

ENVIRONMENTAL IMPACT OF THE TEXAS LOANSTAR PROGRAM

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ABSTRACT

This paper presents an analysis of the environmental impact of the energy reductions that have been measured in the Texas LoanSTAR program. 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 paper. This analysis shows that as of October 1997, there has been a reduction of emissions of 1,863 tons of NO_x, 1,200 tons of SO₂, and 530,000 tons of CO₂ through the implementation of energy conserving measures in the 27 sites¹ covering 290 buildings with retrofit savings of \$36.6 million. The paper presents the results of the analysis and includes a discussion of the method used to calculate the emissions reduction.

INTRODUCTION

Emissions from electric power plants are generally available on a plant specific basis. However, it is difficult to estimate a "typical" set of emissions for any resource type. Emissions depend on several factors other than simply the plant type, including: the age and type of the plant; fuel type, grade and sulfur content; installed emission control technology; plant operation, including the heat rate, combustion temperature, and steam or limestone injection. Finally, the estimate of emissions per unit of energy output can further be complicated by the allocation of emissions to joint products, such as steam and electricity [Ottinger et al., 1991]. The three major pollutants considered in this analysis are SO₂, CO₂ and NO_x.

Carbon dioxide (CO₂) is one of the major green house gases and is responsible for the green

house effect. There is a scientific consensus that an increase in greenhouse gas emissions, specially CO₂ will result in climate change, although the nature and the extent of the change, as well as its ramifications for human well-being are uncertain. Sulfur dioxide (SO₂) has many deleterious impacts on humans and the environment. It is the major cause of acid rain. SO₂ also causes human respiratory health problems, degrades visibility and causes vegetation and material damage through deposition on plant and material surface. Oxide of Nitrogen (NO_x) are particularly troublesome pollutants since they react in the atmosphere to form tropospheric ozone and smog, and precipitate out to form acid rain. They also contribute to the greenhouse effect by their conversion to nitrous oxide N₂O and by production of ozone. Recent works suggest that NO_x also promotes the growth of cancer [Ottinger et al., 1991].

Numerous state and national studies have analyzed the economic and emission impacts of investing in energy efficiency. Most of these studies have shown a positive correlation between energy savings and emission reductions, increased employment, and economic activity. 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 October 1997 the LoanSTAR program is measuring savings for 27 sites covering 290 buildings where retrofits have been fully or partially completed. The completed retrofits show \$36.6 million in measured savings, which is more than 106% 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.

Emission factors from three different sources were considered for this paper. This analysis shows that as of October 1997, there has been a reduction in

¹ One (1) site (Ward Memorial Hospital) is not included in Tables 3, 4 & 5 as it only had demand savings.

emissions of 1,863 tons of NO_x, 1,200 tons of SO₂, and 530,000 tons of CO₂ through the implementation of energy conservation measures in the Texas LoanSTAR program.

THE LOANSTAR PROGRAM

The Texas LoanSTAR 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 the General Service Commission 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. 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 372 state, city and school district buildings, and complexes covering a floor area of 28 million square feet. As of October 1997 the LoanSTAR program is measuring savings for 27 sites covering 290 buildings where retrofits have been fully or partially completed. The completed retrofits show about \$36.6 million in measured savings, which is more than 106% 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 which leads to a reduction in emissions.

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	CO₂	SO₂	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	CO₂	SO₂	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	CO₂	SO₂	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	CO₂	SO₂	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 NO_x 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 October 1997

Site Name	Heating Savings (MMBtu)	Heating * Savings (MCF)	CHW Savings (MMBtu)	CHW ** Savings (MWh)	Electricity Savings (MWh)
Zachry Engineering Center	82,749	107	99,400	8,283	10,082
U.T. Austin	371,443	481	842,334	70,195	125,635
U.T. Arlington	24,047	31	77,124	6,427	38,379
Fort Worth ISD	0	0	0	0	1,020
Victoria ISD	112,497	146	0	0	(1,326)
UT Health Science Center, Houston	0	0	0	0	27,592
Texas Dept. of Health, Austin	26,826	35	36,859	3,072	3,665
UT Medical Branch, Galveston	98,026	127	238,311	19,859	14,863
Nacogdoches ISD	0	0	0	0	4,927
Midland County Courthouse	0	0	0	0	1,348
Unv. of North TX Med. Center (TECOM)	32,454	42	0	0	507
Galveston ISD	0	0	0	0	2,198
UTMDA Cancer Center, Houston	0	0	0	0	43,367
Delmar College	249,351	323	57,770	4,814	1,358
Dallas County Govt. Center	36,722	48	0	0	(293)
State Capitol Complex, Austin	255,523	331	(44,456)	(3,705)	68,420
Austin State Hospital	0	0	0	0	7,383
UT Health Science Center, San Antonio	0	0	4,026	336	2,284
UT Dallas	(3,763)	(5)	10,144	845	4,794
College of the Mainland	37,375	48	13,778	1,148	13,096
Texas Women University, Houston	17,653	23	18,185	1,515	866
Unv. of Houston, Clear Lake	0	0	0	0	0
TAMU, Galveston	40,865	53	0	0	2,481
Texas Dept. of MHMR	30,495	39	0	0	4,876
Texas A&M University (2nd Loan)	14,516	19	8,942	745	1,542
City of Austin	0	0	0	0	188
TOTAL	1,426,800	1,847	1,362,400	113,535	379,250

* 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).

Table 3, 4 and 5 give the emissions reduced in heating, cooling, and electricity. Figure 1 is a

summary of those savings. An explanation of how the reductions were calculated follows:

Emission Reduction From Heating Savings

At the majority of 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 the Environmental Protection Agency's report (EPA 1992) are then used to translate savings in natural gas to environmental emissions reductions. At the LoanSTAR sites, all the boilers have uncontrolled burners (no low NO_x burners); therefore, an NO_x emission factor of 0.275 tons/MMCF is used. It should be noted that seasonal boiler efficiencies as low as 50% to 60% have been reported by Tierney and Fishman (1994). Emission factors higher 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.

Table 3 shows how the heating savings in MMBtu are converted to natural gas savings in MCF. The table also shows the emission factors for the three pollutants in tons/MMCF of natural gas saved. The heating savings for all the individual sites in the LoanSTAR program are shown through October 1997. The tons of pollutants saved from each individual site are shown along with 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/Ton² (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

² where 1,000 kWh = 1 MWh and 1 Ton = 0.012 MMBtu/h.

of 1.0 kW/ton is a reasonable approximation. Figures 2 and 3 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 [EPA 6202J]. 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.

Table 4 shows how the chilled water savings in MMBtu are converted to electricity savings in MWh. The table also shows the emission factors for the three pollutants in tons/MWh of electricity saved. The chilled water savings for all the individual sites in the LoanSTAR program are shown through October 1997. The tons of pollutants saved from each individual site are shown along with 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 contributors to 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.

Table 5 shows the emission factors for all three pollutants in tons/MWh of electricity saved. The table also shows the electricity saved for all the individual sites in the LoanSTAR program through October 1997. The tons of pollutants saved from each individual site are shown along with the site name and a total for each pollutant is shown at the bottom.

SUMMARY

Figure 1 shows the combined reduction in various environmental pollutants. This preliminary analysis shows that as of October 1997, there has been a reduction in emissions of 1,863 tons of NO_x, 1,200 tons of SO₂, and 530,000 tons 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.

ACKNOWLEDGMENTS

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CONVERSION FACTORS

1 kWh	=	1,000 Watt-hours
1MWh	=	1,000 kWh
1 MCF	=	1,000 cubic feet (of Natural Gas)
	=	1.030 x 10 ⁶ Btu = 1.030 MMBtu
1 MMBtu	=	1,000,000 Btu
1 MMCF	=	1,000,000 cubic feet
1 Ton	=	12,000 Btu/hr.

Emissions Savings Summary

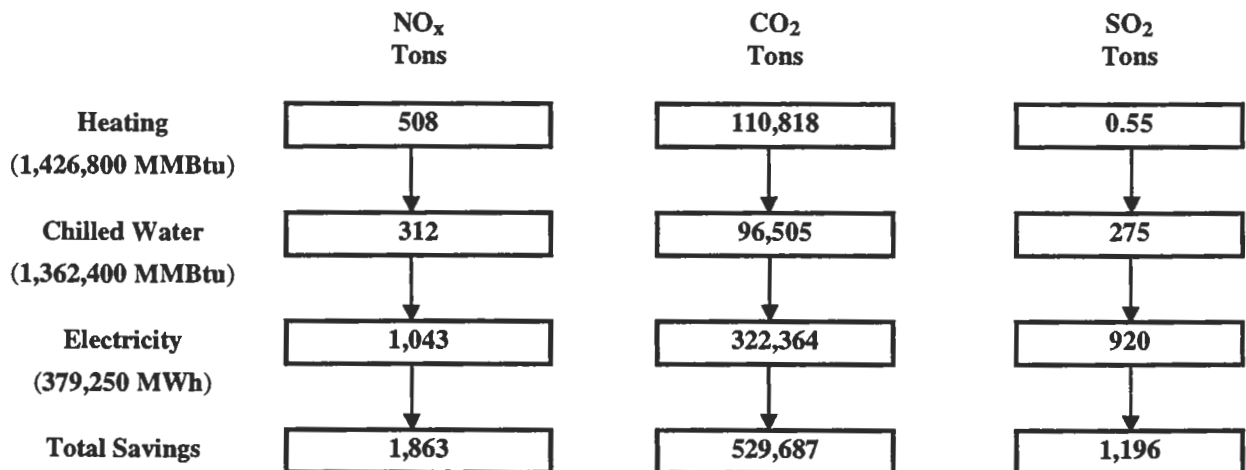


Figure 1: The combined reduction in pollutants resulting from heating, cooling, and electricity savings. The number in parentheses are the total heating, cooling, and electricity savings from the LoanSTAR program.

MEASURED SAVINGS To DATE	Heating MMBTUs	Heating MMCF eff=.75	Emission Savings (Tons)		
			NOx (0.275 tons/MMCF)	C02 (60 tons/MMCF)	S02 (0.0003 tons/MMCF)
Zachry Engineering Center	82,749	107	29.46	6427.11	0.03
U.T. Austin	371,443	481	132.23	28849.94	0.14
U.T. Arlington	24,047	31	8.56	1867.73	0.01
Fort Worth ISD	0	0	0.00	0.00	0.00
Victoria ISD	112,497	146	40.05	8737.63	0.04
UT Health Science Center, Houston	0	0	0.00	0.00	0.00
Texas Dept. of Health, Austin	26,826	35	9.55	2083.57	0.01
UT Medical Branch, Galveston	98,026	127	34.90	7613.67	0.04
Nacogdoches ISD	0	0	0.00	0.00	0.00
Midland County Courthouse	0	0	0.00	0.00	0.00
Unv. of North TX Med. Center (TECOM)	32,454	42	11.55	2520.70	0.01
Galveston ISD	0	0	0.00	0.00	0.00
UTMDA Cancer Center, Houston	0	0	0.00	0.00	0.00
Delmar College	249,351	323	88.77	19367.07	0.10
Dallas County Govt. Center	36,722	48	13.07	2852.19	0.01
State Capitol Complex, Austin	255,523	331	90.96	19846.45	0.10
Austin State Hospital	0	0	0.00	0.00	0.00
UT Health Science Center, San Antonio	0	0	0.00	0.00	0.00
UT Dallas	-3,763	-5	-1.34	-292.27	0.00
College of the Mainland	37,375	48	13.31	2902.91	0.01
Texas Women University, Houston	17,653	23	6.28	1371.11	0.01
Unv. of Houston, Clear Lake	0	0	0.00	0.00	0.00
TAMU, Galveston	40,865	53	14.55	3173.98	0.02
Texas Dept. of MHMR	30,495	39	10.86	2368.54	0.01
Texas A&M University (2nd Loan)	14,516	19	5.17	1127.46	0.01
City of Austin	0	0	0.00	0.00	0.00
TOTAL	1,426,800	1,847	507.91	110817.78	0.55

Table 3: LoanSTAR pollution reduction due to measured heating savings. The numbers in the 2nd column are the heating savings in MMBtu for the individual sites. The 4th, 5th and the 6th columns are the reduction in pollutants from individual sites. The total heating savings through October 1997 are 1,426,800 MMBtu.

MEASURED SAVINGS To DATE	ChW MMBTUs	ChW MWh kW/ton=1	Emission Savings (Tons)		
			NOx (0.00275 tons/MWh)	CO2 (0.85 tons/MWh)	S02 0.002425 tons/MWh)
Zachry Engineering Center	99,400	8,283	22.78	7040.83	20.09
U.T. Austin	842,334	70,195	193.03	59665.33	170.22
U.T. Arlington	77,124	6,427	17.67	5462.95	15.59
Fort Worth ISD	0	0	0.00	0.00	0.00
Victoria ISD	0	0	0.00	0.00	0.00
UT Health Science Center, Houston	0	0	0.00	0.00	0.00
Texas Dept. of Health, Austin	36,859	3,072	8.45	2610.85	7.45
UT Medical Branch, Galveston	238,311	19,859	54.61	16880.36	48.16
Nacogdoches ISD	0	0	0.00	0.00	0.00
Midland County Courthouse	0	0	0.00	0.00	0.00
Unv. of North TX Med. Center (TECOM)	0	0	0.00	0.00	0.00
Galveston ISD	0	0	0.00	0.00	0.00
UTMDA Cancer Center, Houston	0	0	0.00	0.00	0.00
Delmar College	57,770	4,814	13.24	4092.04	11.67
Dallas County Govt. Center	0	0	0.00	0.00	0.00
State Capitol Complex, Austin	-44,456	-3,705	-10.19	-3148.97	-8.98
Austin State Hospital	0	0	0.00	0.00	0.00
UT Health Science Center, San Antonio	4,026	336	0.92	285.18	0.81
UT Dallas	10,144	845	2.32	718.53	2.05
College of the Mainland	13,778	1,148	3.16	975.94	2.78
Texas Women University, Houston	18,185	1,515	4.17	1288.13	3.67
Unv. of Houston, Clear Lake	0	0	0.00	0.00	0.00
TAMU, Galveston	0	0	0.00	0.00	0.00
Texas Dept. of MHMR	0	0	0.00	0.00	0.00
Texas A&M University (2nd Loan)	8,942	745	2.05	633.39	1.81
City of Austin	0	0	0.00	0.00	0.00
TOTAL	1,362,400	113,535	312.22	96504.56	275.32

Table 4: LoanSTAR pollution reduction due to measured cooling savings. The numbers in the 2nd column are the cooling savings in MMBtu for the individual sites. The 4th, 5th and the 6th columns are the reduction in pollutants from individual sites. The total cooling savings through October 1997 are 1,362,400 MMBtu.

MEASURED SAVINGS To DATE	Electricity MWH	Emission Savings (Tons)		
		NOx (0.00275 tons/MWh)	CO2 (0.85 tons/MWh)	S02 0.002425 tons/MWh)
Zachry Engineering Center	10,082	27.73	8569.87	24.45
U.T. Austin	125,635	345.50	106789.56	304.66
U.T. Arlington	38,379	105.54	32622.50	93.07
Fort Worth ISD	1,020	2.80	866.84	2.47
Victoria ISD	-1,326	-3.65	-1127.44	-3.22
UT Health Science Center, Houston	27,592	75.88	23453.56	66.91
Texas Dept. of Health, Austin	3,665	10.08	3114.95	8.89
UT Medical Branch, Galveston	14,863	40.87	12633.36	36.04
Nacogdoches ISD	4,927	13.55	4187.61	11.95
Midland County Courthouse	1,348	3.71	1146.00	3.27
Unv. of North TX Med. Center (TECOM)	507	1.40	431.25	1.23
Galveston ISD	2,198	6.04	1868.22	5.33
UTMDA Cancer Center, Houston	43,367	119.26	36862.27	105.17
Delmar College	1,358	3.73	1154.26	3.29
Dallas County Govt. Center	-293	-0.81	-249.04	-0.71
State Capitol Complex, Austin	68,420	188.15	58156.73	165.92
Austin State Hospital	7,383	20.30	6275.93	17.90
UT Health Science Center, San Antonio	2,284	6.28	1941.20	5.54
UT Dallas	4,794	13.18	4074.61	11.62
College of the Mainland	13,096	36.01	11131.27	31.76
Texas Women University, Houston	866	2.38	736.33	2.10
Unv. of Houston, Clear Lake	0	0.00	0.00	0.00
TAMU, Galveston	2,481	6.82	2108.68	6.02
Texas Dept. of MHMR	4,876	13.41	4144.93	11.83
Texas A&M University (2nd Loan)	1,542	4.24	1310.72	3.74
City of Austin	188	0.52	160.13	0.46
TOTAL	379,250	1042.94	322364.30	919.69

Table 5: LoanSTAR pollution reduction due to measured electricity savings. The numbers in the 2nd column are the electricity savings in MWh for the individual sites. The 3rd, 4th and the 5th columns are the reduction in pollutants from individual sites. The total cooling savings through October 1997 are 379,250 MWh.

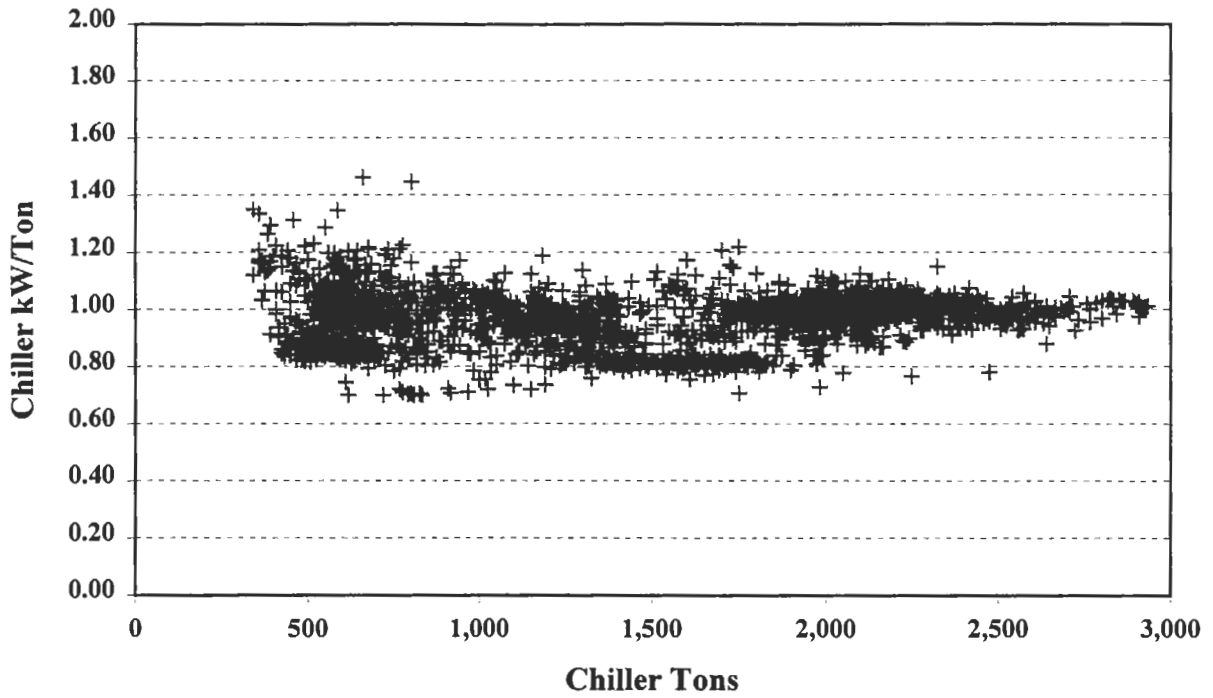


Figure 2: kW/ton of the electric chillers at M. D. Anderson Cancer Center's chilling plant in Houston, TX.

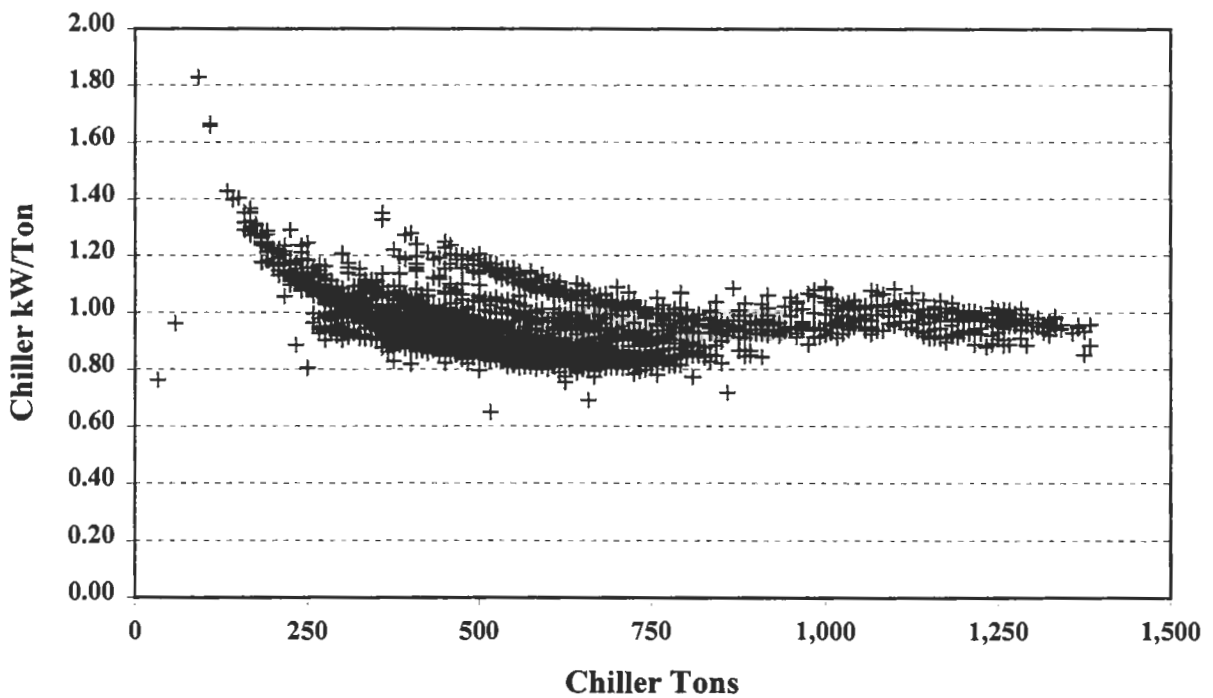


Figure 3: kW/ton of the electric chillers at the Delmar College in Corpus Christi, TX.