

LoanSTAR Monitoring and Analysis Program

**A Report on the
Environmental Impact
of the Texas LoanSTAR Program
from May 1989 to September 1995**

November 1995

Submitted to the
Texas State Conservation Office
by the
Monitoring Analysis Task

Mr. Mustafa Abbas
Dr. Dan Turner
Dr. David Claridge
Dr. Jeff Haberl
Dr. Namir Saman

LoanSTAR Monitoring and Analysis Program

**A Report on the
Environmental Impact
of the Texas LoanSTAR Program
from May 1989 to September 1995**

November 1995

Submitted to the
Texas State Conservation Office
by the
Monitoring Analysis Task

Mr. Mustafa Abbas
Dr. Dan Turner
Dr. David Claridge
Dr. Jeff Haberl
Dr. Namir Saman

EXECUTIVE SUMMARY

The Texas LoanSTAR (Loans to Save Taxes and Resources) program was created by the state of Texas in 1989 to lend money for energy conserving improvements, or retrofits, in public buildings. As of September 1995 the LoanSTAR program is measuring savings for 22 loan sites covering 153 buildings where retrofits have been fully or partially completed. The completed retrofits show \$21.1 million in measured savings, which is more than 119% of the energy savings predicted by the energy auditors. This corresponds to 23.9% of the pre-retrofit consumption cost at these sites. Through energy savings, the Texas LoanSTAR program has made a significant contribution towards reducing hazardous environmental emissions.

There are a number of factors that influence emission factors. The three major pollutants considered in this analysis are CO₂, SO₂, and NO_x. Emission factors from three different sources were considered for this report. This analysis shows that as of September, 1995, there has been a reduction in emissions of 1.88 million pounds of NO_x, 1.19 million pounds of SO₂, and 532 million pounds of CO₂ through the implementation of energy conservation measures in the Texas LoanSTAR program.

CONVERSION FACTORS

1 kWh	=	1,000 Watthours
1MWh	=	1,000 kWh
1 Mcf	=	1,000 cubic feet (of Natural Gas) = 1.030×10^6 Btu = 1.030 MMBtu
1 MMBtu	=	1,000,000 Btu

ENVIRONMENTAL IMPACT OF THE TEXAS LOANSTAR PROGRAM

THE LOANSTAR PROGRAM

The Texas LoanSTAR (Loans to Save Taxes and Resources) program was created by the state of Texas in 1989 to lend money for energy conserving improvements, or retrofits, in public buildings. The program's \$98.6 million are funded by Petroleum Violation Escrow (PVE) dollars or fines paid by oil companies for excessive petroleum charges in the 1970s and 1980s. The State Energy Conservation Office (SECO) of Texas administers the LoanSTAR program.

The LoanSTAR program uses a revolving loan financing mechanism to fund energy conserving retrofits in state, public schools and local government buildings. Retrofit projects are identified by energy audits conducted by engineering teams under contract with the SECO. The projects funded by the LoanSTAR program primarily include retrofits to lighting, HVAC systems, building shells, electric motors, energy management and control systems, cool storage systems, boilers, and thermal energy recovery systems.

ENERGY SAVINGS

Energy metering and monitoring equipment was first installed on the Texas A&M University campus (Zachry Engineering Center) in May 1989. Since then, LoanSTAR metering and monitoring equipment has been installed in 264 state, city and school district buildings, and complexes covering a floor area of 23 million square feet. As of September 1995 the LoanSTAR program is measuring savings for 22 loan sites covering 153 buildings where retrofits have been fully or partially completed. The completed retrofits show about \$21.1 million in measured savings, which is more than 119% of the energy savings predicted by the energy auditors. This corresponds to 23.9% of the pre-retrofit consumption cost at these sites.

The LoanSTAR program energy savings are reported in three major categories, namely, heating and chilled water savings (in MMBtu), and electricity savings (in kWh). These categories are also useful for evaluating the environmental impact of the program.

ENVIRONMENTAL IMPACT OF THE LOANSTAR PROGRAM

The primary objective of the LoanSTAR program is to reduce building energy consumption through efficient operation of the energy consuming equipment. Through energy savings, the Texas LoanSTAR program has made a significant contribution towards reducing hazardous environmental emissions. As energy consumption is reduced, an equal amount of energy production is avoided.

Translating the energy savings into a corresponding reduction in environmental emissions requires some effort. There are a number of factors that influence the amount of emission of a certain environmental pollutant as a result of burning a particular type of fuel. Not only do different types of fuels emit varying amounts of pollutants during the combustion process but the manner in which the fuel is burnt and the source of the fuel are also major factors in determining the amount of environmental emissions.

In an effort to obtain reasonable emission factors, the major utilities across the state of Texas were contacted. The emission factors from these utilities were compared with average emission factors for the state of Texas and with the national average. As expected, there were some differences. One of the reasons for the differences is that the utilities do not have the same fuel mix. Some utilities are more coal dependent while others use more natural gas or other fuels. Emission factors also vary by time-of-the-day and time-of-the-year. For example, a utility may use coal to generate base load power and natural gas to generate peaking power, which obviously has different emission factors. Therefore, there are a number of factors that dictate the emission factors. The three major pollutants considered in this analysis are CO₂, SO₂, and NO_x. The following table shows a comparison of average emission factors for these pollutants for the state of Texas and for the USA from three sources.

Table 1: Average Emission Factors

NATURAL GAS				
Region	Source	CO ₂	SO ₂	NO _x
		lbs/MWh	lbs/MWh	lbs/MWh
TX	EIA (1993)	1,216	0.00	4.71
TX	EPA	1,700	4.85	5.50
USA	EIA (1993)	1,187	0.00	4.53

COAL				
Region	Source	CO ₂	SO ₂	NO _x
		lbs/MWh	lbs/MWh	lbs/MWh
TX	EIA (1993)	1,960	5.87	9.50
TX	EPA	1,700	4.85	5.50
USA	EIA (1993)	1,933	18.21	8.87

PETROLEUM				
Region	Source	CO ₂	SO ₂	NO _x
		lbs/MWh	lbs/MWh	lbs/MWh
TX	EIA (1993)	1,753	0.00	0.00
TX	EPA	1,700	4.85	5.50
USA	EIA (1993)	NA	0.00	0.00

NATURAL GAS				
Region	Source	CO ₂	SO ₂	NO _x
		lbs/Mcf	lbs/Mcf	lbs/Mcf
USA	EPA (1992)	120	0.00060	0.55*
TX	EIA (1993)	118	0.0	0.46
USA	EIA (1993)	112	0.0007	0.43

* 0.081 lbs/Mcf for large boilers with low NOX burners

* 0.55 lbs/Mcf for large boilers with uncontrolled burners

The Energy Information Agency (EIA 1993) reports emission factors based on different fuel types for the individual states as well as for the USA. The Environmental Protection Agency

(EPA) lists overall (not based on fuel type) emission factors (per kWh of electricity generated) based on ten geographic regions of the USA. The Environmental Protection Agency also reports overall emission factors (lbs/Mcf) for different pollutants from natural gas combustion (EPA 1992).

Table 1 shows that CO₂, SO₂, NO_x emissions are lower from burning natural gas than from burning coal. The emission factors for natural gas combustion are more or less consistent across the sources. However, NO_x emissions are heavily dependent on the type of burner in a boiler. For low NO_x burners, NO_x emissions are 0.081 lbs/Mcf of natural gas burnt as compared to 0.55 lbs/Mcf of natural gas burnt for uncontrolled burners (EPA 1992).

EMISSIONS FROM LOANSTAR SITES

In the LoanSTAR program, energy savings are measured for three major categories, namely; heating savings (MMBtu), chilled water savings (MMBtu), and electricity savings (MWh). Table 2 lists the LoanSTAR energy savings on a site by site basis. Certain assumptions were made in order to translate these energy savings into environmental emissions reductions as discussed below.

Table 2: Cumulative Energy Savings May 1989 through September 1995

Site Name	Heating Savings (MMBtu)	Heating * Savings (Mcf)	CHW Savings (MMBtu)	CHW ** Savings (MWh)	Electricity Savings (MWh)
Zachry Engineering Center	55,030	71,236	65,169	5,431	6,813
UTMB Galveston	45,866	59,373	105,628	8,802	8,929
UTMDA Cancer Center	0	0	0	0	23,203
UTHSC (MSB & SPH)	0	0	0	0	13,468
Midland County Courthouse	0	0	0	0	722
Nacogdoches Ind. Sch. Dist.	0	0	0	0	3,158
UT Arlington	14,813	19,175	46,126	3,844	7,662
Fort Worth ISD (Simms & Dunbar)	0	0	0	0	727
Univ. of North TX Medical Center (TECOM)	32,317	41,834	0	0	1,525
FWISD (42 other schools)	0		0	0	9,480
UT Austin	203,546	263,490	556,267	46,356	73,139
TX Dept. of Health	16,317	21,122	31,853	2,654	2,067
Victoria ISD	73,383	94,994	0	0	-190
Delmar College	153,274	198,413	0	0	0
Dallas County Govt. Center	27,589	35,714	0	0	588
State Capitol Complex	117,968	152,709	0	0	24,321
MHMR Austin	0	0	0	0	3,575
UTHSC, San Antonio	0	0	593	49	290
Total	740,103	958,062	805,636	67,136	179,477

* Heating savings in MMBtu are translated into natural gas savings in Mcf using a boiler efficiency of 75% and a natural gas heating value of 1.030 MMBtu/Mcf.

** Chilled Water savings in MMBtu are translated into electricity savings in MWh using a chiller performance factor of 0.001 MW/Ton (where 1 Ton = 0.012 MMBtu/h).

Figures 1, 2, and 3 give the emissions reduced in heating, cooling, and electricity. Figure 4 is a summary of those savings. An explanation of how the reductions were calculated follows:

Emission Reduction From Heating Savings

At the majority of the LoanSTAR sites, heat to the buildings is provided by steam or hot water which is produced by boilers operating on natural gas. Heating energy savings in MMBtu are converted to Mcf of natural gas by using an average boiler efficiency of 75% (Dukelow 1991) and a heating value of 1.030 MMBtu/Mcf of natural gas. Emission factors from Environmental Protection Agency's report (EPA 1992) are then used to translate savings in natural gas to environmental emissions reductions. In the LoanSTAR sites, all the boilers have uncontrolled burners (no low NO_x burners); therefore, a NO_x emission factor of 0.55 lbs/Mcf is used. It should be noted that seasonal boiler efficiencies as low as 50% to 60% have been reported by Tierney and Fishman (1994). Higher emission factors than the ones used in this report have also been reported in the literature. The emission factors used are from the Environmental Protection Agency's report (EPA 1992), which yields a conservative estimate.

Figure 1 is a flow chart that shows how the heating savings in MMBtu are converted to natural gas savings in Mcf. The figure also shows the emission factors for the three pollutants in lbs/Mcf of natural gas saved. The heating savings (in parentheses) for all the individual sites in the LoanSTAR program are shown through September 1995. The pounds of pollutant saved for each individual site are shown under the site name and a total for each pollutant is shown at the bottom.

Emission Reduction From Chilled Water Savings

The chilled water savings in the LoanSTAR program are also reported in MMBtu. At the majority of the LoanSTAR sites, chilled water is produced by electric-driven chillers. A few sites have a portion of the chilled water which is produced by absorption and/or steam-driven chillers. In order to simplify the calculations, it is assumed that the chilled water supplied to all the LoanSTAR sites is from electric-driven chillers. This assumption makes it possible to translate chilled water savings in MMBtu to electricity savings in MWh by using a chiller performance characteristic of 1.0 kW/Ton¹ (EPRI 1993). This assumption is reasonable because regardless of how chilled water is produced (electric, steam driven, etc.), the emission factors are similar if one takes into account the efficiencies involved in generating electricity. An analysis of two LoanSTAR sites has also shown that a chiller performance factor of 1.0 kW/ton is a reasonable approximation. Figures 5 and 6 show the kW/ton for the electric chillers at the M. D. Anderson Cancer Center in Houston and at the Delmar College in Corpus Christi.

Once chilled water savings in MMBtu are converted into equivalent electricity savings in MWh, it is further translated into reduced emissions by using emission factors from the EPA-Green Light Report. As mentioned earlier, this report lists average emission factors for each pollutant regardless of the fuel used. These factors lie between the factors reported by EIA (1993) for natural gas and coal and, hence, provide a consistent approach and a reasonably conservative estimate.

¹ where 1,000 kWh = 1MWh and 1 Ton = 0.012 MMBtu/h.

Figure 2 is a flow chart that shows how the chilled water savings in MMBtu are converted to electricity savings in MWh. The figure also shows the emission factors for the three pollutants in lb/MWh of electricity saved. The chilled water savings (in parenthesis) for all the individual sites in the LoanSTAR program are shown through September 1995. The pounds of pollutant saved for each individual site are shown under the site name and a total for each pollutant is shown at the bottom.

Emission Reduction From Electricity Savings

Electricity savings from the LoanSTAR program are by far the greatest contributor to the pollution reduction. The approach used to estimate emission reduction is similar to that used for chilled water savings. Electricity savings in kWh are directly translated into emission reductions by using emission factors from the EPA-Green Lights Report.

Figure 3 is a flow chart that shows the emission factors for the three pollutants in lbs/MWh of electricity saved. The figure also shows the electricity saved (in parentheses) for all the individual sites in the LoanSTAR program through September 1995. The pounds of pollutant saved for each individual site are shown under the site name and a total for each pollutant is shown at the bottom.

SUMMARY

Figure 4 shows the combined reduction in various environmental pollutants. This preliminary analysis shows that as of September 1995, there has been a reduction in emissions of 1.88 million pounds of NO_x, 1.19 million pounds of SO₂, and 532 million pounds of CO₂ through the implementation of energy conservation measures in the Texas LoanSTAR program. As energy savings continue to accumulate from the retrofits that are already in place and from additional retrofits which are being installed in many new sites, the LoanSTAR program's contribution towards a cleaner environment in Texas will also grow.

REFERENCES

Dukelow, S. G. 1991. *The Control of Boilers*. 2nd Edition. Instrument Society of America. Research Triangle Park, NC 27709. p 97.

Energy Information Administration (EIA)/Electric Power Annual. 1993. *1991 U.S. Electric Utility Environmental Statistics*. pp 69-70. February.

Environmental Protection Agency (EPA) Report # AP-42. 1992. *Compilation of Air Pollutant Emission Factors*. Table 1.4. pp 1.4-5 - 1.4-6. October.

Environmental Protection Agency (EPA) Report. *Green Light Implementation Report Codes*. Air and Radiation (6202J). Washington, DC 20460.

EPRI Report TR-100537s. 1993. *CFCs and Electric Chillers. Selection of Large-Capacity Water Chillers in the 1990s (Revision 1)*. Gilbert & Associates. p 7-8. May.

Tierney, T. M. and Fishman, C. J. 1994. "Real-World Seasonal Efficiency of Gas-Fired Steam Boilers". *ASHRAE Journal*. p 34. September.

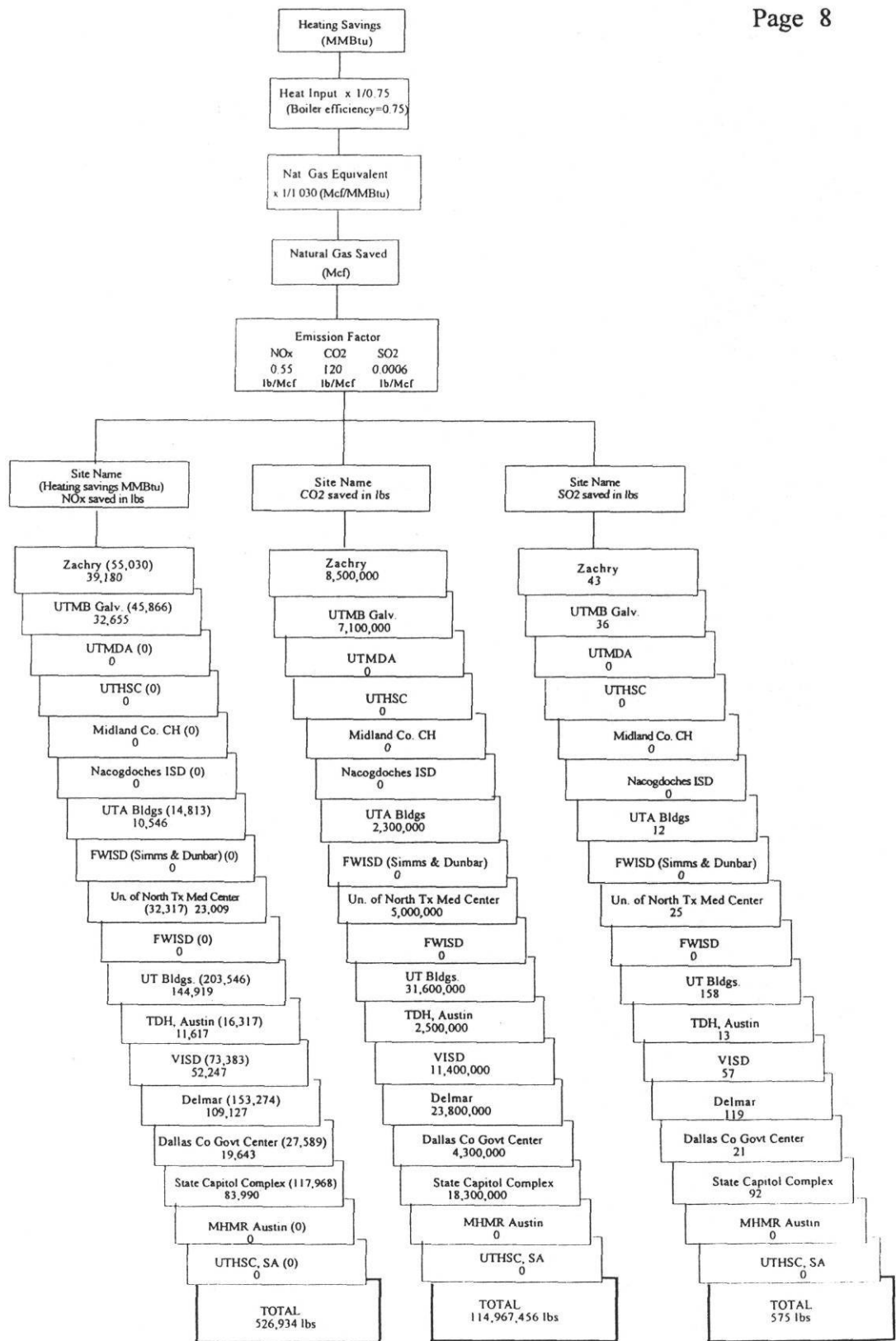


Figure 1: LoanSTAR pollution reduction due to measured heating savings. The number in paranthesis in blocks are the heating savings in MMBtu for the individual sites. The second number is the reduction in pollutant emissions in pounds for individual sites. The total LoanSTAR heating savings through September 1995 are 740,103 MMBtus.

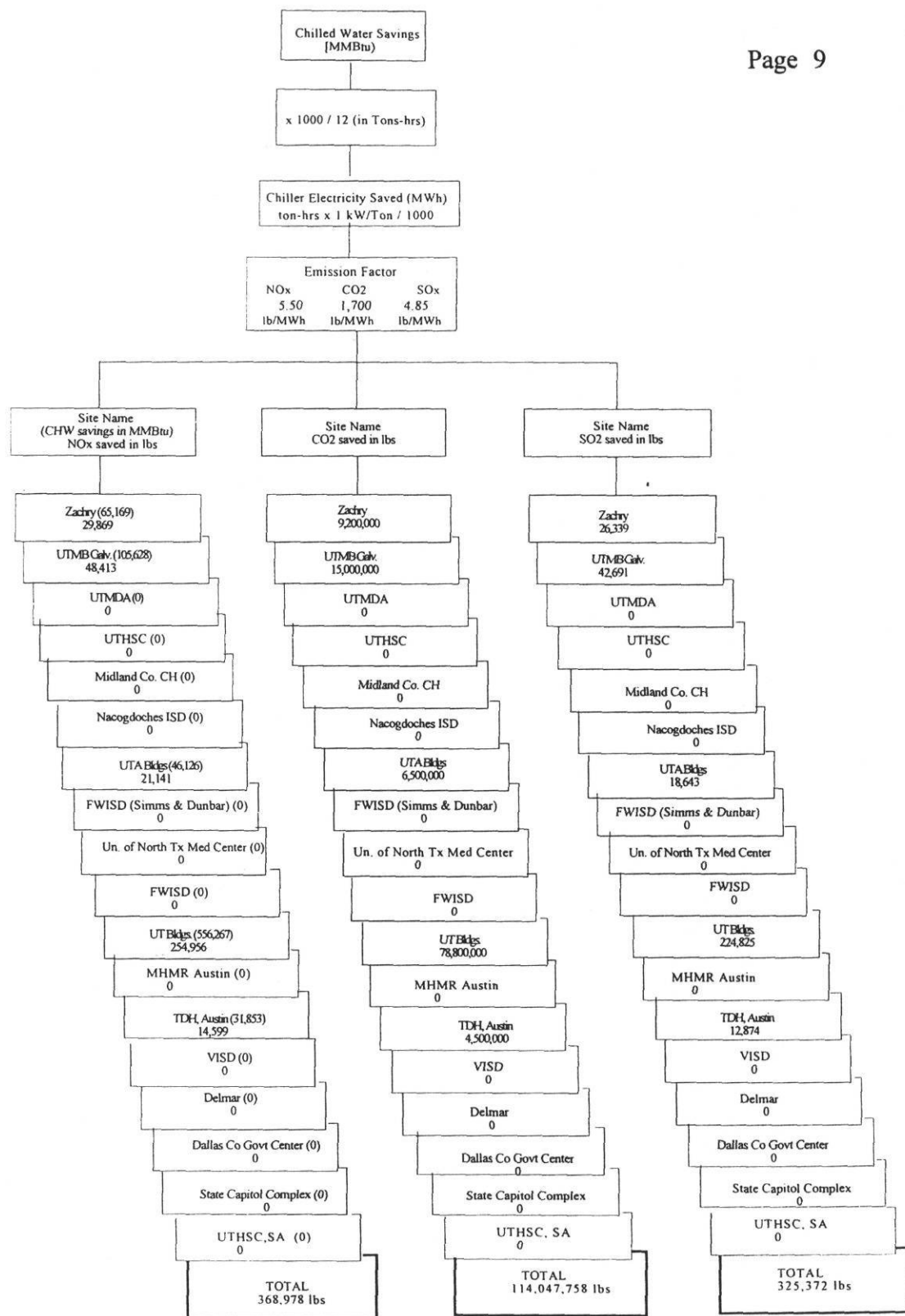


Figure 2: LoanSTAR pollution reduction due to measured cooling savings. The number in paranthesis in blocks are the chilled water savings in MMBtu for the individual sites. The second number is the reduction in pollutant emissions in pounds for individual sites. The total LoanSTAR chilled water savings through September 1995 are 805,636 MMBtus.

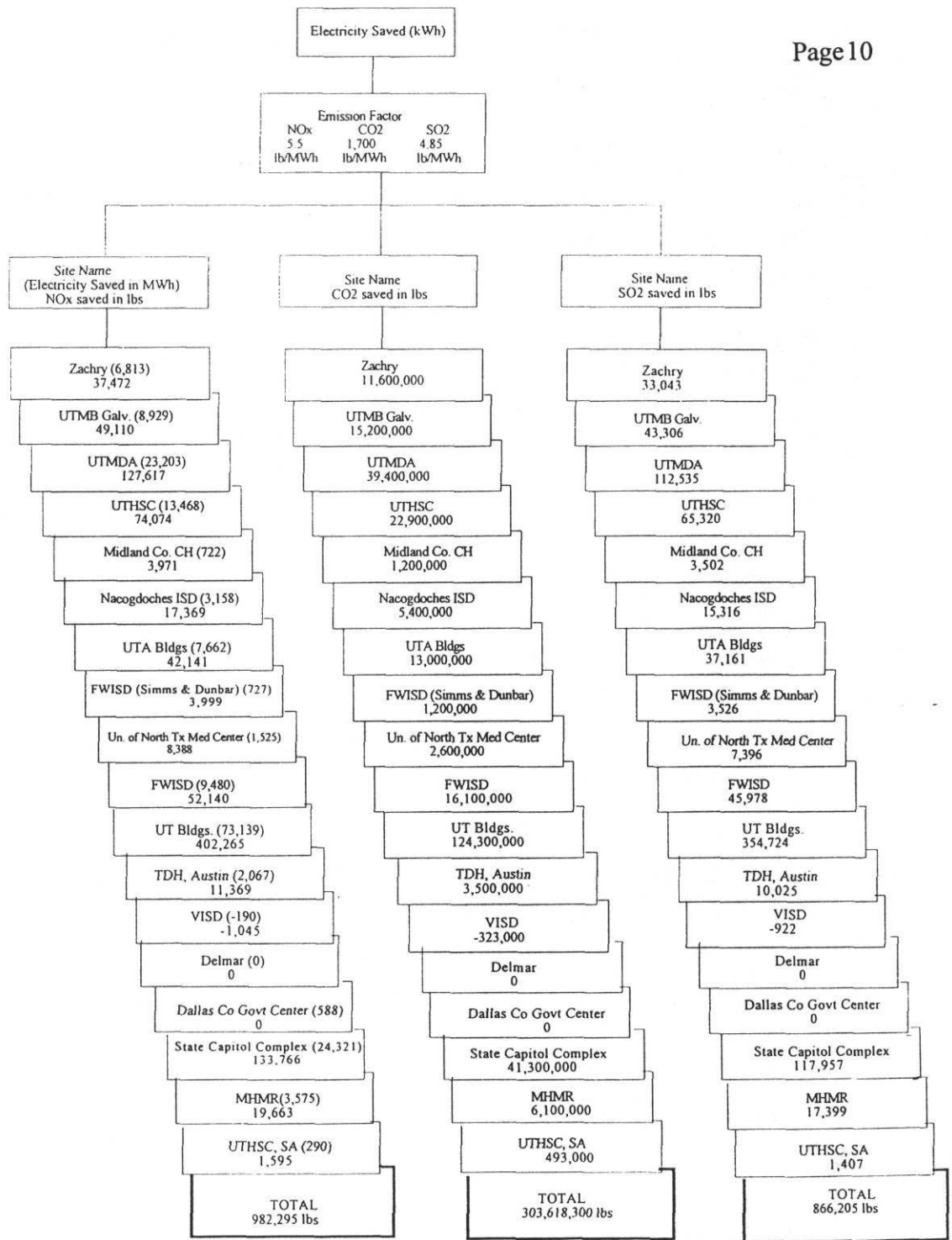


Figure 3: LoanSTAR pollution reduction due to measured electricity savings. The number in parenthesis in blocks are the electricity savings in MWh for the individual sites. The second number is the reduction in pollutant emissions in pounds for individual sites. The total LoanSTAR electricity savings through September 1995 are 179,477 MWh.

Emission Savings Summary

(As of Sept. 1995)

	NOx (lbs)	CO2 (lbs)	SO2 (lbs)
Heating (740,103 MMBtu)	526,934	114,967,456	575
Chilled Water (805,636 MMBtu)	368,978	114,047,758	325,372
Electricity (179,477 MMh)	982,295	303,618,300	866,205
TOTAL	1,878,207	532,600,000	1,192,152

Figure 4: The combined reduction in pollutant emission in pounds resulting from heating, cooling, and electricity savings. The numbers in parantheses are the total heating, cooling, and electricity savings from all the LoanSTAR sites.

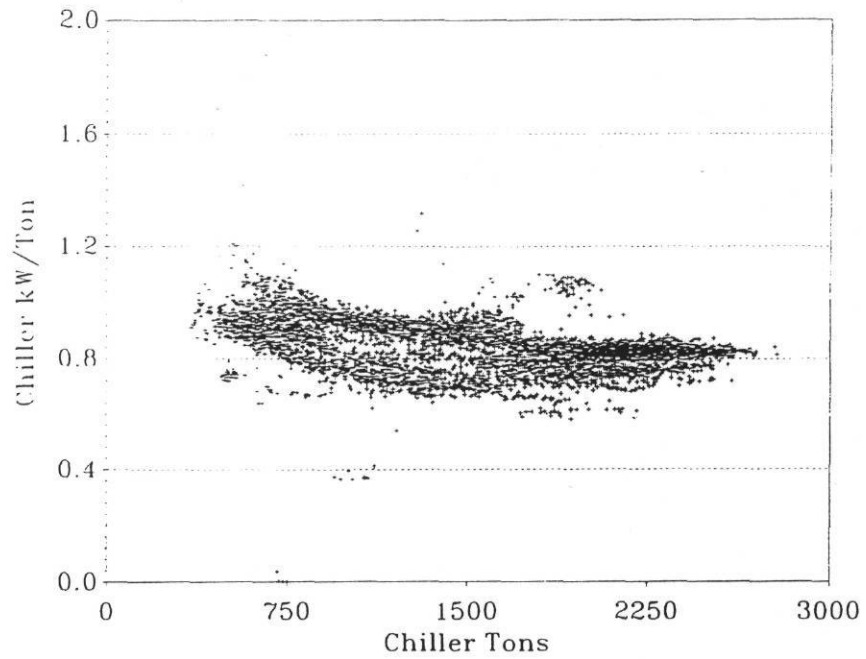


Figure 5: kW/ton of the electric chillers at the M. D. Anderson Cancer Center's chilling plant in Houston, TX.

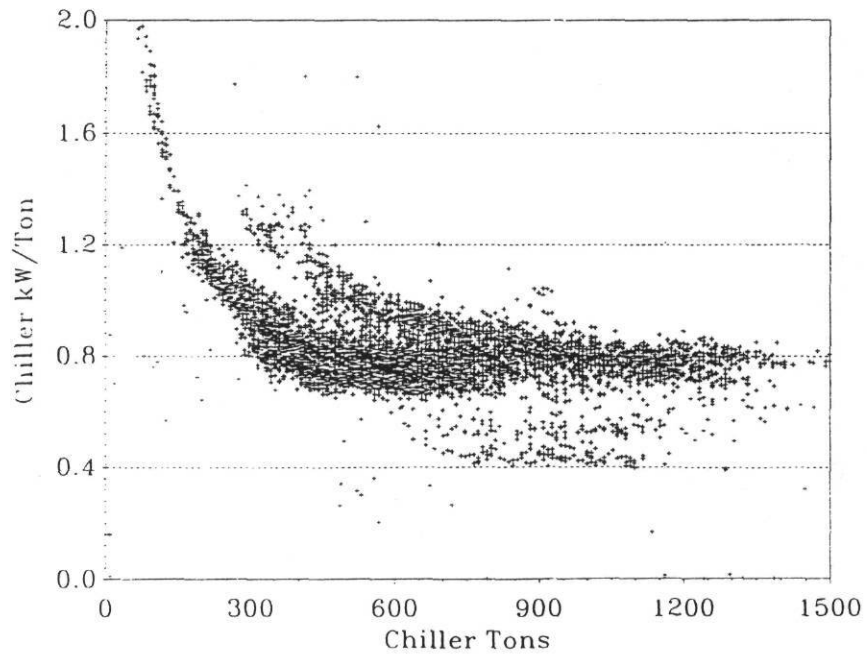


Figure 6: kW/ton of the electric chillers at the Delmar College in Corpus Christi, TX.