#6153

Texas LoanSTAR Monitoring & Analysis Program
Characterizing Loanstar Buildings & Energy Consumption

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ABSTRACT

This paper presents an overview of the buildings participating in the Texas LoanSTAR program. In this paper, we categorized the buildings in terms of their number, size, percent area effected, types of buildings, types of retrofits, their estimated costs and savings, and the connected loads. Nine buildings are analyzed in additional detail, including indices that look at the maximum-minimum and mean electricity, chilled water, and steam/hot water consumption for the first year of recorded consumption.

INTRODUCTION

The Texas LoanSTAR program is an eight year, $98 million revolving loan program for energy conservation retrofits in Texas State, local government and school buildings funded by oil overcharge dollars. The program began in 1988. Public sector institutions participating in the program must repay the loans according to the estimated savings in four years or less. As a part of this program, a state-wide Monitoring and Analysis Program (MAP) was established in 1989.

LoanSTAR BUILDINGS

There are 47 buildings which are currently being monitored under the LoanSTAR program. More buildings are included each month as the program grows. The buildings are spread over the entire state of Texas. Figure 1 shows the locations of these buildings. Twenty five sites are in the Austin area; most under the authority of the State Purchasing and General Services Commission (SP&GSC). The remainder are on the University of Texas (UT) Austin campus. There are six sites in Galveston and three sites in Houston. In the Dallas/Fort Worth area, there are six sites, including 3 buildings at the UT Arlington campus.

The size of the buildings being monitored varies. The smallest building is the W.C.Hogg building on the UT campus with conditioned area of 54,000 ft², while there are large medical complexes, such as M.D.Anderson center in Houston with an overall area of over 1.2 million ft². Table 1 provides a list of buildings which are being monitored with their respective areas, codes used in the paper, and recommended retrofits with their current completion status.

Figure 2 provides a breakdown of 47 buildings by area and count. The buildings are binned according to square foot area. The left Y-axis shows the number of buildings, while the right Y-axis shows the percentage area of the buildings in each bin. About three quarters of the total square footage is in buildings of greater than 200,000 ft². There are 5 sites which have overall conditioned areas of more than 500,000 ft². These sites are large complexes, such as M.D.Anderson Center and the Texas Department of Health in Austin. They account for 36% of the total area being monitored.

Figure 3 is a pie chart showing the breakdown by square footage of buildings according to their functions. The functions represent seven different types; medical facilities/classrooms (36.3%), classrooms/offices/ laboratories (22.6%), offices/computers (13.7%), classrooms/offices (13.1%), offices (6.3%), libraries (5.4%), and classrooms/offices/theaters (2.6%). Most of the buildings are university buildings with classrooms and offices. Some also have laboratories and theaters. Several buildings have large computer facilities, such as the Zachry Engineering Center (ZEC) on the Texas A&M University campus, the L.B.Johnson building and the J.E. Rudder building at SP&GSC, which contribute a significant amount of the building electric load. These buildings are represented as a separate group labeled as "Offices/Computer Facilities". Many of the offices buildings are those at the Capitol State Complex. There are also 3 libraries, which account for 5% of the total area.

The pie chart (Figure 3) gives a similar picture to that shown in Figure 2, namely, that the 5 largest sites with areas of over 500,000 ft² are medical complexes accounting for 36% of the total monitored area. The remaining 64% is divided among 40 odd buildings which are mostly university and office buildings.

Figures 4a and 4b provide, on a percentage basis, a breakdown of the audit estimated costs and savings respectively for different types of retrofits. All the retrofits combined have an estimated retrofit cost of about $21 million and annual savings of about $7 million, for a simple payback of 3 years. The boiler retrofits have the lowest payback of only 0.8 years, while variable speed pumping retrofits have the highest payback of more than 5 years. A complete breakdown is provided in Table 2.

Variable Air Volume (VAV) conversion of Constant Volume (CV) systems are by far the most widely recommended measure. This measure (also known as an ECRM, i.e., Energy Cost Reduction Measure) is broken down into 2 categories, HVAC

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System Retrofits and Variable Speed Drive (VSD) conversion. Other widely recommended measures are the conversion of incandescent lighting to fluorescent lighting and installing an Energy Monitoring and Control System (EMCS). The estimated savings from these retrofits are more or less in line with the costs, for instance the VAV accounts for about 55% of the costs and results in about 57% of savings.

As for the type of energy savings, Figure 5 gives the breakdown in terms of source energy (1 kW = 11,600 Btu/h). Since VAV and lighting retrofits are the most widely recommended measures, electricity savings are by far the highest. VAV also accounts for the major portion in savings for chilled water energy and steam/hot water energy. Table 3 provides savings breakdown both in terms of site energy and source energy. In all, these retrofits have a potential source energy savings of over 2 Trillion (million million) Btus/year.

Figure 6a has been constructed with data from 24 buildings, while Figure 6b has been constructed with data from 19 buildings. These buildings are representative of many of the buildings being monitored. Large medical complexes have not been included since areas for individual building within the complexes are not currently available. Figures 6a and 6b provide W/ft² indices for the connected lighting load and Motor Control Centers (MCC) respectively for the buildings separated in 0.5 W/ft² interval bins. The left Y-axis shows the number of buildings while the right Y-axis shows the percent area occupied by those buildings. On the average, the connected MCC load for all the 24 buildings is 1.79 W/ft² and the connected lighting load is 1.74 W/ft². Indices for MCC, which account for air handling unit (AHU) fan motors and pump motors, shows that 79% of the buildings (65% by area) fall into the 1 W/ft² to 2.5 W/ft² range. However, the S.F. Austin building at the SP&GSC is an outlier with a significant connected MCC load (3.05 W/ft ²). This is because this building has several large chilled water and condensate return pumps which are used in the central plant that serves 1.27 million ft² of office space. If it is removed from the group, the average falls by 0.05 W/ft². For lighting loads, 70% of the buildings (60% by area) fall into the 1 W/ft² to 2.5 W/ft² range. Only the LBJ building has a lighting load in excess of 2.5 W/ft² (2.67 W/ft²), which is due to a large number of lights in the stacks on all floors, which are used for an extended period of time. If it is removed from the group, the average falls by 0.05 W/ft².

Building Energy Usage

Nine buildings have been analyzed for their whole-building electricity, steam, and chilled water consumption. These buildings are partially representative of the whole group, for example, the Perry Casteneda Library (PCL) is a library on the UT Austin campus, the Zachry Engineering Center (ZEC) is classroom/office type building with a big computer load. Other buildings have classrooms, offices, laboratories, and theaters. A brief discussion of each building is provided in the next section followed by the energy consumption analysis.

The Zachry Engineering Center

The Zachry Engineering Center (ZEC) on the Texas A&M university campus in College Station was built in 1973. It houses classrooms, laboratories, a big computer facility, and faculty offices. It is a 4-story (plus basement parking level) structure with approximately 324,000 ft² of gross floor area and 258,000 ft² of conditioned space. It is a heavy structure with 6" concrete floors. The walls are made of 6" concrete and the single-pane windows cover approximately 22% of the exterior wall area including 3,100 ft² of clerestory windows. The lighting is primarily fluorescent and consumes approximately 1.35 W/ft² . Chilled water, hot water, steam, and electricity are provided to the facility by a central plant. At present (i.e. after the retrofit), the building is served by twelve VAV dual-duct AHUs (40 hp each), seven CV AHUs (30 hp total), and ten fan-coil units (5 hp total). There are two constant volume chilled water pumps (30 hp each) and two constant volume hot water pumps (20 hp each). There are also 7 miscellaneous pumps (5.8 hp total) and 50 exhaust fans (25 hp total). The domestic hot water for the building is produced by a steam-fed converter.

The Education Building

The Education building (EDB) on the UT Austin campus was erected in 1976. It houses classrooms and faculty offices. The building is five stories in height with a total area of 251,000 ft². The walls are made of face brick on block with a flat built-up roof .The windows are single-pane glass, covering 18% of the total wall area. Lighting is primarily 34W fluorescent. Chilled water, steam, and electricity are supplied by a central plant. At present, there are eight VAV dual-duct AHUs (50 hp each), three CV dual-duct AHUs (20 hp total), eight variable frequency return fans (6-15 hp, 2-20 hp), and two CV return fans (3 hp total). There is one variable volume chilled water pump (75 hp), two constant volume chilled water pumps (1-75 hp, 1-1 hp), and one hot water pump (3/4 hp). There are both chilled water and steam coils in the large AHUs. Domestic hot water is produced through a steam heat exchanger.

The University Teaching Center

The University Teaching Center (UTC) at the U.T Austin campus is a six-level structure built in 1984. It has a gross area of 153,000 ft². It houses classrooms and faculty offices. The exterior walls consist of limestone panels on concrete block. The windows consist of 1/4 in., single-pane tinted glass and cover approximately 20% of the total exterior wall area. It has a built-up roof with light weight insulation fill. Lighting is primarily 34W fluorescent, there are few incandescent and high pressure sodium lamps. Chilled water, steam, and electricity are being provided by a central plant. Steam from the campus loop is used in the AHU coils and domestic hot water generator. At present, there are eight VAV AHUs(2-30 hp, 2-20 hp, 3-25 hp, 1-15 hp), eight variable frequency air return fans (55 hp total), and eight variable frequency hot deck fans (70 hp total). There is one variable volume chilled water pump (50 hp) and one CV chilled water pump (50 hp).

The Perry Castaneda Library

The Perry Casteneda Library (PCL) on the UT Austin campus is a six-story structure built in 1977. It has a gross area of 484,000 ft². It houses reading rooms, halls, and administrative offices. The exterior walls consist of limestone panels on concrete block. The windows are 1/4 in., single-pane tinted glass and cover approximately 12% of the exterior wall area. It has a flat, built-up roof with light weight insulation fill. Lighting is primarily 34W fluorescent. At present, the PCL building is conditioned by eight VAV single-duct AHUs (75 hp each), four VAV AHUs (100 hp each), twelve variable frequency air return fans (25 hp each), and four variable frequency hot deck fans (50 hp each). There are two constant volume chilled water pumps (1-60 hp, 1-3 hp), one variable volume chilled water pump (60 hp), and one hot water pump (3 hp). Chilled water, steam, and electricity are being provided by a central plant.

Garrison Hall

Garrison Hall on the UT Austin campus was constructed in 1926. Its has a gross area of 54,000 ft². It houses an auditorium, American studies, history classrooms and faculty offices. The floor is reinforced concrete, the walls are hollow clay tile with a cut stone exterior. The windows are operable, clear, and single-pane. The roof has clay tiles. The lighting system is primarily 34W fluorescent although there are few incandescent fixtures. Chilled water, steam, and electricity are provided by a central plant. At present, there are two VAV dual-duct (1-30 hp & 1-25 hp), one VAV multi-zone (5 hp), one CV single-zone (3 hp) AHU, and seven exhaust fans (21 hp total). There is one variable volume chilled water pump (15 hp) and one constant volume hot water pump (3 hp). There is a steam to hot water converter for domestic hot water.

Waggener Hall

Waggener Hall on the UT Austin campus was constructed in 1931. It is a 58,000 ft², five-story building. It houses classrooms, laboratories, and faculty offices. The building has reinforced concrete frame and floors, walls of hollow clay tile with a cut stone exterior, single-pane, clear, operable windows, and a clay tile roof. The lighting system is primarily 34W fluorescent with few incandescent lamps. Chilled water, steam, and electricity are provided by a central plant. At present, there are two VAV dual-duct AHUs (40 hp each). There is one CV chilled water pump (5 hp), one CV hot water pump (2 hp), and a steam to hot water converter.

Burdine Hall

Burdine Hall on the UT Austin campus is a 103,000 ft², five-story building, built in 1970. The building houses liberal arts classrooms, lecture halls, an auditorium, and faculty office. The building has brick on concrete exterior walls, operable, clear, single-pane windows and a concrete roof. Lighting is primarily 34W fluorescent. Chilled water, steam, and electricity are provided by a central plant. At present, there are two VAV dual-duct (1-100 hp, 1-75 hp) AHUs, two CV single-zone (1-15 hp, 1-0.5 hp), and two outside air fans (10 hp each). There is one variable volume chilled water pump (40 hp) and one CV chilled water pump (40 hp). All AHUs utilize steam heating coils. A steam to hot water storage heater and a circulating pump (0.75 hp) provide domestic hot water 24 hours a day.

The Nursing Building

The Nursing building on the UT campus was constructed in 1974. It is a 95,000 ft², five-story building. It houses classrooms, laboratories, and faculty offices. The floor is reinforced concrete on steel frame. The exterior walls are made of precast concrete panels. The roof is made of concrete and the windows are inoperable, tinted, and single pane. Lighting is provided primarily by 34W fluorescent. The Nursing building also receives its chilled water, steam, and electricity from a central plant. At present, there are two VAV AHUs (100 hp each), eight relief fans (5 hp each), and ten exhaust fans (0.1 hp to 1 hp range). There is also a packaged direct-expansion roof-top unit. There is one variable volume chilled water pump (30 hp) serving both the AHUs. A steam to hot water heater and a circulating pump (0.09 hp) provide domestic hot water 24 hours a day.

The W.C.Hogg

The William C. Hogg building on the UT Austin campus was constructed in 1933. It is a 49,000 ft² building with 4 floors and a basement. The building houses an auditorium, classrooms, workshops, and offices. The walls are hollow clay tile with cut stone exterior and the windows are single-pane, and cover approximately 12% of the total wall area. The roof is made of clay tiles on concrete. The lighting system in the building is primarily 34W fluorescent. The W.C. Hogg building receives steam, chilled water and electricity from a central plant. At present, there are two VAV dual-duct AHUs (40 hp each), two CV AHUs (5 hp each), six exhaust fans (2 hp total). There is one variable volume chilled water pump (25 hp) and one condensate pump (1.75 hp). AHUs have steam heating coils.

Electricity Consumption

Figure 7 shows the whole-building electricity consumption for the nine buildings as W/ft² to facilitate comparison. The buildings are arranged according to the average $/ft² per month savings for electricity, chilled water, and steam/hot water consumption for 1991. For the NUR building, the net steam/hot water savings are negative because of HVAC control problems (which are discussed in more detail later). For each building, there are 12 dot and whisker lines, each represent three data measures during the month. The top of each line corresponds to the peak hourly consumption recorded during the month, while the bottom of each line corresponds to the minimum hourly reading during that month. The dark point located somewhere between the two extreme points corresponds to the mean hourly consumption during the month, and is calculated as

$$\text{Mean Consumption} = \frac{\text{Total Monthly Consumption}}{\text{\# of hours in a month x square foot area}}$$

The "R" at the top of the whisker represents the month when the retrofits in the building were fully complete and operational. For the UTC and the PCL, retrofits were completed before 1991. Pre-retrofit data for these two buildings had to be estimated. Estimated pre-retrofit consumption is shown in Figure 7 and is marked as "E".

In most of the buildings in Figure 7, there is an appreciable drop in the maximum and mean consumption in the first few months after the retrofits. The retrofits most directly responsible for the drop are the VAV conversion of the CV AHUs and the lighting retrofits.

All three points (i.e, maximum, minimum, and mean consumption) are of significance. The maximum consumption indicates the electric demand, the mean indicates electricity consumption, while the minimum suggests whether the building is turned-off during unoccupied/nights/weekends hours. None of the nine buildings are charged directly for demand, since electricity is supplied by the their central plants. However, maximum demand does effect the capacity requirement of the plant and therefore remains important.

The location of the mean provides another interesting insight into the manner in which the building is operated. If the mean point is located more towards the maximum point, for example in the PCL, it means that the building is predominantly operated in the "on" position, and possibly that systems are being left-on at night. Conversely, if the mean point is located nearer the minimum point, it means that the building is operated on a scheduled basis and is regularly turned-off at night.

The location of the minimum point in itself shows how low the consumption drops when the building is turned-off. It is interesting to note that except for the Zachry building and Waggener building, all other buildings have a minimum consumption approaching 0.5 W/ft², which can be seen as a reasonable target for other buildings to achieve (Haberl and Komor, 1990a : 1990b).

In the Education building, the maximum electricity consumption has dropped from 3.5 W/ft² to 1.5 W/ft² and the mean electricity consumption has dropped from 2 W/ft² to 1 W/ft² after it was retrofitted with VAV and lighting modifications in May, 1991. Interestingly enough, the minimum remained mostly unchanged and may be indicating that the building was and still is turned-off regularly during off-hours. The mean consumption, which indicates the electricity consumption of the building has been very consistent over the months after it was retrofitted.

Another interesting example is the Nursing building, which like the Education building was retrofitted with VAV and Lighting modifications in May, 1991. The data for the Nursing building was adjusted to exclude the electricity consumption of adjacent tennis courts. For the Nursing building, the maximum consumption has dropped from 3.27 W/ft² to 2.5 W/ft², and the mean consumption has dropped from 1.75 W/ft² to 1.25 W/ft². This building, however, has not been able to maintain this drop and during the last quarter of 1991, it went back up to around three-quarters of its pre-retrofit consumption (2.5 W/ft²) mainly due to an increase in AHU electricity use. This rise in the electricity consumption of the AHUs is largely due to control problems and a lack of heating capacity in the heating coils. This problem became apparent after the first cold spell when the outside temperature went down below 55°F, the matter is being further investigated (Athar et. al, 1992).

The Zachry Engineering Center on the Texas A&M campus shows a markedly smaller effect due to the retrofits. The main retrofit in this building was a VAV conversion of CV AHUs and was completed in March, 1991. Since March, 1991, the mean and minimum electricity consumption has decreased noticeably, although the maximum has not been similarly effected. The ZEC is the 2nd largest of the nine buildings with over 324,000 ft² of gross area, and a drop of 0.5 W/ft² to 1.0 W/ft² translates into appreciable savings. The ZEC's minimum consumption is by far the highest of the 9 buildings. This is mainly due to a large super computer and other numerous office and lab equipment which is used 24 hours a day and thus contributes to a big base load for this building.

Both the PCL and the UTC buildings, which were retrofitted before 1991, show a drop of about 1 W/ft² in their maximum and mean electricity consumption. Their estimated pre-retrofit consumption is based on one-time measurements taken at each site and information from the audit report. The PCL building shows a remarkably consistent consumption pattern. There are obvious drops in mean consumption during January, May, and December, 1991 which are the times when the library was open for the least number of hours due to semester breaks. This is also true for all other buildings (except the Nursing and Burdine buildings) which show a drop in electricity consumption during semester breaks.

For all nine buildings, the total pre-retrofit maximum demand was 5.51 MW (Mega Watts) and the total post-retrofit maximum demand was 4.28 MW, resulting in a savings of 1.23 MW of demand. The total reduction in mean electricity consumption for the nine buildings amount to 900 MWh per month.

Steam Consumption

Figure 8 shows the heating energy use for eight buildings. The data are again normalized by conditioned area to facilitate comparison. The data are hourly condensate return, converted to Btu/ft²-h. As in Figure 7, dot and whisker line represents one month of data. As expected, the consumption for summer months is low and gradually increases as the outside temperature decreases during winter. Large variation can be seen between the maximum and the minimum monthly points, as high as 30:1, during the peak winter months. This variation diminishes appreciably as the summer months approach.

The Nursing building shows a very high steam consumption in November and December, 1991. As discussed earlier, this was due to control problems which resulted in AHU fans and heating coils running at maximum capacity, and is further investigated in Athar et. al., 1992.

Chilled water Consumption

In Figure 9 minimum, maximum, and mean chilled water consumption is shown as a Btu/ft²-h dot and whisker plots for eight buildings. Data for all the months for ZEC, August and September for the UTC, November for WAG, July, August, October for BUR, and July, 1991 for the WCH were omitted due to hardware problems. The data are again normalized by conditioned area to facilitate comparison. The data are hourly chilled water consumption, converted to Btu/ft²-h. The chilled water consumption patterns for all the buildings show, as expected, a near inverse behavior as compared to steam consumption. The graph more or less, follows a predictable curve, showing the dependency of chilled water use on outside temperature. However, the chilled water consumption remains high during cooler months mainly because all the buildings have significant internal and solar loads that must be met by the chilled water system.

Like steam consumption, important information regarding the VAV retrofit is obscured by the fact that the retrofits were completed before the hotter summer months and therefore their effectiveness on chilled water consumption during summer months cannot be readily seen. The effectiveness of the retrofits may be easier to observe when one plots the dot and whisker plots versus average monthly temperature.

CONCLUSIONS

This paper presents an overview of the Texas LoanSTAR program. As of December 1991, 47 buildings are being monitored. The buildings have been categorized in terms of their number, size and usage. The energy cost reduction measures implemented under the LoanSTAR program have proved very effective. The estimated cost savings for the recommended measures add up to $7 million/year with an estimated implementation cost of about $21 million, giving a very reasonable payback of 3 years. In terms of source energy, recommended actions have a potential savings of approximately 2 trillion Btus/year and have permanently reduced 1.23 MW of electric demand for nine buildings. These savings may prove to be of immense significance in the coming decade and beyond, as the importance of conservation increases. The LoanSTAR monitoring program has successfully shown that these recommended measures do result in energy savings when properly monitored. The plots showing maximum, minimum, and mean consumption for one year of data very clearly show the drop in energy consumption after the retrofits were put in place.

ACKNOWLEDGMENTS

The Texas LoanSTAR program is funded through the Texas Governor's Energy Office using oil overcharge funds.

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Code	Building	Area Sq-ft	Recommended Retrofits	Retrofit Completion Date
ZEC	Zachry Engineering Center	324,000	VAV (480hp), EMCS	March 1991
	U.T. Austin			
EDB	Education Building	251,161	Lights (incd), OS, VAV (400hp), VSP (75hp)	May 1991
UTC	University Teaching Center	152,690	Lights, VAV (262hp), VSP (50hp)	Nov. 1990
PCL	Perry Castaneda Library	483,895	OS, VAV (1,500hp), VSP (60hp)	Nov. 1990
GAR	Garrison Hall	54,069	VAV (60hp), VSP (15hp), EMCS	May 1991
GEA	Gearing Hall	61,000	VAV (110hp), VSP (15hp)	May 1991
WAG	Waggener Hall	57,600	VAV (80hp)	May 1991
WEL	Welch Hall	439,540	Lights (Incd), VAV, VSP	In Construction
BUR	Burdine Hall	103,441	VAV (175hp), VSP (40hp)	May 1991
NUR	Nursing Building	94,815	VAV (200hp), VSP (30hp)	Apr. 1991
WIN	Winship Hall	109,000	VAV (185hp), VSP (50hp)	May 1991
STD	Steindham Hall	56,800	H/C DR	Jul. 1991
PAI	Painter Hall	128,409	HVAC Mod. VAV	In Construction
WCH	W.C. Hogg Hall	48,905	VAV (80hp), VSP (25hp), Replace Economizer	May 1991
	U.T. Arlington			
UVH	University Hall	123,450	Lights, VAV, VSP	Aug. 1991
BUS	Business Building	149,900	Lights, VAV	Aug. 1991
FIA	Fine Arts Building	223,000	Lights, VAV, VSP	Aug. 1991
	State Capitol Complex			
CPP	Central Power Plant	10,000	Replace Boiler & Chiller, Pump Mod.	Dec. 1991
SHB	Sam Houston Building	182,961	MD, RES, Lights	In Design Mode
SFA	Stephen F. Austin Building	470,000	VFD, Lights, Pump Mod.	In Design Mode
JHR	John H. Reagan	169,756	NSB, RES, Lights, MD	In Design Mode
JER	James E. Rudder	80,000	RES, Chiller Modifications	In Design Mode
INS	Insurance Building	102,000	MD, NSB, RES, Lights, Reduce Air Flow	In Design Mode
INX	Insurance Annex	62,000	MD, Pump shut-off, RES, H/C DR	In Design Mode
ARC	Archive Building	120,000	Pump Shut-off, RES, MD, NSB	In Design Mode
WBT	William B. Travis	491,000	HVAC Mod., Lights	In Design Mode
LBJ	Lyndon B. Johnson	308,080	VFD, Lights, Lights (incd)	In Design Mode
JHW	J. H. Winter's Complex	503,000	EMCS, Lights (Incd)	In Design Mode
	U.T.H.S.C. San Antonio			
	Medical School	606,097	VAV, Phocell Control	In Design Mode
	Dental School	484,019	VSP, VAV, Solar screens	In Design Mode
TDH	Texas Dept. of Health	284,000	EMCS	In Design Mode
	U.T.H.S.C. Houston			
SPH	School of Public Health	233,738	HVAC Mod., EMCS, VAV, VSP	In Design Mode
MSB	Medical School Building	887,187	Lights, VFD to AHUs	In Design Mode
	Victoria ISD			
	Stroman High School	210,474	EMCS, Replace Chiller	Jul. 1991
	Victoria High School	257,014	EMCS, Replace Chiller, Lights	Jul. 1991
	UTMB Galveston			
	Moody Memorial	67,380	Lights, Solar Screen, VSP	In Design Mode
	Basic Sciences	137,856	Lights, HVAC Mod., VSP	In Design Mode
	Clinical Sciences	124,870	Lights, VSP	In Design Mode
	John Sealy North	54,494	Lights, New AHU	In Design Mode
	John Sealy South	373,085	Lights, VSP	In Design Mode
	Fort Worth ISD			
	Sims Elementary School	62,400	Lights	In Construction
	Dunbar Middle School	92,884	Lights	In Construction
	Midland County	129,100	EMCS, OS, Lights, Chiller control	In Design Mode
	Texas A&M University Galveston	193,424	EMCS, VSCT, VSP, Lights, PF	In Design Mode
UTD	University of Texas, Dallas	481,549	Lights, MD, Skylights	In Design Mode
TECOM	Texas College of Ostp. Medicine	496,000	MD, TC, VAV, CWR/HWR, Replace Boiler	In Design Mode
UTP	University of Texas Panam	909,462	VSP, Lights, VFD, MD, Outside Air Cont.,	In Design Mode
			EMCS, New Chiller	
UTMDA	U.T. M.D.Anderson Cancer Center	1,109,321	Lights, EMCS, Fumehood Mod.	In Design Mode
NSB	Night Set Back	Lights	Replacement of Incandescent Lights	
H/C DR	Hot/Cold Deck Reset	OS	Install Occupancy Sensors	
VSCT	Variable Speed Cooling Tower	VAV	Variable Air Volume Conversion	
PF	Power Factor Correction	VSP	Variable Speed Pumping	
TC	Time Clocks	MD	Install Motion Detectors	
CHWR/HWR	Chilled Water & Hot Water Reset	RES	Replace Exit Signs	
EMCS	Energy Management Control Sys	VFD	Variable Frequency Drives	
Lights	Lighting Modifications			

Table 1: Buildings participating in the LoanSTAR program, as of December, 1991. This table shows the buildings participating in the LoanSTAR program, their codes used in the paper, square-foot area, recommended retrofits, and current completion status

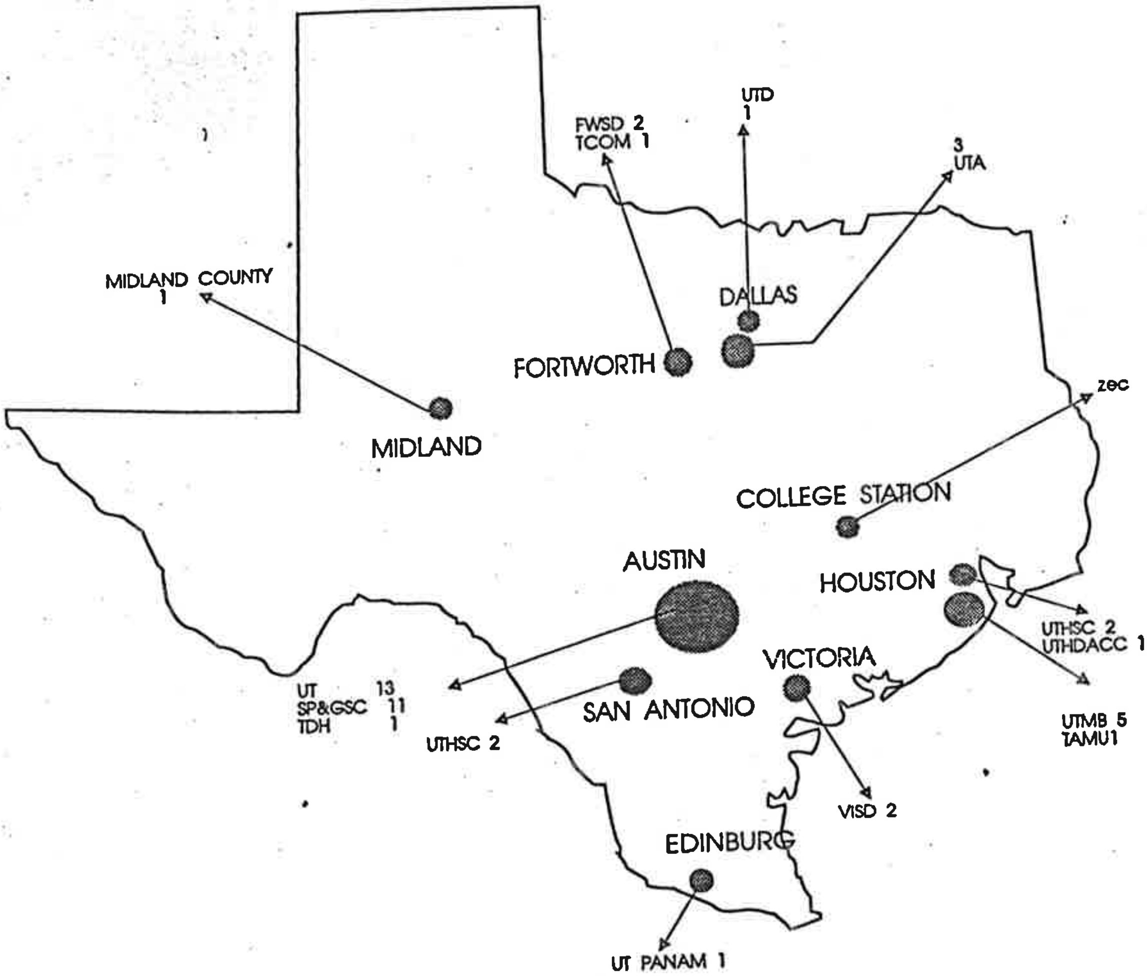

Figure 1: Location of LoanSTAR participants, as of December, 1991. This figure provides a map showing the location of buildings participating in the LoanSTAR program.

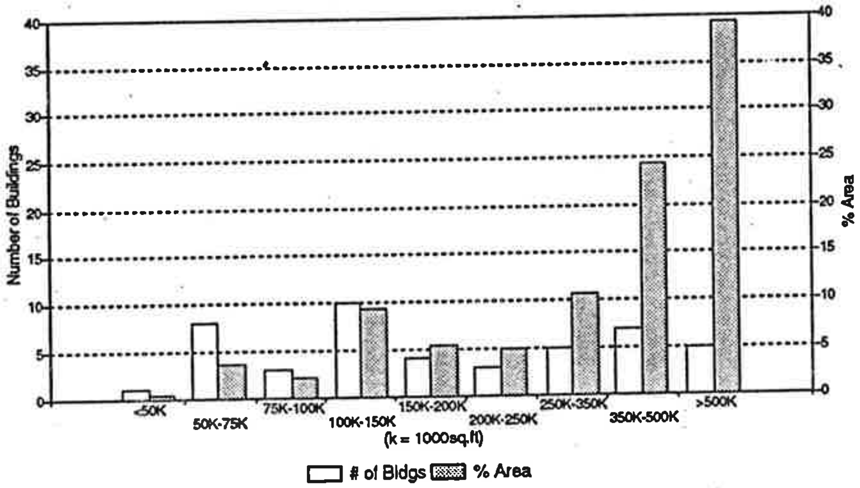

Figure 2: Buildings participating in the LoanSTAR participants, as *of December, 1991.* This figure shows the number of buildings and percent of total program area.

ECRM Recommendations	Impl. Cost $	% of Total Imp. Cost	Cost Savings $	% of Total Saving	Simpl Payba Yrs
HVAC System Retrofits	$6,895,174	33	$2,624,926	38	2.6
Boiler & Steam Retrofits	$508,300	2	$615,206	9	0.8
Motor/VSD/VSP Conversion	$4,730,693	23	$1,388,439	20	3.4
Chiller & CHW Retrofits	$1,900,910	9	$394,218	6	4.8
Lighting Retrofits	$2,503,171	12	$934,429	13	2.7
EMC Systems	$2,755,081	13	$656,734	9	4.2
Pumping System Retrofits	$608,631	3	$120,439	2	5.1
Others	$1,078,444	5	$241,887	3	4.5
Totals	$20,980,404	100	$6,976,278	100	3.0

Table 2: Recommended retrofits, their costs, and savings for all the buildings participating in the LoanSTAR program as of Dec, 1991. This table shows the implementation costs, annual savings, payback, and respective percentages for all the retrofits recommended by the audit companies.

Purchased Utility Category	Site Energy	Source Energy* (million Btu/yr)	Fractional Energy Savings (%)
Electricity	94,215,886 (kWh/yr)	1,092,904	52
Natural Gas	270,046 (MCF/yr)	278,147	13
Steam/Hot Water	280,010 (million Btu/yr)	373,347	18
Chilled Water	29,095,432 (Ton-hr/yr)	349,145	17
Total		2,093,544	100

* Btu savings calculated on the basis of source Btus (i.e. 11,600 Btu/kWh, 1,030,000 Btu/MCF, boiler efficiency of 75% and 12,000 Btu/ton-hr)

Table 3: Site and source energy savings for all the buildings participating in the LoanSTAR program, as of December, 1991. This table shows the site and source energy savings from all the retrofits recommended by the audit companies.

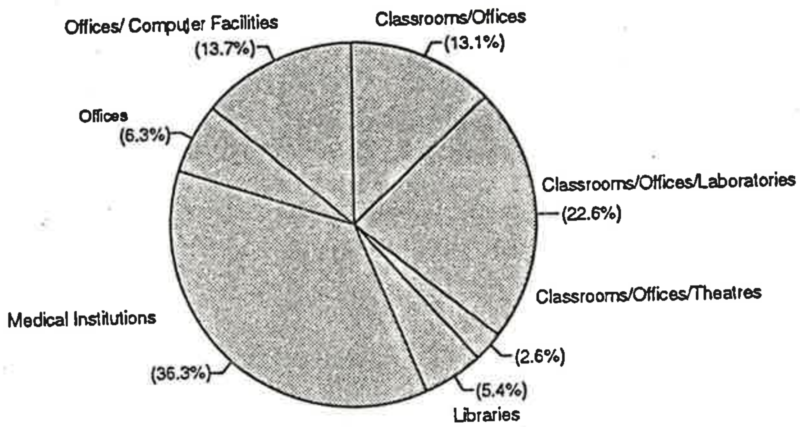

Figure 3: Buildings participating in the LoanSTAR program, as of December, 1991. This figure shows the types of buildings and percent by functional use.

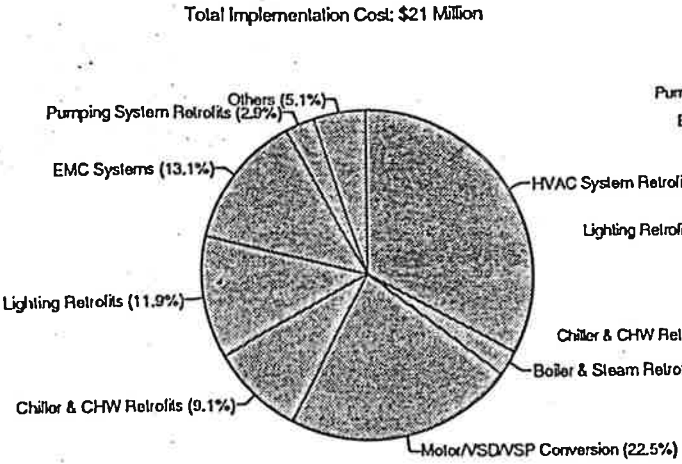

Figure 4a: Estimated retrofit implementation costs of all the buildings participating in the LoanSTAR program, as of December, 1991. This figure shows the breakdown of the retrofits recommended by the audit companies as percent of total implementation cost.

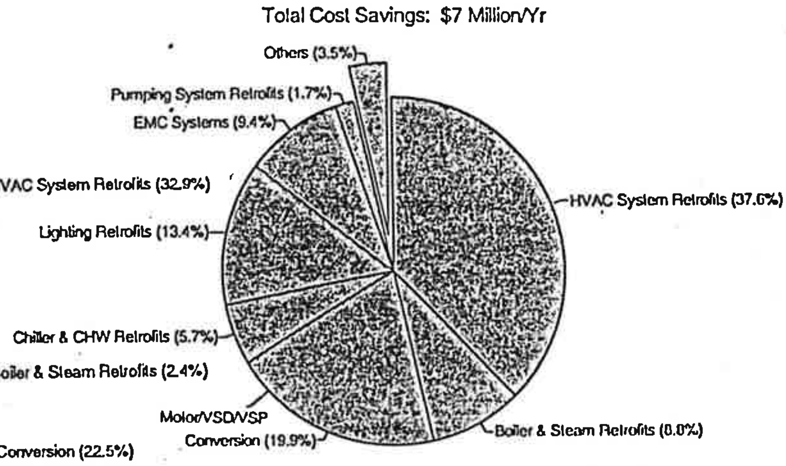

Figure 4b: Estimated annual savings for the buildings participating in the LoanSTAR program, as of December, 1991. This figure shows the breakdown of the estimated annual savings from the retrofits as percent of total annual savings.

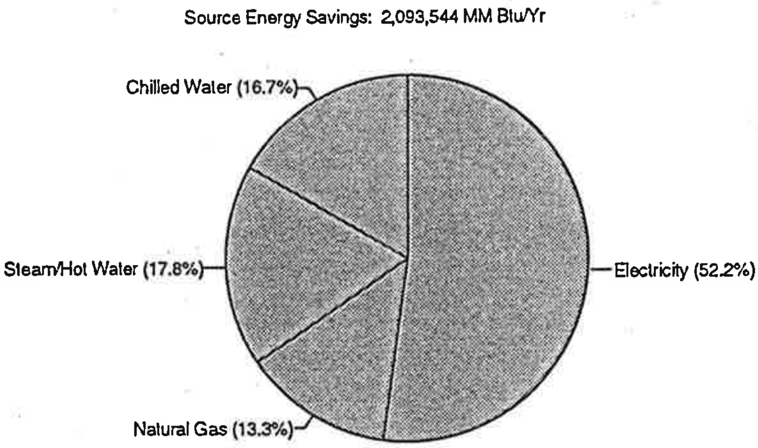

Figure 5: Estimated annual savings for the buildings participating in the LoanSTAR program, as of December, 1991. This figure shows the breakdown of the estimated annual source energy savings from the retrofits as percent of site energy savings.

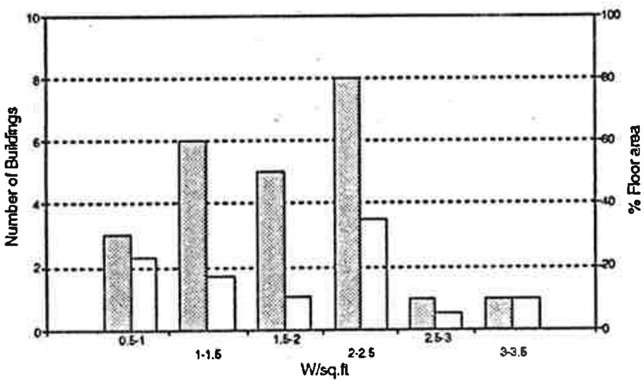

Figure 6a: Connected Motor Control Center (MCC) loads for 24 selected buildings in the LoanSTAR program. This figure shows the MCC loads in W/ft² as count and percent of total area.

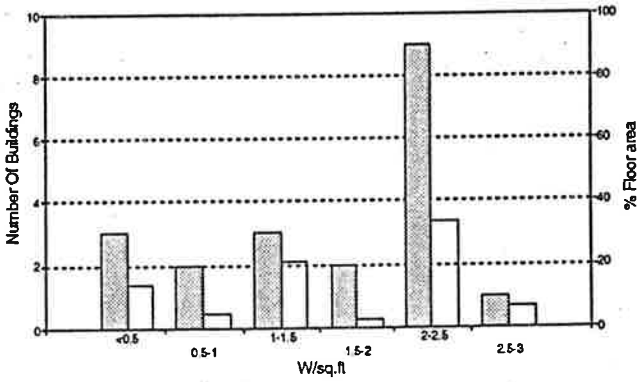

Figure 6b: Connected Lighting loads for 20 selected buildings in the LoanSTAR program. This figure shows the lighting loads in W/ft² as count and percent of total area.

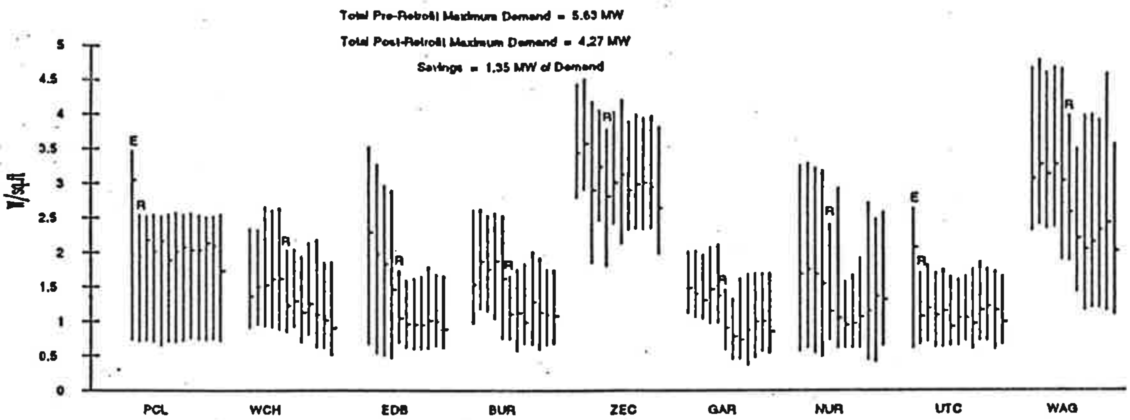

Figure 7: Maximum, Minimum, and Mean Electricity Consumption for 9 buildings in the LoanSTAR Program. Each dot and whisker represents one month of monitored data. The top of the whisker represents the maximum consumption, the bottom represents the minimum consumption. The dot represents the mean consumption. "R" represents the month when the retrofit was completed. "E" represents the estimated consumption for the pre-retrofit.

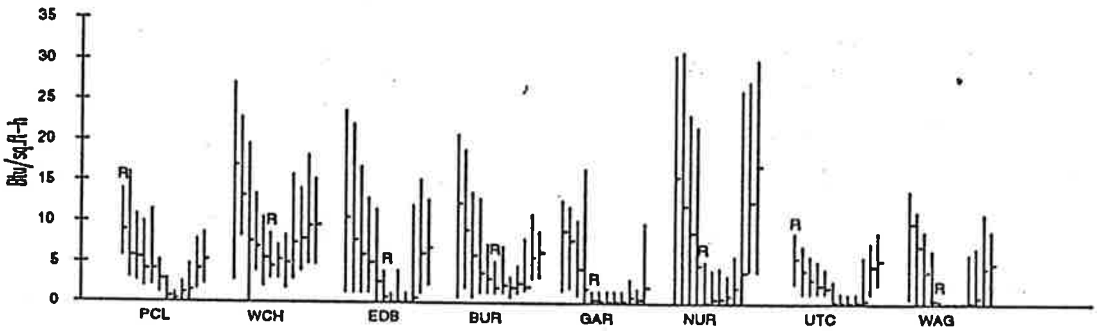

Figure 8: Maximum, Minimum, and Mean Steam Consumption for 8 selected Buildings in the LoanSTAR program.

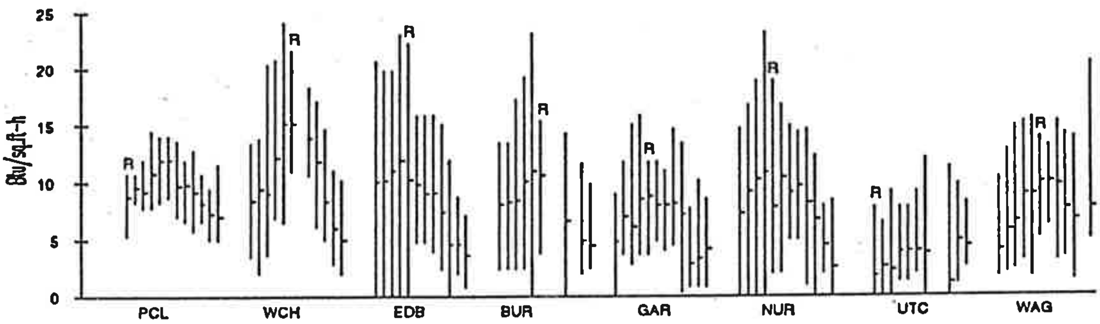

Figure 9: Maximum, Minimum, and Mean Chilled Water Consumption for 8 buildings in the LoanSTAR Program.