March, 1993 at Dunbar Middle School (the test started at midnight)*

Figure E-1 shows the lighting electricity consumption decreasing from the start of the test to minute 55 as the lighting panels were turned off one by one. The power panel of the data logger was accidentally turned off at minute 56; hence, no lighting consumption was recorded. After turning on this panel, it showed electrical power of 2 kW. Then the

lighting panels which control the security lights were turned on and the interior lights were turned off manually. The increases of electricity consumption (minute 100 to minute 125) represent the process of turning the lighting panels on, and the following decrease represents the process of turning off interior lights. Finally, the security lighting electricity consumption was measured as 4.5 kW.

Figure E-2 shows the other-than-lighting building electricity consumption variation with time during the short-term test performed on 8 March, 1993. The control panels which are used to control the HVAC systems started to be turned off from minute 55, and finished at minute 98. It shows that the building can be operated with 11.5 kW power consumption when the HVAC systems are turned off. After minute 121, the HVAC systems were turned on again and the other-than-lighting electricity consumption was restored to the level before the test.

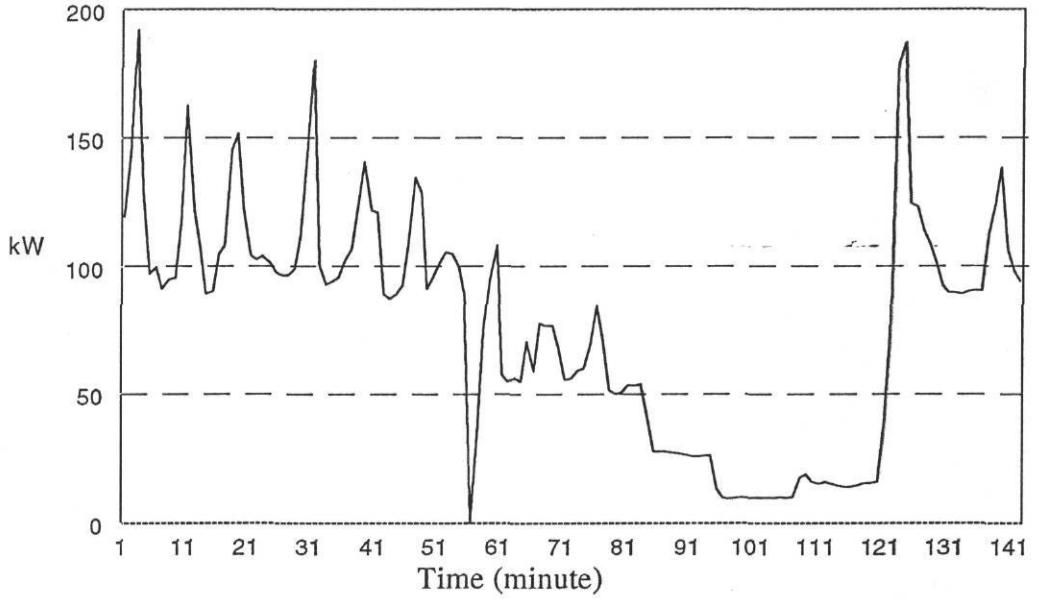

Figure E-2: *The Measured Other-Than-Lighting Electricity Consumption during the Short-Term Test Performed on 8 March, 1993 at Dunbar Middle School (The test started at midnight).*

Figure E-3 shows the results of the short-term tests performed on 31 March, 1993 at Sims Elementary School. Both the whole-building electricity consumption and lighting electricity consumption are shown in the figure. All lights were turned on first, which corresponds to minutes 1 to 35 in the Figure, then all the electricity panels were turned off, which corresponds to minute 35 to minute 70, finally, the electricity panels were turned on again. The test showed that the lighting electricity can be controlled to zero while the security lights and exit lights were on. It seems that the security lights and exit lights are not monitored by the LoanSTAR lighting channels. The test also showed that the total electricity consumption of the building could be controlled to 14 kW when the HVAC systems and interior lights were turned off.

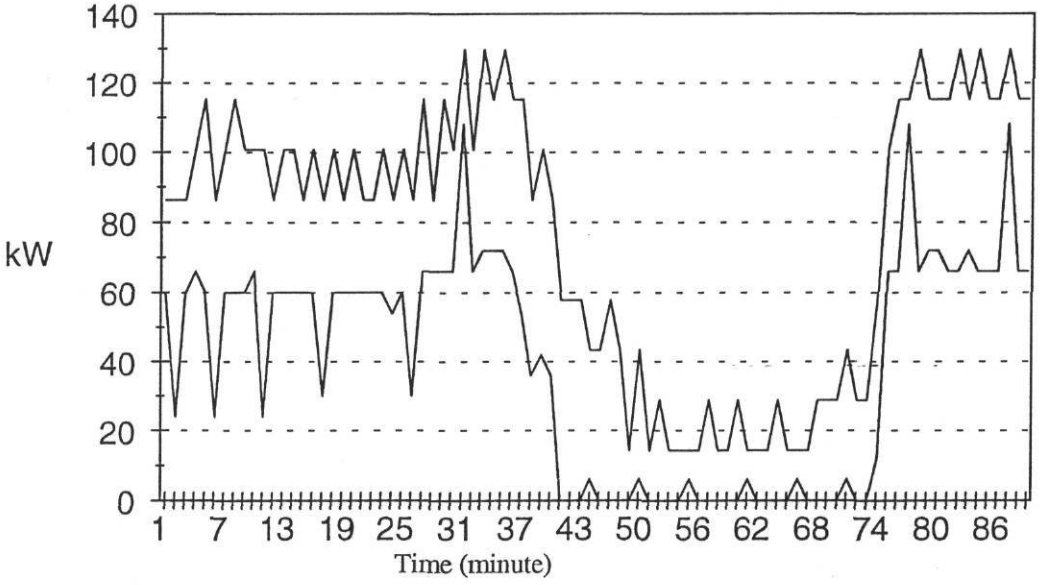

Figure E-3: *Variation of the Measured Whole-Building Electricity and Lighting Electricity Consumption (lower line) during the Short-Term Test performed on 31 March, 1993 at Sims Elementary School (The test started at 4:30 p.m.)*

APPENDIX F

This appendix describes the savings calculations, which include HVAC system savings (electricity and gas), and lighting savings (improved custodial operation, late night lighting shut-off, and daytime lighting savings). The savings are first summarized, then the methodology used for the calculations is explained, and finally the calculation procedure and data are presented.

Summary

Table F-1 summarizes the savings for both Dunbar Middle School and Sims Elementary School. Column 2 lists the gas savings due to the HVAC systems shut-down at night, column 3 the electricity savings due to the HVAC system shut-down at night, column 4 the lighting electricity savings due to improved custodial operation, column 5 the lighting electricity savings due to lighting shut-off late at night, and column 6 the lighting electricity savings due to installation of motion sensors in the auditorium, activity center, and gymnasium. Column 7 lists the total savings for each school. The last row of the table lists the sum of the savings for each option.

Table F-1: *Summary of the Annual Savings ($) for Each O&M Measure at Dunbar Middle and Sims Elementary School*

School	S_{gas} ($/year)	$S_{e,o}$ ($/year)	$S_{l,c}$ ($/year)	$S_{l,n}$ ($/year)	$S_{l,d}$ ($/year)	Total ($/year)
Dunbar	2,437	32,248	2,839	2,452	481	40,457
Sims	2,515	10,815	1,889	1,271	200	16,690
Total	4,952	43,063	4,728	3,723	681	57,147

Note: S_{gas} -gas savings due to HVAC systems shut-down at night
$S_{e,o}$ -electricity savings due to HVAC systems shut-down at night
$S_{l,c}$ -lighting electricity savings due to improved custodial operation
$S_{l,n}$ -lighting electricity savings due to lighting shut-off at late night
$S_{l,d}$ -lighting savings due to the installation of motion sensors at gymnasium activity center, and auditorium

Methodology

The savings was calculated as the difference between measured total energy consumption in 1992 and the required energy consumption, which was identified by the short-term tests and site visits.

The monthly gas savings was calculated using the following formula:

$$S_{gas} = \begin{cases} E_{gas,night} - E_{base} - 0.1 \times E_{gas,day} & \text{Jan. \& Dec.} \\ E_{gas,night} - E_{base} & \text{Other months} \end{cases}$$

Where, S_{gas} is the gas savings, $E_{gas,night}$ is the measured monthly nighttime (6:00 p.m. to 7:00 a.m.) gas consumption, E_{base} is the measured minimum monthly gas consumption at night which might be consumed by pilot lights, $E_{gas,day}$ is the measured monthly daytime gas consumption. Note that 10% of the daytime gas consumption was used to account for the penalty for shutting-down at night during the coldest months (January and December). This estimate is based on moring heat-up observed in other LoanSTAR buildings where systems are shut-down at night.

The electricity savings due to HVAC systems shut-down at night was calculated as:

$$S_e = E_{eu,night} - H \times P_{ui} - 0.1 \times E_{eu,day}$$

Where, S_e is the electricity savings due to the HVAC system shut-down at night (6:00 p.m to 7:00 a.m.), $E_{eu,night}$ is the measured monthly other-than-lighting electricity consumption (whole-building electricity consumption minus lighting electricity consumption), P_{ui} is the measured un-interrupted electricity power when the HVAC system was complete shut down at night, (this was determined by the short-term test), H is the number of nighttime hours, and $E_{eu,day}$ is the measured monthly other-than-lighting electricity consumption during daytime. The second term on the right handside of the equation considers the electricity consumption of the refrigerators and some office machines. The third term on

the right handside of the equation takes into account the penalty of shutting down HVAC systems at night.

The custodial lighting savings was calculated using the measured lighting electricity consumption and the assumption that the lights are on only in the working areas. The savings was calculated using the formula:

$$S_{l,c} = E_{l,c} - H_{custodian} \times N \times P_c - H_{evening} \times P_s$$

where, $S_{l,c}$ is the electricity savings due to improved custodial operation, $E_{l,c}$ is the measured lighting electricity consumption during the custodial hours, $H_{custodian}$ is the number of custodian hours for each working day, N is the number of school days each month, P_c is the lighting electricity consumption during the custodial hours when the lights are on only in the working areas, (which was taken as the half of the installed kW in corridors, gymnasium, activity center, and cafeteria), $H_{evening}$ is the number of hours of the custodian working period each month, and P_S is the security lighting consumption rate.

The electricity savings due to lighting shut-off late at night was calculated as the difference between measured lighting electricity consumption in 1992 and the required electricity consumption by the security lights. The savings was calculated using the following formula:

$$S_{l,n} = E_{e,n} - H_{night} \times P_s$$

where, $S_{l,n}$ is the electricity saved due to lighting shut-off late at night, $E_{e,n}$ is the measured monthly lighting electricity consumption late at night (11:00 p.m. to 7:00 a.m for Dunbar Middle School, midnight to 7:00 a.m. for Sims Elementary School), H_{night} is the number of late night hours, and P_s is the security lighting consumption rate.

The electricity savings due to installation of motion sensors in the auditorium, gymnasium, and activity center were determined based on the following assumptions: (1) motion sensors will reduce lighting usage about 4 hours each school day, and (2) each

area required 0.32 kW. The electricity savings in these areas were calculated using the formula:

$$S_{l,d} = 4 \times N \times P_d$$

Where, $S_{l,d}$ is the electricity savings due to the installation of motion sensors, and P_d is the installed kW under the control of motion sensors.

The parameters used for these savings calculations are summarized in Table F-2.

Table F-2: Summary of the Basic Parameters Used in the Savings Calculations

School	E_{base} MBtu/month	P_{ui} kW	P_c kW	P_s kW	P_d kW	$H_{custodian}$ hour
Dunbar	10	11.5	18.33	4.5	9.81	5
Sims	4	11.0	29.70	3.0	4 .00	6

Note:
- E_{base} -the measured minimum monthly gas consumption at night (6:00 p.m. to 7:00 a.m.)
- P_{ui} -the uninterrupted power consumption during nighttime due to kitchen and other equipment
- P_c -the maximum electricity power consumption during custodial hours
- P_s -the electricity power consumption of security lights
- P_d -the electricity power reduction due to the installation of the motion sensors
- $H_{custodian}$ -the custodial hours in the evening

Calculation Table

Table F-3: Summary of the Gas Savings Calculations for Dunbar Middle School

Month	Nighttime MBtu/month	Daytime MBtu/month	Savings MBtu/month	Cost Savings $/month
1	245.41	339.39	201.56	$907.04
2	98.44	176.51	88.53	$398.38
3	39.75	91.32	29.84	$134.29
4	17.73	47.65	7.82	$47.65
5	17.69	33.68	7.78	$35.02
6	11.19	14.05	1.28	$5.77
7	9.91	11.11	0.00	$0.00
8	11.74	15.41	1.83	$8.23
9	11.04	27.56	1.13	$5.10
10	13.00	33.46	3.09	$13.92
11	80.15	117.01	70.24	$316.07
12	162.45	242.01	128.34	$577.53
Total	718.53	1,149.17	541.46	$2,436.55

Note: Column 1= month
Column 2= monthly nighttime gas consumption (6:00 p.m. to 7:00 a.m)
Column 3= monthly daytime gas consumption (7:00 a.m. to 6:00 p.m) MBtu.
Column 4= gas savings, (raw savings minus 10% of the monthly daytime consumption for January and December; corrected savings are the same as raw savings for the rest of the months)
Column 5= monthly gas cost savings, ($/month, determined according to the corrected monthly gas savings with a unit price of $4.6/MBtu)

***Table F-4:** The Electricity Savings due to HVAC Systems Shut-down at Dunbar Middle School*

Month	Nighttime kWh/month	Daytime kWh/month	H hr/month	Savings kWh/month	Savings $/month
1	30,613	32,652	403	22,712.93	$1,530.85
2	25,490	28,573	377	18,296.89	$1,233.21
3	26,319	32,678	403	18,417.10	$1,241.31
4	40,349	52,269	390	30,636.58	$2,064.91
5	58,043	68,598	403	46,549.17	$3,137.41
6	69,931	74,806	390	57,965.75	$3,906.89
7	98,063	90,006	403	84,428.08	$5,690.45
8	82,302	75,288	403	70,139.06	$4,727.37
9	66,784	83,345	390	53,964.38	$3,637.20
10	45,891	66,038	403	34,652.21	$2,335.56
11	29,636	36,476	390	21,503.37	$1,449.33
12	26,616	27,922	403	19,189.03	$1,293.34
Total	600,037	668,652	4,758	478,454.55	$32,247.84

Note: Column 1= month

Column 2= monthly nighttime other-than-lighting electricity consumption (whole-building electricity consumption minus lighting consumption)

Column 3= monthly daytime other-than-lighting electricity consumption (7:00 a.m to 6:00 p.m.) kWh/month

Column 4= number of nighttime hours

Column 5= other-than-lighting savings due to HVAC systems shut-down at night (kWh/month) (which is calculated as (2)-11.5*(4)-0.1*(3). It was assumed 10% of nighttime shut off penalty, and 11.5 kW uninterrupted consumption at night)

Column 6= electricity cost savings due to HVAC system shut-down at night (which is determined according to electricity savings with a constant price of $0.0674/kWh)

Table F-5: Lighting Savings Calculation due to Improved Custodial Operation at Dunbar Middle School

Month	Electricity kWh/month	$H_{evening}$ hr/month	N day/month	Savings kWh/month	Cost Savings $/month
1	5,944	155	18	4,421.55	$298.01
2	6,256	145	20	4,701.73	$316.90
3	5,629	155	17	4,164.61	$280.69
4	5,429	150	21	3,807.13	$256.60
5	4,659	155	21	3,014.03	$203.15
6	1,938	150	3	1,127.22	$75.97
7	2,787	155	0	2,089.90	$140.86
8	3,093	155	8	2,034.75	$137.14
9	5,674	150	21	4,051.53	$273.07
10	7,215	155	22	5,525.74	$372.43
11	5,139	150	19	3,607.32	$243.13
12	4,943	155	15	3,569.10	$240.56
Total	58,705	1,830	182	42,127.78	$2,839.41

Note: Column 1= month.

Column 2= measured lighting electricity consumption during custodial hours (6:00 p.m. to 11:00 p.m.) (kWh/month)

Column 3= number of hours during custodial working period

Column 4= number of schooldays each month

Column 5= custodial lighting savings, (kWh/month, which is calculated as: (1)-5*(4)*18.33/2-4.5*(3). It was assumed that custodian turns on the lights only for the immediate working areas or half of the lights (9.17 kW), plus the security lighting consumption of 4.5 kW)

Column 6= custodial lighting cost savings (which is determined according to the electricity savings with a constant price of $0.0674/kWh)

Table F-6: Lighting Savings due to Lighting Shut-off Late at night and Daytime Lighting Savings at Dunbar Middle School

Month	Lighting	H_{night}	N	Night	Savings	Day Time	Savings
	kWh/month	hr/month	day/month	kWh/month	$/month	kWh/month	$/month
1	4,917	248	18	3,801	$256.17	706	$47.61
2	4,511	232	20	3,467	$233.65	772	$52.05
3	4,381	248	17	3,265	$220.09	656	$44.24
4	4,197	240	21	3,117	$210.09	811	$54.65
5	3,741	248	21	2,625	$176.95	811	$54.65
6	2,938	240	3	1,858	$125.20	116	$7.81
7	4,695	248	0	3,579	$241.19	0	$0.00
8	3,456	248	8	2,340	$157.71	309	$20.82
9	3,646	240	21	2,566	$172.92	811	$54.65
10	5,321	248	22	4,205	$283.38	850	$57.26
11	4,216	240	19	3,136	$211.37	734	$49.45
12	3,532	248	15	2,416	$162.86	579	$39.04
Total	49,550	2,928	182	36,374	$2,451.59	7,144	$481.47

Note: Column 1= month
Column 2= measured lighting electricity consumption from 11:00 p.m. to 7:00 a.m. kWh/month
Column 3= number of hours from 11:00 p.m to 7:00 a.m. each month.
Column 4= number of schooldays each month
Column 5= electricity savings due to lighting shut-off late at night (which is calculated as : (2)-4.5*(3), which assumes 4.5 kW security lighting consumption)
Column 6= electricity cost savings due to lighting shut-off at night (which is calculated according to the electricity savings with a constant price of $0.0674/kWh)
Column 7= electricity savings due to installation of motion sensors (which was calculated as: (4)*4 hour/day*9.81 kW. It was assumed that three motion sensors be installed in the Auditorium, Gymnasium, and activity center, which will essentially reduce the lighting usage about 4 hours per schoolday. The installed lighting demands were 10.77 kW. However, the lighting saving demand was taken as 9.81 kW because of the concern of security during daytime)
Column 8= electricity cost saving due to the installation of the motion sensors

Table F-7: Summary of Gas Savings Calculations for Sims Elementary School

Month	Nighttime MBtu/month	Daytime MBtu/month	Savings MBtu/month	Cost Savings $/month
1	147	134	129.61	$596.21
2	100	96	96.29	$442.93
3	79	80	74.56	$342.96
4	33	42	29.26	$134.59
5	10	23	6.07	$27.93
6	6	8	2.00	$9.20
7	5	5	0.71	$3.27
8	4	8	0.37	$1.71
9	4	14	0.00	$0.00
10	11	24	7.17	$32.96
11	85	86	80.57	$370.61
12	136	122	120.19	$552.86
Total	621	641	546.79	$2,515.22

Note: Column 1= month
Column 2= monthly nighttime gas consumption (6:00 p.m. to 7:00 a.m)
Column 3= monthly daytime gas consumption (7:00 a.m. to 6:00 p.m)
Column 4= monthly gas savings (raw savings minus 10% of the monthly daytime consumption for January and December, corrected savings are the same as raw savings for other months)
Column 5= monthly gas cost savings ($/month, determined using corrected monthly savings with a unit price of $4.6/MBtu)

Table F-8: Electricity Savings Due to HVAC System Shut-down at Night for Sims Elementary School

Month	Nighttime kWh/month	Daytime kWh/month	H hr/month	Savings kWh/month	Cost Savings $/month
1	8,691	13,102	403	2,948	$198.69
2	8,848	14,905	377	3,211	$216.41
3	11,527	17,118	403	5,383	$362.78
4	16,603	23,180	390	9,995	$673.63
5	21,534	29,456	403	14,156	$954.09
6	31,673	29,265	390	24,457	$1,648.39
7	39,218	33,337	403	31,451	$2,119.83
8	31,807	32,073	403	24,167	$1,628.85
9	31,026	37,284	390	23,007	$1,550.69
10	19,238	27,262	403	12,079	$814.12
11	10,477	16,576	390	4,529	$305.27
12	10,963	14,462	403	5,084	$342.67
Total	241,606	288,021	4,758	160,466	$10,815.42

Note: Column 1= month

Column 2= monthly nighttime (6:00 p.m to 7:00 a.m) other-than-lighting electricity onsumption (whole-building electricity consumption minus lighting consumption)

Column 3= monthly daytime (7:00 a.m. to 6:00 p.m.) other-than-lighting electricity consumption (kWh/month)

Column 4= number of nighttime hours

Column 5= monthly other-than-lighting savings due to HVAC system shut-down at night (kWh/month, which is calculated as (2)-11*(4)-0.1*(3). It was assumed 10% of nighttime shut off penalty, and 11 kW uninterrupted consumption at night)

Column 6= other-than-lighting electricity cost savings (which is determined according to electricity savings with a constant price of $0.0674/kWh)

Table F-9: Lighting Savings due to Improved Custodial Operation at Sims Elementary School

Month	Electricity kWh/month	$H_{evening}$ hr/month	N	Savings kWh/month	Cost Savings $/month
1	4,776	186	18	2,606.46	$175.68
2	5,115	174	20	2,803.84	$188.98
3	4,312	186	17	2,231.96	$150.43
4	5,077	180	21	2,658.40	$179.18
5	5,035	186	21	2,598.66	$175.15
6	2,820	180	3	2,005.60	$135.18
7	1,505	186	0	939.26	$63.31
8	2,312	186	8	1,033.76	$69.68
9	4,747	180	21	2,328.60	$156.95
10	5,696	186	22	3,170.56	$213.70
11	4,999	180	19	2,759.20	$185.97
12	4,798	186	15	2,895.76	$195.17
Total	51,191	2,196	182	28,032.06	$1,889.36

Note: Column 1= month

Column 2= measured lighting electricity consumption during custodial hours (6:00 p.m to 11:00 p.m) kWh/month

Column 3= number of hours of the custodial working period

Column 4= number of schooldays each month

Column 5= lighting savings due to improved custodial operation (kWh/month, which is calculated as: (1)-6*(4)*29.7/2-3.04*(3). It was assumed that the custodian turns on the lights only for the immediate working areas or half of the lights (14.8 kW), plus the security lighting consumption 3.04 kW)

Column 6= lighting electricity savings due to improved custodial operation (which is determined according to the lighting savings with a constant price of $0.0674/kWh)

***Table F-10:** Lighting Electricity Savings due to Lighting Shut-off at Late Night and Day-time Lighting Electricity Savings at Sims Elementary School*

Month	Electricity	H_{night}	N	Late Night	Savings	Day Time	Savings
	kWh/month	hr/month		kWh/month	$/month	kWh/month	$/month
1	1,753	217	18	1,093.62	$73.71	288.00	$19.41
2	1,795	203	20	1,178.18	$79.41	320.00	$21.57
3	1,890	217	17	1,230.42	$82.93	272.00	$18.33
4	2,108	210	21	1,469.60	$99.05	336.00	$22.65
5	2,266	217	21	1,605.82	$108.23	336.00	$22.65
6	3,013	210	3	2,374.50	$160.04	48.00	$3.24
7	2,221	217	0	1,560.82	$105.20	0.00	$0.00
8	2,042	217	8	1,382.02	$93.15	128.00	$8.63
9	2,237	210	21	1,598.30	$107.73	336.00	$22.65
10	2,322	217	22	1,662.62	$112.06	352.00	$23.72
11	2,377	210	19	1,738.30	$117.16	304.00	$20.49
12	2,630	217	15	1,970.42	$132.81	240.00	$16.18
Total	26,653	2,562	185	18,864.62	$1,271.48	2,960.00	$199.50

Note: Column 1= month
Column 2= measured lighting electricity consumption from midnight to 7:00 a.m (kWh/month)
Column 3= number of hours from midnight to 7:00 a.m each month.
Column 4= number of school-days each month
Column 5= electricity savings due to lighting shut-off late at night (which is calculated as : (2)-3.04*(3), which assumes 3.04 kW security lighting consumption)
Column 6= electricity cost savings due to lighting shut-off at late night (which is calculated according to the electricity savings with a constant price of $0.0674/kWh)
Column 7= electricity savings due to installation of motion sensors (which was calculated as: (4)*4 hour/day*4 kW. It was assumed that motion sensor be installed in the Gymnasium, which will essentially reduce the lighting usage about 4 hours per schoolday)
Column 8= electricity cost saving due to the installation of the motion sensors

APPENDIX G

This appendix summarizes the measured savings of shutting down the HVAC system by the EMS following the short-term test at Dunbar Middle School.

Figures G-1 and G-2 show the measured whole-building electricity and lighting consumption at Dunbar Middle School from 2 March to 12 April, 1993. The short-term test was performed on 8 March, and the EMS system began shutting down the HVAC systems at night and weekends on 12 March, 1993.

Figure G-1 shows that the total building electricity consumption dropped 75 kW from 110 kW to 35 kW at night and weekends, which is somewhat above the estimated night consumption of 16 kW. Since the shut-down can be implemented on weekend days, it increases O&M savings by 25% over the estimation presented in this report. Although the actual electricity consumption is higher than the optimized value, the actual savings over one week substantially larger than the savings estimated in this report.

Figure G-2 shows measured lighting electricity consumption. Note that the lighting electricity consumption was reduced to about 4 kW at night after the short-term test on 8 March, 1993. It appears that the custodial staff made changes which lowered nighttime consumption for March 14-Aprile 1. However, there was substantial nighttime use from April 2-10.

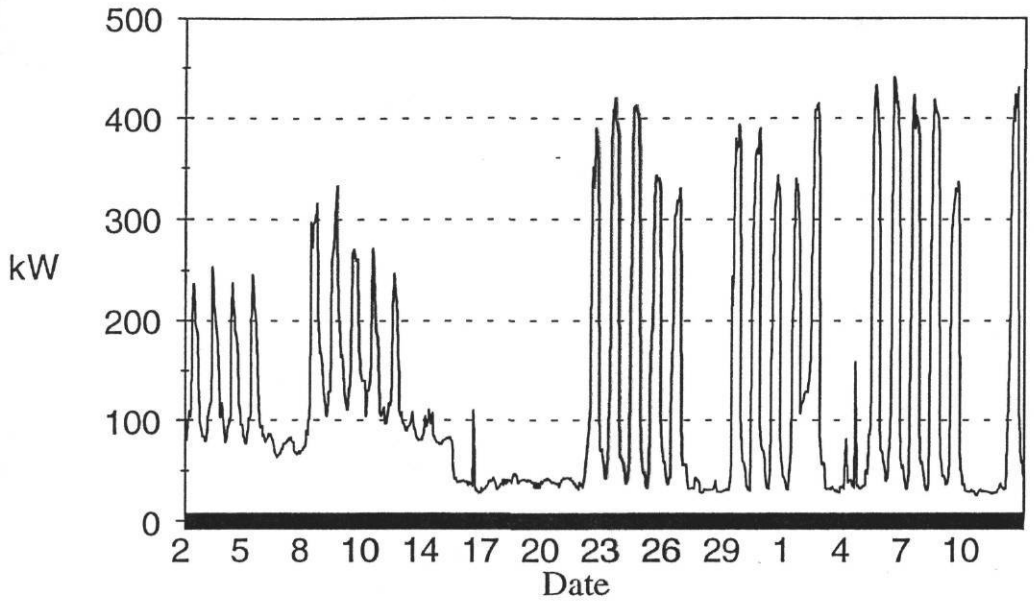

Figure G-1: *Measured Whole-building Electricity Consumption from 2 March to 12 April, 1993 at Dunbar Middle School. Note that the nighttime shut down was started on 12 March after the site visit on 8 March, 1993.*

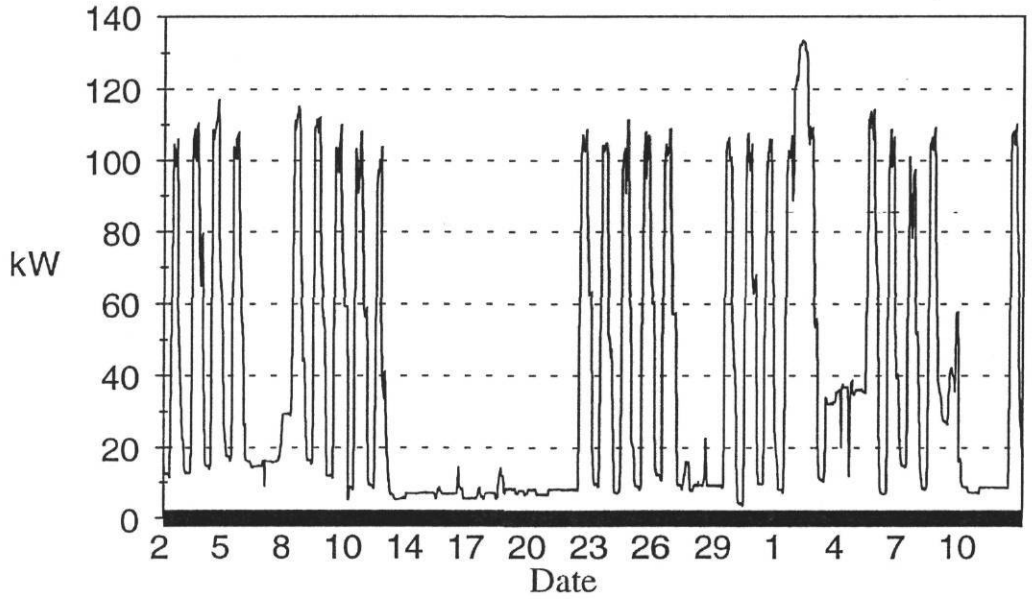

Figure G-2: *Measured Lighting Electricity Consumption at Dunbar Middle School from 2 March to 12 April, 1993.*