IMPACT OF THE IMPLEMENTATION OF THE 2000/2001 IECC ON COMMERCIAL ENERGY USE IN TEXAS: ANALYSIS OF COMMERCIAL ENERGY SAVINGS

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ABSTRACT

In September 2001, Texas adopted the 2000 International Energy Conservation Code, which references ASHRAE Standard 90.1-1999 in Chapter 7. This building code has substantially improved the energy efficiency of commercial buildings in Texas, resulting in reduced annual heating/cooling utility bills for commercial customers. Since this time the Texas Legislature has required that the energy savings and emissions reductions from the implementation of the Texas Energy Building Standards (TBEPS) be tracked annually and reported to the Texas Commission on Environmental Quality (TCEQ). To accomplish this code-compliant DOE-2 simulations and DOE-sponsored national average savings were used to calculate the savings per square foot of commercial construction, which were then multiplied by commercial building statistics for each county, and aggregated to state-wide totals. This paper outlines the analysis methods for accomplishing this task and reports the savings for 2005 for commercial construction.

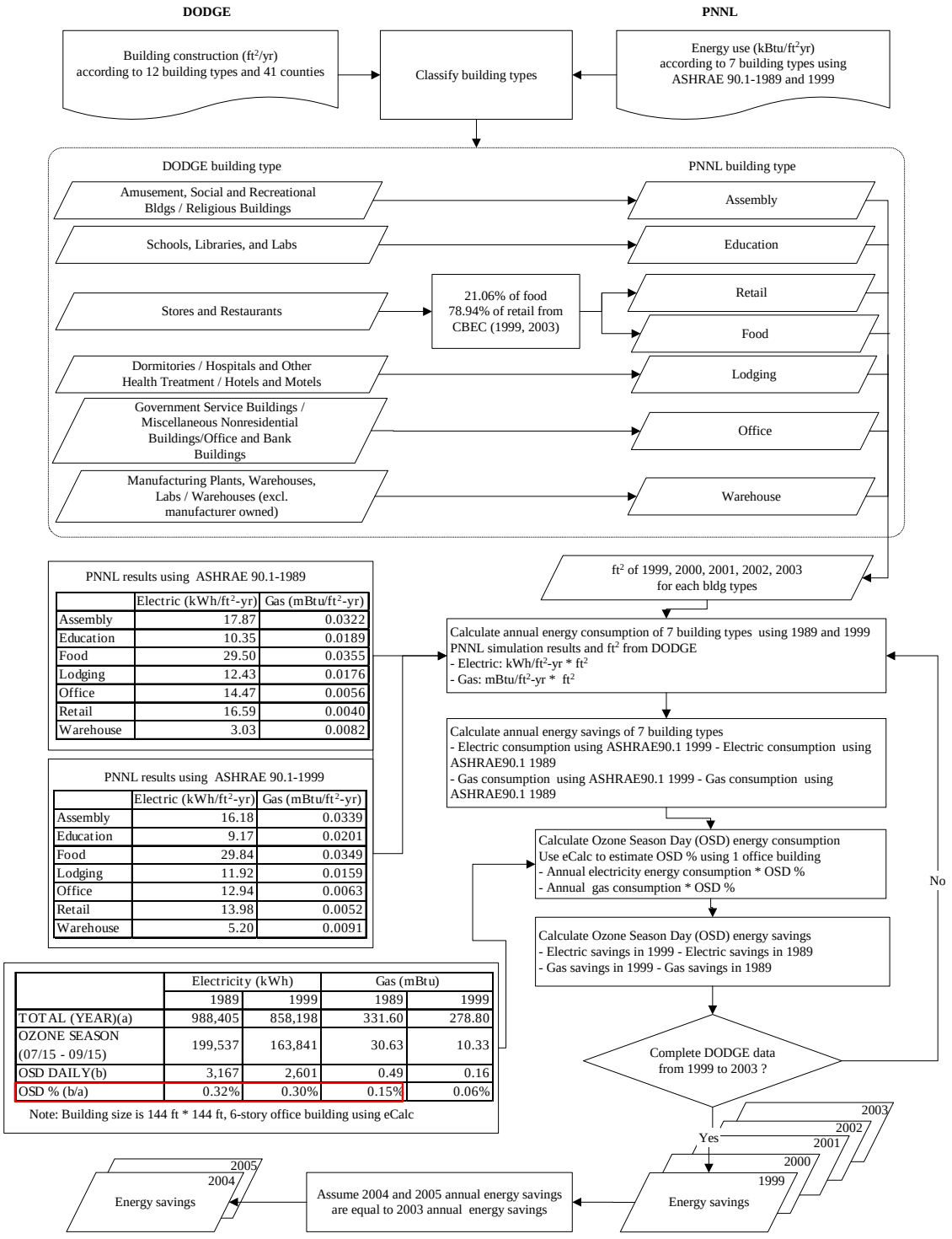
BACKGROUND:

In 2001, the Texas State Legislature formulated and passed Senate Bill 5 to further reduce ozone levels by encouraging the reduction of emissions of NOx by sources that are currently not regulated by the state, including area sources (e.g., residential emissions), on-road mobile sources (e.g., all types of motor vehicles), and non-road mobile sources (e.g., aircraft, locomotives, etc.)[1] . An important part of this legislation is the evaluation of the State's new energy efficiency programs, which includes reductions in energy use and demand that are associated with specific utility-based energy conservation measures, and implementation of the International Energy Conservation Code (IECC), published in 2000 as amended by the 2001 Supplement (IECC 2000; 2001). This paper provides a detailed discussion of the analysis methods and simulation tools employed to quantify the total savings achieved by the implementation of 2000/2001 IECC (ASHRAE Standard 90.1 1999) in commercial new construction in non-attainment and affected counties.

METHODOLOGY:

In order to quantify the energy savings achieved by the implementation of 2000/2001 IECC (ASHRAE Standard 90.1 1999) in the 41 affected and non-attainment counties, data from two sources was merged into one analysis as shown in Figure 1. In 2002, the US-DOE instructed PNNL to complete a detailed analysis of the energy savings for buildings built to ASHRAE standard 90.1-1989 versus ASHRAE Standard 90.1-1999 according to the commercial building types. In addition, F.W. Dodge publishes annual data about the total square footage of commercial building being constructed by building type. Unfortunately, the commercial building types in the PNNL study did not exactly match the F.W. Dodge data. Therefore, certain categories were combined and one category, "stores and restaurants" was split into two categories using CBECS data as shown.

[1] In the 2003 Texas State legislative session, the emissions reductions legislation in Senate Bill 5 was modified by House bill 3235, and House bill 1365. In the 2005 Texas State Legislative sessions, the TERP was modified by House bills 965 and 2129. In general, this new legislation strengthens the previous legislation, and did not reduce the stringency of the building code or the reporting of the emissions reductions.



PNNL results using ASHRAE 90.1-1989	Electric (kWh/ft²-yr)	Gas (mBtu/ft²-yr)
Assembly	17.87	0.0322
Education	10.35	0.0189
Food	29.50	0.0355
Lodging	12.43	0.0176
Office	14.47	0.0056
Retail	16.59	0.0040
Warehouse	3.03	0.0082

PNNL results using ASHRAE 90.1-1999	Electric (kWh/ft²-yr)	Gas (mBtu/ft²-yr)
Assembly	16.18	0.0339
Education	9.17	0.0201
Food	29.84	0.0349
Lodging	11.92	0.0159
Office	12.94	0.0063
Retail	13.98	0.0052
Warehouse	5.20	0.0091

	Electricity (kWh)		Gas (mBtu)	
	1989	1999	1989	1999
TOTAL (YEAR)(a)	988,405	858,198	331.60	278.80
OZONE SEASON (07/15 - 09/15)	199,537	163,841	30.63	10.33
OSD DAILY(b)	3,167	2,601	0.49	0.16
OSD % (b/a)	0.32%	0.30%	0.15%	0.06%

Note: Building size is 144 ft * 144 ft, 6-story office building using eCalc

Figure1: Process flow for calculating energy savings from the implementation of ASHRAE Standard 90.1-1999.

As shown in Figure 1, the Dodge database of the square footage of new commercial construction in Texas (F.W. Dodge, 2005), was merged with the energy savings calculations published by the Pacific Northwest National Laboratory (PNNL 2002), in a report prepared for the U.S.D.O.E. This allowed for the new construction to be tracked by county, and energy savings to be calculated by building type. Twelve building categories from F.W. Dodge were mapped to the seven categories used by PNNL in their analysis. The Dodge category of "Stores and Restaurants" was separated into "Retail" and "Food" in the PNNL analysis. To provide the correct division between these two categories, the CBEC database (1999,2003) was used, which shows 21.06% for "Food" and 78.94% for retail. After the correct mapping of the building types, the F.W. Dodge data were multiplied by the annual kWh/ft^2 and $MBtu/ft^2$ consumption from the PNNL analysis for both ASHRAE Standard 90.1-1989 and ASHRAE Standard 90.1-1999. The annual savings for each building type were then obtained by multiplying the total square footage from the F.W. Dodge data with the difference of energy consumption per square foot for each building type by the implementation of ASHRAE Standard 90.1-1999.

Figure 2 and Figure 3 show the annual electric and natural gas consumption, by county and building type for both ASHRAE Standard 90.1-1989 and ASHRAE Standard 90.1-1999. In this figure, it is clear that the gas consumption is going up for most building types when ASHRAE Standard 90.1-1989 is compared with ASHRAE Standard 90.1-1999 values. This difference is due to the adoption of low-e windows, which reduces the solar heat gain in summer and winter.

In order to calculate the Ozone Season Day (i.e., July 15 to Sept. 15) electricity and natural gas savings, simulations were performed on a typical office building that simulated a 6 story, 90,000 ft^2 office building in Central Texas. Measured 1999 weather data for Houston George Bush International airport packed in a TRY format was used for the simulations. The results of these simulations showed a 13% annual energy use reduction, which is consistent with the savings reported by PNNL. In Table 1, a ratio was calculated to allow for the conversion of annual savings to OSD savings. This ratio was then used in the remaining building types to accomplish this conversion. The OSD electric and natural gas consumption, by county and building type for both ASHRAE Standard 90.1-1989 and ASHRAE Standard 90.1-1999 is shown in Figure 4 and Figure 5.

In the next calculation step, electric utility providers were assigned to each county according to the published 1998 sales data from the Texas Public Utilities Commission as shown in Table 2 and Table 3. In the case where more than one utility was shown selling electricity in a county, the electricity use was proportioned according to the PUC's 1998 sales data. In the lower half of Table 3 the total electricity savings, by utility provider is shown for 2005 for all estimated new commercial construction. In a similar fashion as the annual calculations, electric utility providers were assigned to each county to calculate the OSD electricity savings by utility, as shown in Table 4.

Commercial Simulation Model:

Table 5 and Table 6 provide the DOE-2 parameters that were required to generate the commercial simulation model for the six-story office building. The parameters are divided into three major categories; LOADS, SYSTEMS and PLANT to facilitate simulation with DOE-2. The loads are then further divided into building, construction, space and shading parameters. The building parameters are used to define the location, orientation and the basic dimensions and layout of the building. Currently, the simulation model has the provision of only creating a 4-sided building model with up to one hundred stories with or without a basement. This portion of the input file also has the "building type" parameter which switches between the office and retail version of the inputs.

If a retail building is chosen then four additional parameters are activated, which allow the retail store to be positioned within a larger conditioned space. The switch between quick and thermal mass mode is fixed at quick construction for the current version. This means that the current DOE-2 simulation is using ASHRAE pre-calculated weighting factors for the calculation of a code-complaint building. The construction parameters include the material properties and U-values for the different components including the glazing properties and the window-to-wall area ratio. The user has the provision of entering different window areas for the different orientations. The upper limit on the window-to-wall ratio depends on the plenum

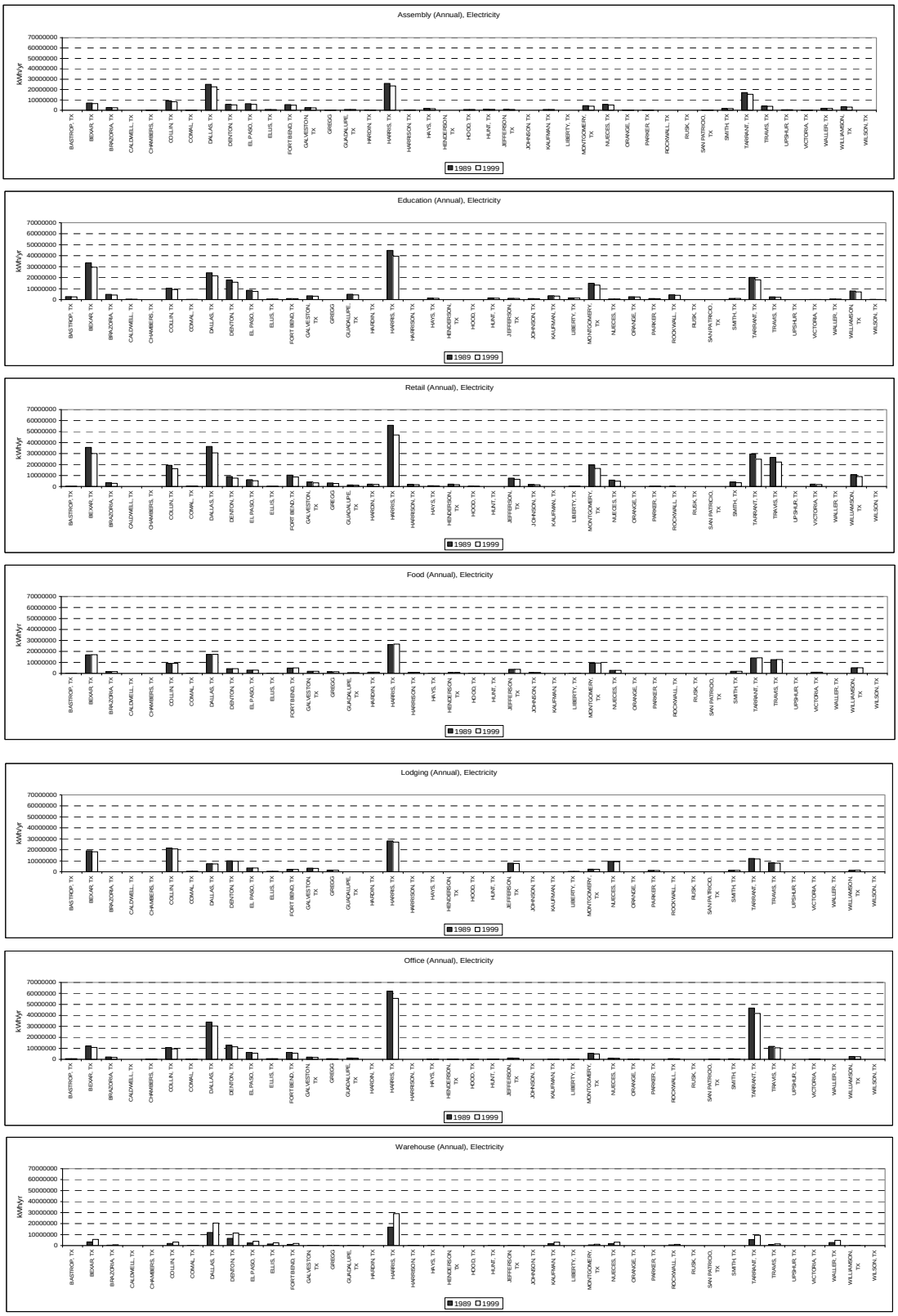


Figure 2: Calculated ASHRAE Standard 90.1 -1989 and 1999 Annual Electricity Use for Assembly, Education, Retail, Food, Lodging, Office, and Warehouse Building Types (USDOE 2004).

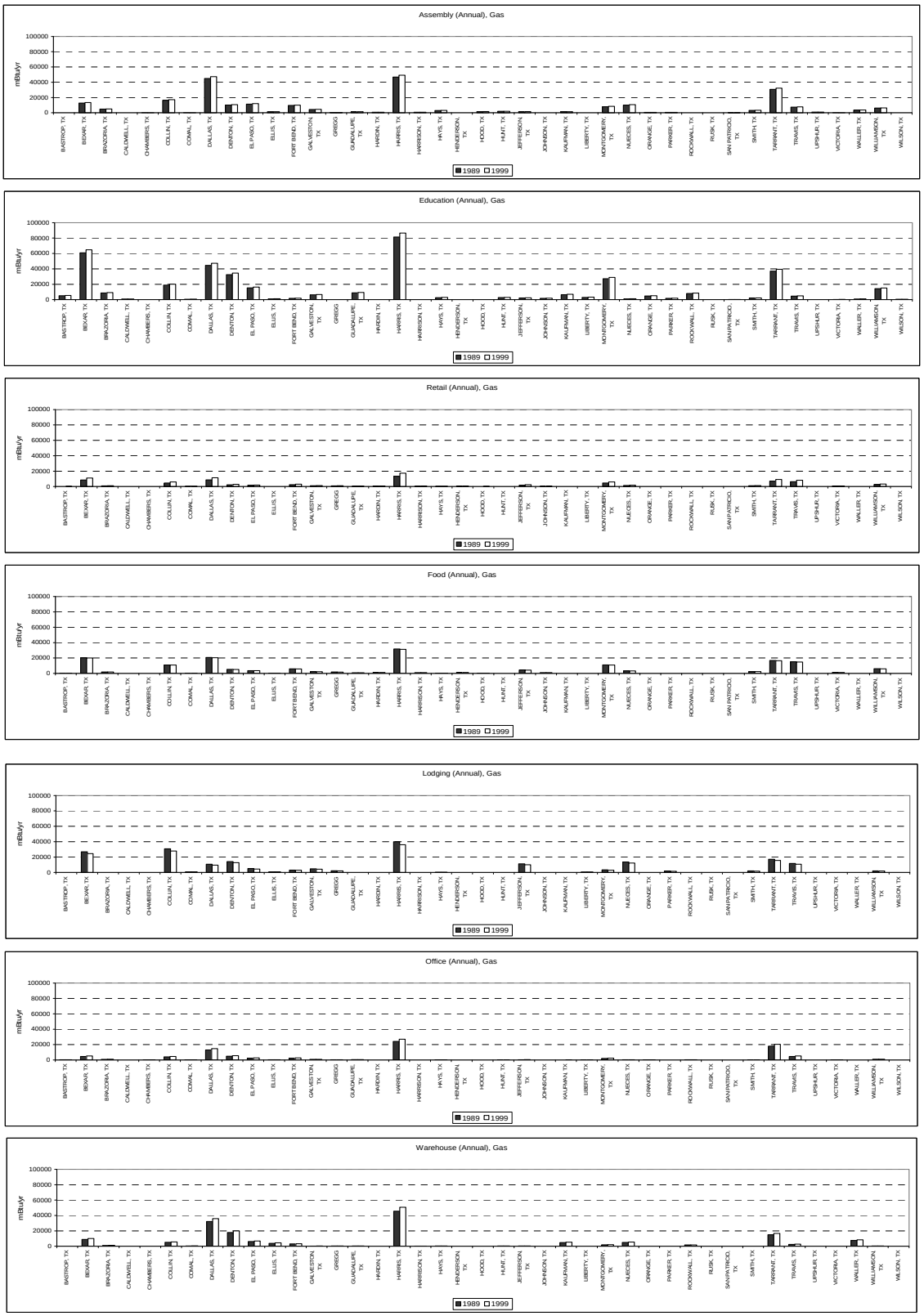


Figure 3: Calculated ASHRAE Standard 90.1 -1989 and 1999 Annual Natural Gas Use for Assembly, Education, Retail, Food, Lodging, Office, and Warehouse Building Types (USDOE 2004).

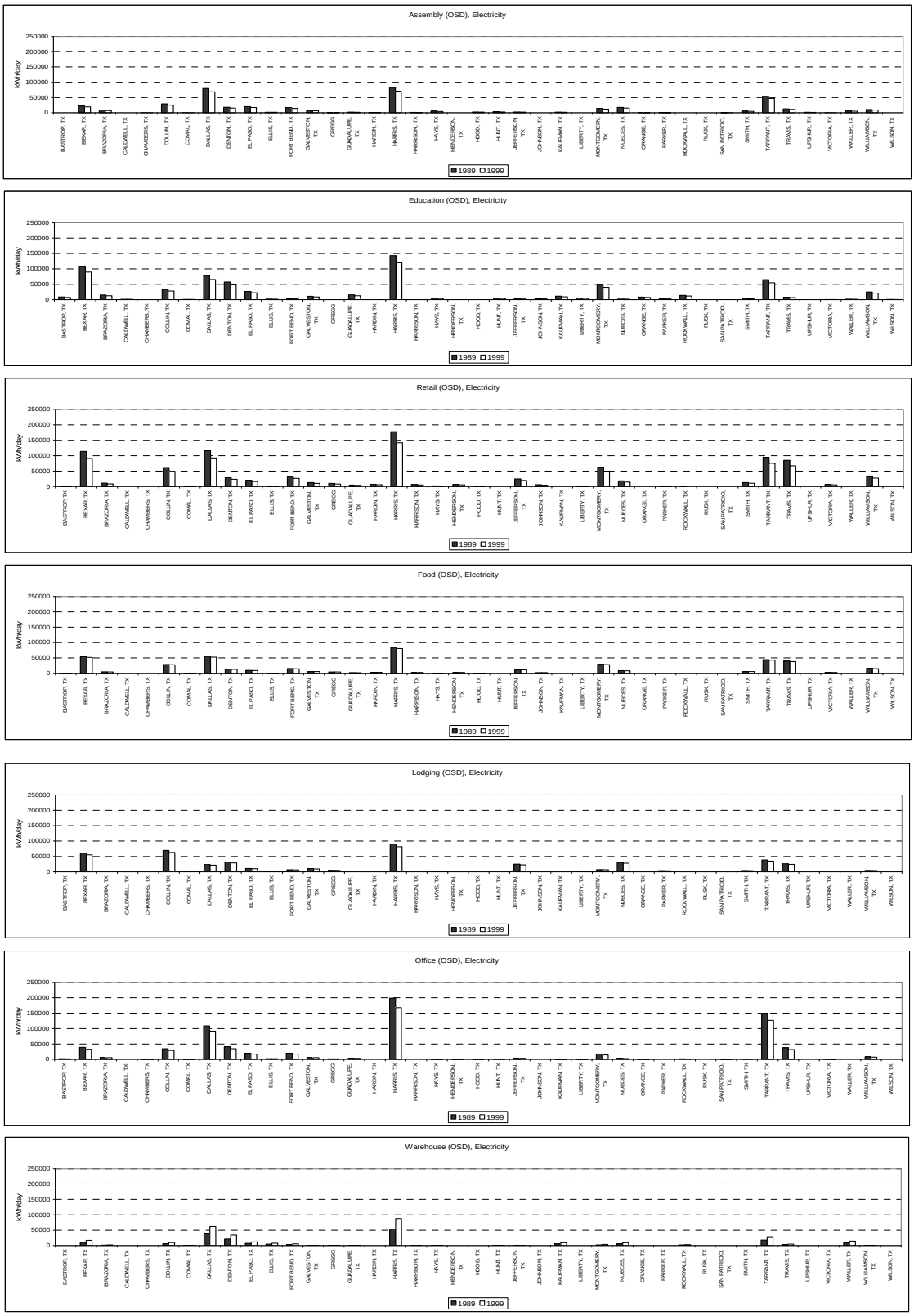


Figure 4: Calculated ASHRAE Standard 90.1 -1989 and 1999 OSD Electricity Use for Assembly, Education, Retail, Food, Lodging, Office, and Warehouse Building Types (USDOE 2004).

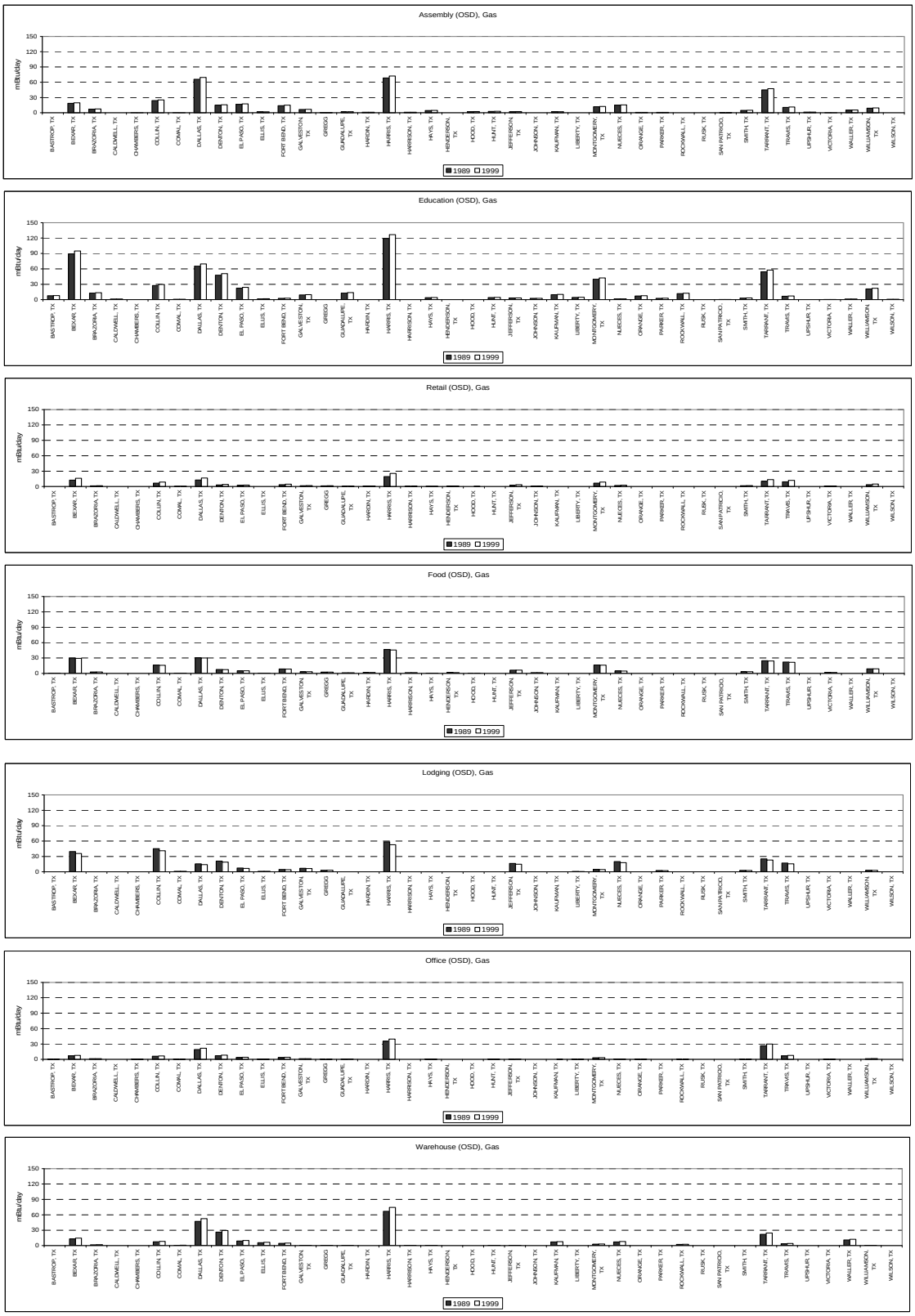


Figure 5: Calculated ASHRAE Standard 90.1 -1989 and 1999 OSD Natural Gas Use for Assembly, Education, Retail, Food, Lodging, Office, and Warehouse Building Types (USDOE 2004).

Table 1: Simulated Electricity and Natural Gas for Building Built to 90.1-1989 Standard for Annual and OSD (07/15 – 09/15).

	Electricity (kWh)		Gas (MBtu)	
	1989	1999	1989	1999
TOTAL (YEAR) (a)	988,405	858,198	331.6	278.8
Ozone Season (07/15 - 09/15)	199,537	163,841	30.6	10.3
OSD Daily (b)	3,167	2,601	0.49	0.16
OSD % (b/a)	0.32%	0.30%	0.15%	0.06%

Table 2: 2005 Allocation of PCA for each of 41 Non-attainment and Affected Counties.

NERC Region	County	Elec. Utilities 1	PCA	1998 Annual net Generation (MWh)	Percentage	Elec. Utilities 2	PCA	1998 Annual net Generation (MWh)	Percentage
ERCOT	BASTROP	ONCOR	TXU Electric/PCA	97,581,030	100%	Smithville			
	BEXAR	CPSB	San Antonio Public Service Bd/PCA	14,641,059	100%	Bandera EC			
	BRAZORIA	RELIANT(CENTER POINT)	Reliant Energy HL&P/PCA	74,386,176	97%	T-NMP	Texas-New Mexico Power Co/PCA	2,067,714	3%
	CALDWELL	CPL(AEP)	American Electric Power - West (ERCOT)/PCA	17,162,569	100%	Luling			
	CHAMBERS	RELIANT(CENTER POINT)	Reliant Energy HL&P/PCA	74,386,176	70%	ENTERGY	Entergy Electric System/PCA	32,288,113	30%
	COLLIN	ONCOR	TXU Electric/PCA	97,581,030	98%	T-NMP	Texas-New Mexico Power Co/PCA	2,067,714	2%
	COMAL	CPSB	San Antonio Public Service Bd/PCA	14,641,059	100%	New Braunfels			
	DALLAS	ONCOR	TXU Electric/PCA	97,581,030	100%	Garland			
	DENTON	ONCOR	TXU Electric/PCA	97,581,030	98%	T-NMP	Texas-New Mexico Power Co/PCA	2,067,714	2%
	ELLIS	ONCOR	TXU Electric/PCA	97,581,030	100%	Navarro County EC			
	FORT BEND	RELIANT(CENTER POINT)	Reliant Energy HL&P/PCA	74,386,176	100%				
	GALVESTON	RELIANT(CENTER POINT)	Reliant Energy HL&P/PCA	74,386,176	97%	T-NMP	Texas-New Mexico Power Co/PCA	2,067,714	3%
	GUADALUPE	CPSB	San Antonio Public Service Bd/PCA	14,641,059	100%	Seguin			
	HARRIS	RELIANT(CENTER POINT)	Reliant Energy HL&P/PCA	74,386,176	70%	ENTERGY	Entergy Electric System/PCA	32,288,113	30%
	HAYS	San Marcos	*Lower Colorado River Authority/PCA		100%	Pedernales EC			
	HENDERSON	ONCOR	TXU Electric/PCA	97,581,030	100%	Trinity Valley EC			
	HOOD	ONCOR	TXU Electric/PCA	97,581,030	98%	T-NMP	Texas-New Mexico Power Co/PCA	2,067,714	2%
	HUNT	ONCOR	TXU Electric/PCA	97,581,030	98%	T-NMP	Texas-New Mexico Power Co/PCA	2,067,714	2%
	JOHNSON	ONCOR	TXU Electric/PCA	97,581,030	98%	T-NMP	Texas-New Mexico Power Co/PCA	2,067,714	2%
	KAUFMAN	ONCOR	TXU Electric/PCA	97,581,030	100%	Trinity Valley EC			
	NUECES	CPL(AEP)	American Electric Power - West (ERCOT)/PCA	17,162,569	100%	Robstown			
	PARKER	ONCOR	TXU Electric/PCA	97,581,030	100%	Weatherford			
	ROCKWALL	ONCOR	TXU Electric/PCA	97,581,030	100%	FEC Electric			
	SAN PATRICIO	CPL(AEP)	American Electric Power - West (ERCOT)/PCA	17,162,569	100%	San Patricio EC			
	SMITH	ONCOR	TXU Electric/PCA	97,581,030	100%	SWEPCO(AEP)			
	TARRANT	ONCOR	TXU Electric/PCA	97,581,030	100%	Tri-County EC			
	TRAVIS	ONCOR	TXU Electric/PCA	97,581,030	97%	Austin Energy	Austin Energy/PCA	3,359,240	3%
	VICTORIA	CPL(AEP)	American Electric Power - West (ERCOT)/PCA	17,162,569	100%	Victoria EC			
	WALLER	RELIANT(CENTER POINT)	Reliant Energy HL&P/PCA	74,386,176	100%	Hempstead			
	WILLIAMSON	ONCOR	TXU Electric/PCA	97,581,030	97%	Austin Energy	Austin Energy/PCA	3,359,240	3%
	WILSON	Floresville	*San Antonio Public Service Bd/PCA	N/A	100%	Guadalupe Valley EC			
SPP	GREGG	SWEPCO(AEP)	Southwestern Public Service Co/PCA			Rusk County EC			
	HARRISON	SWEPCO(AEP)	Southwestern Public Service Co/PCA			Panola-Harrison EC			
	RUSK	SWEPCO(AEP)	Southwestern Public Service Co/PCA			ONCOR			
	UPSHUR	SWEPCO(AEP)	Southwestern Public Service Co/PCA			Upshur-Rural EC			
SERC	HARDIN	ENTERGY	Entergy Electric System/PCA	32,288,113	30%	RELIANT(CENTER POINT)	Reliant Energy HL&P/PCA	74,386,176	70%
	JEFFERSON	ENTERGY	Entergy Electric System/PCA	32,288,113	100%				
	LIBERTY	ENTERGY	Entergy Electric System/PCA	32,288,113	100%	Sam Houston EC			
	MONTGOMERY	ENTERGY	Entergy Electric System/PCA	32,288,113	30%	RELIANT(CENTER POINT)	Reliant Energy HL&P/PCA	74,386,176	70%
	ORANGE	ENTERGY	Entergy Electric System/PCA	32,288,113	100%	Jasper-Newton EC			
WSCC	EL PASO	EPEC	El Paso Electric Co/PCA	3,066,882	100%	Rio Grande EC			
* The electricity providers for Hays and Wilson county were identified by personal communication with the proper representatives. Below is the contact information									
	* Hays County: SAN MARCOS ELECTRIC UTILITY (SAN MARCOS, CITY OF) 630 E. Hopkins St. San Marcos TX 78666-6397 512/396-2451 Robert L. Higgs Dir., Electric Utility Mun								
	* Wilson County: FLORESVILLE ELECTRIC LIGHT & POWER SYSTEM 1400 Fourth St. P.O. Box 218 Floresville TX 78114-2372 830/216-7000 David K. McMillan General Manager Muni								

height (i.e., the plenum height is added to the building section to calculate the maximum window-to-wall area ratio for that building. The maximum upper limit is 90%.

With regards to internal loads, Table 6.5, 13.2 and 13.4 of ASHRAE Standard 90.1-1989 describes the requirements for lighting, occupancy and receptacles according to the square footage and end-use. ASHRAE Standard 90.1-1999 does not give requirements for occupancy and receptacles, but defines the lighting power density (LPD) requirements for different building types in Table 9.3.1.1. For example, Standard 90.1-1999 allows a LPD of 1.3 W/ft2 and 1.9 W/ft2 for office and retail respectively.

The SYSTEM parameters include the type of systems, the system capacity and the efficiencies of the system selected. Currently the user can choose from three kinds of system: 1) a Variable Air Volume (VAV) system with a central HVAC plant, 2) a packaged variable air volume (PVAV) system, and 3) a packaged single zone (PSZ) system with either gas or electric heating. The DHW heater can be either gas or electric. If the DHW heater is gas then one

Table 3: Totalized Annual Electricity Savings from 90.1-1999 by PCA for Commercial Buildings.

NERC	County	Total Energy Savings by County (MWh)	PCA 1	Percentage	Energy Savings by County for PCA 1 (MWh)	PCA 2	Percentage	Energy Savings by County for PCA 2 (MWh)
ERCOT	CALDWELL	62.07	American Electric Power - West (ERCOT)/PCA	100%	62.07			0.00
	NUECES	738.02	American Electric Power - West (ERCOT)/PCA	100%	738.02			0.00
	SAN PATRICIO	36.14	American Electric Power - West (ERCOT)/PCA	100%	36.14			0.00
	VICTORIA	420.10	American Electric Power - West (ERCOT)/PCA	100%	420.10			0.00
	HAYS	396.21	Lower Colorado River Authority/PCA	100%	396.21			0.00
	BRAZORIA	1323.03	Reliant Energy HL&P/PCA	97%	1,287.25	Texas-New Mexico Power Co/PCA	3%	35.78
	CHAMBERS	38.30	Reliant Energy HL&P/PCA	70%	26.71	Entergy Electric System/PCA	30%	11.59
	FORT BEND	2309.93	Reliant Energy HL&P/PCA	100%	2,309.93			0.00
	GALVESTON	1635.90	Reliant Energy HL&P/PCA	97%	1,591.66	Texas-New Mexico Power Co/PCA	3%	44.24
	HARRIS	12459.62	Reliant Energy HL&P/PCA	70%	8,688.35	Entergy Electric System/PCA	30%	3,771.27
	WALLER	-1866.05	Reliant Energy HL&P/PCA	100%	-1,866.05			0.00
	BEXAR	10257.22	San Antonio Public Service Bd/PCA	100%	10,257.22			0.00
	WILSON	33.62	San Antonio Public Service Bd/PCA	100%	33.62			0.00
	COMAL	40.10	San Antonio Public Service Bd/PCA	100%	40.10			0.00
	GUADALUPE	980.83	San Antonio Public Service Bd/PCA	100%	980.83			0.00
	BASTROP	452.44	TXU Electric/PCA	100%	452.44			0.00
	COLLIN	6056.85	TXU Electric/PCA	98%	5,931.17	Texas-New Mexico Power Co/PCA	2%	125.68
	DALLAS	6462.01	TXU Electric/PCA	100%	6,462.01			0.00
	DENTON	1027.81	TXU Electric/PCA	98%	1,006.49	Texas-New Mexico Power Co/PCA	2%	21.33
	ELLIS	-823.62	TXU Electric/PCA	100%	-823.62			0.00
	HENDERSON	348.63	TXU Electric/PCA	100%	348.63			0.00
	HOOD	148.24	TXU Electric/PCA	98%	145.16	Texas-New Mexico Power Co/PCA	2%	3.08
	HUNT	225.45	TXU Electric/PCA	98%	220.77	Texas-New Mexico Power Co/PCA	2%	4.68
	JOHNSON	410.85	TXU Electric/PCA	98%	402.32	Texas-New Mexico Power Co/PCA	2%	8.53
	KAUFMAN	-834.31	TXU Electric/PCA	100%	-834.31			0.00
	PARKER	224.75	TXU Electric/PCA	100%	224.75			0.00
	ROCKWALL	142.30	TXU Electric/PCA	100%	142.30			0.00
	SMITH	1096.85	TXU Electric/PCA	100%	1,096.85			0.00
	TARRANT	10596.37	TXU Electric/PCA	100%	10,596.37			0.00
	TRAVIS	6012.55	TXU Electric/PCA	97%	5,812.46	Austin Energy/PCA	3%	200.09
	WILLIAMSON	3340.55	TXU Electric/PCA	97%	3,229.38	Austin Energy/PCA	3%	111.17
WSCC	EL PASO	1807.92	El Paso Electric Co/PCA	100%	1,807.92			0.00
SERC	HARDIN	402.41	Entergy Electric System/PCA	30%	121.80	Reliant Energy HL&P/PCA	70%	280.61
	JEFFERSON	1875.38	Entergy Electric System/PCA	100%	1,875.38			0.00
	LIBERTY	262.62	Entergy Electric System/PCA	100%	262.62			0.00
	MONTGOMERY	5629.05	Entergy Electric System/PCA	30%	1,703.80	Reliant Energy HL&P/PCA	70%	3,925.25
	ORANGE	374.08	Entergy Electric System/PCA	100%	374.08			0.00
SPP	GREGG	587.69	Southwestern Public Service Co/PCA	100%	587.69			0.00
	HARRISON	325.26	Southwestern Public Service Co/PCA	100%	325.26			0.00
	RUSK	0.00	Southwestern Public Service Co/PCA	100%	0.00			0.00
	UPSHUR	54.43	Southwestern Public Service Co/PCA	100%	54.43			0.00

PCA	Total Electricity Savings by PCA (MWh/year)
American Electric Power - West (ERCOT)/PCA	1,256.34
Austin Energy/PCA	311.27
Brownsville Public Utils Board/PCA	0.00
Lower Colorado River Authority/PCA	396.21
Reliant Energy HL&P/PCA	16,243.71
San Antonio Public Service Bd /PCA	11,311.77
South Texas Electric Coop Inc/PCA	0.00
Texas Municipal Power Pool/PCA	0.00
Texas-New Mexico Power Co/PCA	243.31
TXU Electric/PCA	34,413.17
Total	64,175.77

Table 4: 2005 Totalized OSD Electricity Savings From IECC / IRC by PCA for Commercial Buildings (w/7% T&D).

NERC	County	Total Energy Savings by County (MWh)	PCA 1	Percentage	Energy Savings by County for PCA 1 (MWh)	PCA 2	Percentage	Energy Savings by County for PCA 2 (MWh)
ERCOT	CALDWELL	0.28	American Electric Power - West (ERCOT)/PCA	100%	0.28			0.00
	NUECES	7.32	American Electric Power - West (ERCOT)/PCA	100%	7.32			0.00
	SAN PATRICIO	0.17	American Electric Power - West (ERCOT)/PCA	100%	0.17			0.00
	VICTORIA	1.98	American Electric Power - West (ERCOT)/PCA	100%	1.98			0.00
	HAYS	2.06	Lower Colorado River Authority/PCA	100%	2.06			0.00
	BRAZORIA	6.80	Reliant Energy HL&P/PCA	97%	6.62	Texas-New Mexico Power Co/PCA	3%	0.18
	CHAMBERS	0.18	Reliant Energy HL&P/PCA	70%	0.13	Entergy Electric System/PCA	30%	0.05
	FORT BEND	12.80	Reliant Energy HL&P/PCA	100%	12.80			0.00
	GALVESTON	8.16	Reliant Energy HL&P/PCA	97%	7.94	Texas-New Mexico Power Co/PCA	3%	0.22
	HARRIS	86.12	Reliant Energy HL&P/PCA	70%	60.05	Entergy Electric System/PCA	30%	26.07
	WALLER	-4.68	Reliant Energy HL&P/PCA	100%	-4.68			0.00
	BEXAR	54.82	San Antonio Public Service Bd/PCA	100%	54.82			0.00
	WILSON	0.15	San Antonio Public Service Bd/PCA	100%	0.15			0.00
	COMAL	0.50	San Antonio Public Service Bd/PCA	100%	0.50			0.00
	GUADALUPE	4.67	San Antonio Public Service Bd/PCA	100%	4.67			0.00
	BASTROP	2.08	TXU Electric/PCA	100%	2.08			0.00
	COLLIN	33.67	TXU Electric/PCA	98%	32.97	Texas-New Mexico Power Co/PCA	2%	0.70
	DALLAS	48.70	TXU Electric/PCA	100%	48.70			0.00
	DENTON	15.47	TXU Electric/PCA	98%	15.15	Texas-New Mexico Power Co/PCA	2%	0.32
	ELLIS	-1.70	TXU Electric/PCA	100%	-1.70			0.00
	HENDERSON	1.64	TXU Electric/PCA	100%	1.64			0.00
	HOOD	0.71	TXU Electric/PCA	98%	0.70	Texas-New Mexico Power Co/PCA	2%	0.01
	HUNT	1.27	TXU Electric/PCA	98%	1.25	Texas-New Mexico Power Co/PCA	2%	0.03
	JOHNSON	1.92	TXU Electric/PCA	98%	1.88	Texas-New Mexico Power Co/PCA	2%	0.04
	KAUFMAN	-1.35	TXU Electric/PCA	100%	-1.35			0.00
	PARKER	1.19	TXU Electric/PCA	100%	1.19			0.00
	ROCKWALL	1.48	TXU Electric/PCA	100%	1.48			0.00
	SMITH	5.35	TXU Electric/PCA	100%	5.35			0.00
	TARRANT	59.17	TXU Electric/PCA	100%	59.17			0.00
	TRAVIS	30.62	TXU Electric/PCA	97%	29.60	Austin Energy/PCA	3%	1.02
	WILLIAMSON	15.94	TXU Electric/PCA	97%	15.41	Austin Energy/PCA	3%	0.53
WSCC	EL PASO	12.21	El Paso Electric Co/PCA	100%	12.21			0.00
SERC	HARDIN	1.90	Entergy Electric System/PCA	30%	0.58	Reliant Energy HL&P/PCA	70%	1.33
	JEFFERSON	9.91	Entergy Electric System/PCA	100%	9.91			0.00
	LIBERTY	1.25	Entergy Electric System/PCA	100%	1.25			0.00
	MONTGOMERY	27.62	Entergy Electric System/PCA	30%	8.36	Reliant Energy HL&P/PCA	70%	19.26
	ORANGE	1.73	Entergy Electric System/PCA	100%	1.73			0.00
SPP	GREGG	3.15	Southwestern Public Service Co/PCA	100%	3.15			0.00
	HARRISON	1.63	Southwestern Public Service Co/PCA	100%	1.63			0.00
	RUSK	0.00	Southwestern Public Service Co/PCA	100%	0.00			0.00
	UPSHUR	0.26	Southwestern Public Service Co/PCA	100%	0.26			0.00

PCA	Total Electricity Savings by PCA (MWh/OSD)
American Electric Power - West (ERCOT)/PCA	9.75
Austin Energy /PCA	1.55
Brownsville Public Utils Board/PCA	0.00
Lower Colorado River Authority /PCA	2.06
Reliant Energy HL&P/PCA	103.44
San Antonio Public Service Bd /PCA	60.14
South Texas Electric Coop Inc/PCA	0.00
Texas Municipal Power Pool/PCA	0.00
Texas-New Mexico Power Co/PCA	1.51
TXU Electric /PCA	213.53
Total	391.97

Table 5: Commercial Simulation Input Parameters (LOADS).

NAME	DESCRIPTION	DEFAULT	STATUS	COMMENT
LOADS				
b01	Quick or thermal mode (Q or T)	Quick (Q)	Fixed	Q simulates the building as massless, T will include thermal mass
b02	Location	Bastrop (BAS)	User Defined	41 counties linked to 9 TRY packed weather files according to climate zone
b03	Azimuth of building (degree)	0	User Defined	Orientation of the building
b04	Length of building (ft)	122	User Defined	
b05	Width of building (ft)	122	User Defined	
b06	Floor to ceiling height (ft)	9	User Defined	
b07	Door height (ft)	7	Fixed	
b08	Door width (ft)	6	Fixed	
b09	Run year	2000	User Defined	
b10	Floor to floor height (ft)	13	User Defined	This defines the plenum height in conjunction with b06
b11	Number of floor	6	User Defined	
b12	Perimeter depth (ft)	15	Fixed	Used for thermal zoning
b13	Void			
b14	Underground floor mode	No (N)	User Defined	This allows the user to activate/deactivate underground floors
b15	Front wall: Attached to another building?	No (N)	User Defined	These 4 parameters are used to attach buildings to the different orientations of the model for the retail scenario
b16	Right wall: Attached to another building?	No (N)	User Defined	
b17	Back wall: Attached to another building?	No (N)	User Defined	
b18	Left wall: Attached to another building?	No (N)	User Defined	
b19	Building type	Office (O)	User Defined	Allows the user to switch between Office and Retail
b20	Code compliance	Code (C)	User Defined	Allows user to run user defined model or either of ASHRAE 90.1 1989 or 1999
c01	Roof absorptance	0.45	User Defined	c01 and c03 are used to determine "roof color"
c02	Roof roughness	1	Fixed	This is used to calculate the outside film coefficient for heat transfer calculations, DOE-2 allows values from 1 to 6 increasing in smoothness
c03	Roof outside emissivity	0.89	User Defined	c01 and c03 are used to determine "roof color"
c04	Roof insulation R-value (hr-sq.ft-F/Btu)	R-15	User Defined	
c05	Wall absorptance	0.57	User Defined	c05 and c07 are used to define "wall color"
c06	Wall roughness	2	Fixed	This is used to calculate the outside film coefficient for heat transfer calculations, DOE-2 allows values from 1 to 6 increasing in smoothness
c07	Wall outside emissivity	0.9	User Defined	c05 and c07 are used to define "wall color"
c08	Wall insulation R-value (hr-sq.ft-F/Btu)	R-13	User Defined	
c09	Ground reflectance	0.24	Fixed	This defines the fraction of sunlight reflected from the ground
c10	Void			
c11	U-Factor of glazing (Btu/hr-sq.ft-F)	1.22	User Defined	
c12	Solar Heat Gain Coefficient(SHGC)	0.17	User Defined	
c13	Number of pane of glazing	1	Fixed	
c14	Frame absorptance of glazing	0.7	Fixed	
c15	Frame type - A,B,C,D,E	Aluminum w/o thermal break (A)	User Defined	Allows user to select from 5 different frame types
c16	Void			
c17	Floor weight (lb/sq-ft)	70	User Defined	This corresponds to medium construction, user has a choice of light, medium or heavy construction
c18	Slab-on-grade floor insulation R-value (Exterior insulation, horizontal) (hr-sq.ft-F/Btu)	R-0 (A)	User Defined	User can choose from 9 insulation R-values and insulation depths
c19	Slab-on-grade floor R-value (hr-sq.ft-F/Btu)	0.88	Fixed	
c20	Below-grade wall insulation R-value (hr-sq.ft-F/Btu) (Exterior insulation, vertical, basement wall = 8 ft)	R-0 (A)	User Defined	User can choose from 9 insulation R-values
c21	Below-grade wall R-value (concrete wall) (hr-sq.ft-F/Btu)	0.88	Fixed	
c22	Void			
c23	Floor R-value	1.67	Fixed	
c24	Void			
c25	Ceiling R-value (hr-sq.ft-F/Btu)	1.89	Fixed	
c26	Interior wall R-value (hr-sq.ft-F/Btu)	2.01	Fixed	
c27	Percent window-front (%)	50	User Defined	
c28	Percent window-right (%)	50	User Defined	
c29	Percent window-back (%)	50	User Defined	
c30	Percent window-left (%)	50	User Defined	
sp01	void			
sp02	void			
sp03	Area per person (ft^2/person) for office	275	User Defined	
sp04	Lighting load (W/ft2) for office	1.3	User Defined	
sp05	Equipment load (W/ft2) for office	0.75	User Defined	
sp06	Area per person (ft^2/person) for retail	300	User Defined	
sp07	Lighting load (W/ft2) for retail	1.9	User Defined	
sp08	Equipment load (W/ft2) for retail	0.25	User Defined	
s01	Front Shade (S)	0	User Defined	
s02	Back Shade (N)	0	User Defined	
s03	Left Shade (W)	0	User Defined	
s04	Right Shade (E)	0	User Defined	

Table 6: Commercial Simulation Input Parameters (SYSTEMS and PLANT).

NAME	DESCRIPTION	DEFAULT	STATUS	COMMENT
SYSTEM				
sy01	Mode of system	Variable air volume (2)	User Defined	User can choose from Packaged single zone, variable air volume or packaged variable volume system
sy02	Cooling Capacity of cooling system (Btu/hr)	0	Fixed	DOE-2 is autosizing the system
sy03	Heating Capacity of heating system (Btu/hr)	0	Fixed	DOE-2 is autosizing the system
sy04	Seasonal Energy Efficiency Ratio (SEER) for PVAVS and PSZ	10	User Defined	
sy05	ANNUAL FUEL UTILIZATION EFFICIENCY (AFUE) for PSZ	0.8	User Defined	
sy06	**Spare parameter for systems other than VAVS**HEATING SEASONAL PERFORMANCE FACTOR (HSPF)	6.8	User Defined	Unused, since heatpump systems are not included in the office/retail scenario
sy07	**Spare parameter for Pilot light	0	Fixed	Unused
sy08	**Spare parameter for Pilot light	0	Fixed	Unused
sy09	**Spare parameter for Pilot light	0	Fixed	Unused
sy10	Void			
sy11	Exterior lighting (kW)	0	Fixed	
sy12	Void			
sy13	Fan control type	Variable frequency drives (1)	User Defined	User can choose from 4 different type of fan control
sy14	Economizer type	None (1)	User Defined	
sy15	Economizer drybulb limit (F) (use when economizer type(sy14) = dry bulb(2))	65	Fixed	This corresponds to the temperature above which the outside air dampers return to the minimum position
sy16	User input for numbers of fans	Autosized (A)	Fixed	Autosized by DOE-2
sy17	Number of Fans	6	Fixed	equal to the number of floors
sy18	Supply fan total pressure (in W.G)	5.5	Fixed	
sy19	Supply fan efficiency	0.54	Fixed	
sy20	Return fan total pressure (in W.G)	2	Fixed	
sy21	Return fan efficiency	0.51	Fixed	
sy22	Supply motor efficiency	0.5	Fixed	
sy23	Return motor efficiency	0.5	Fixed	
sy24	User input for DHW gallon/hr-person	Autosized (A)	Fixed	The size of DHW depends on the gallons per hour per person requirements of ASHRAE 90.1
sy25	Maximum DHW gallon/h-person (maximum hourly, to be used with occupancy schedule)	0.4	Fixed	
PLANT				
p01	Chiller type	Electric Centrifugal (1)	Fixed	
p02	Number of chillers	1	Fixed	
p03	Chillers size (MBtu/h)	-999	Fixed	Chiller is being autosized by DOE-2
p04	Condenser type	water-cooled (W)	Fixed	
p05	COP	5	User Defined	
p06	Switch for a chiller sizing	Autosized (A)	Fixed	Chiller is being autosized by DOE-2
p07	Cooling tower type	Open tower (O)		
p08	Void			
p09	Gpm/hp	38.2	Fixed	Value from ASHRAE 90.1 1999 for axial fan cooling towers
p10	Cooling tower capacity control	Two-speed fan (1)	Fixed	
p11	Boiler type	Gas fired-hotwater boiler (1)	User Defined	User can choose from gas fired or electric boilers
p12	Number of boilers	1	Fixed	
p13	Boiler size (MBtu/h)	-999	Fixed	Boiler is being autosized by DOE-2
p14	Boiler fuel type	Gas (G)	Fixed	Depends on the value of p10
p15	Boilers efficiency (Et,Ec,AFUE) (%)	80	User Defined	
p16	Switch for a boiler sizing	Autosized (A)	Fixed	Boiler is being autosized by DOE-2
p17	Void			
p18	DHW heater type	Gas water heater (1)	User Defined	User can choose from gas fired or electric water heaters
p19	Number of DHW heater	1	Fixed	
p20	DHW size (MBtu/h)	-999	Fixed	Water heater is being autosized by DOE-2
p21	DHW fuel type	Gas (G)	Fixed	Depends on the value of p18
p22	DHW heater Efficiency (Et,Ec,Energy factor) (%)	54	User Defined	
p23	Switch for a DHW heater sizing	Autosized (A)	Fixed	Water heater is being autosized by DOE-2
p24	DHW Storage Capacity (gal)	75	Fixed	

pilot light is assumed at a fixed load of 500 Btu/hr.

For both ASHRAE Standard 90.1-1989 and ASHRAE Standard 90.1-1999, a complete set of system simulations requires seven DOE-2 runs. The 1989 requires three runs to correctly size the system and then select the right equipment and efficiency. The 1999 simulation requires four simulation runs to perform the same task. A detailed discussion of the complete procedure is present in Ahmad et al. (2005).

RESULTS:

Table 7 shows the square footage of the seven types of building construction for the 41 affected and non-attainment counties in Texas. In this table, the square footage from F.W. Dodge was merged with the building type description to obtain the total square footage of commercial new construction in the 41 counties. A total of 99.5 million square feet of commercial construction was started in 2003. In this analysis, it was assumed that the same rate of commercial new construction was true for 2005. Of the total, 21.7 million square feet of new construction were related to education, which is almost 22% of the total new building stock. The total number of warehouses being built were 20% of the total new construction. Harris County has the highest percentage of new commercial construction (22% of the total new construction).

Table 8 shows the difference in energy use per square foot between the ASHRAE Standard 90.1-1989 and 1999 (PNNL 2002). The maximum annual savings (~16%), which can be achieved by the implementation of ASHRAE Standard 90.1-1999 is from the retail building type. The largest penalty (~72%) from switching to ASHRAE Standard 90.1-1999 from ASHRAE Standard 90.1-1989 was in the warehouse category.

Tables 9 and 10 show the annual savings from the different building types for the 41 counties. Across all 41 counties, the gas consumption for all the building types except for Food and Lodging increasing due to the implementation of ASHRAE Standard 90.1-1999. The largest impacted was the Education building type with an increase of 25,800 MBtu/year. The maximum savings achieved due to the implementation of ASHRAE Standard 90.1-1999 is 47.8 million kWh for the Retail building type. Harris County has the largest amount of savings from all the construction types (12.45 million kWh or16.6% of the total electric savings). The gas penalty for Harris County is 16,621 MBtu/year, which is 23% of the total gas consumption increase due to the implementation of ASHRAE Standard 90.1-1999.

Table 11 and 12 show the Ozone Season Day (OSD) energy savings for the different building types for the 41 affected and non-attainment counties for Texas. As for annual energy savings, the OSD gas consumption went up across all counties and building types except for Food and Lodging. The largest increase in gas consumption was 191 therms/OSD (19.1 MBtu/ OSD) in the Education building type, which is 18% of the total gas consumption increase. Harris County has the largest increase, 244 therms/OSD (24.4 MBtu/OSD), 23% of the total gas increase. The maximum kWh savings, 195,935 kWh/OSD, were obtained for the Retail building type, which is 43% of the total OSD kWh savings. Harris County has the largest kWh savings with 86,000 kWh/OSD.

Figure 6 and Figure 7 show the annual and OSD MWh savings for total new construction in the 41 non-attainment and affected counties. Counties with a high percentage of new warehouse construction show an increase in both electric and natural gas consumption. This is because warehouse construction in ASHRAE Standard 90.1-1989 was more stringent than ASHRAE Standard 90.1-1999. Of the 41 counties, Ellis, Kaufmann and Waller counties show increased energy consumption due to the implementation of ASHRAE Standard 90.1-1999. This is because warehouse construction comprised 60% to 85% of the total new commercial construction in these counties.

SUMMARY:

This paper provides a detailed description of the techniques, published studies and simulation models used to quantify the annual and Ozone Season Day savings achieved by the implementation of the 2000/2001 IECC (ASHRAE Standard 90.1-1999) on the new commercial construction for the 41 affected and non-attainment counties of Texas. To accomplish this code-compliant DOE-2 simulations and nationally published analysis were used to calculate the savings per square foot of commercial construction, which were then multiplied by published commercial building

Table 7: Square footage of New Construction for the 7 Building Types (For 41 affected and non-attainment counties)

	Assembly	Education	Retail	Food	Lodging	Office	Warehouse
BASTROP, TX	0	272	13	4	0	45	0
BEXAR, TX	394	3230	2145	572	1533	840	1092
BRAZORIA, TX	149	462	206	55	2	144	138
CALDWELL, TX	0	46	1	0	0	0	0
CHAMBERS, TX	4	0	2	1	0	15	0
COLLIN, TX	509	1003	1160	309	1752	741	619
COMAL, TX	5	31	28	8	43	16	57
DALLAS, TX	1398	2363	2191	584	605	2343	3936
DENTON, TX	318	1729	547	146	809	878	2190
EL PASO, TX	353	816	377	101	286	437	754
ELLIS, TX	39	60	12	3	40	50	476
FORT BEND, TX	299	96	621	166	181	434	362
GALVESTON, TX	136	337	240	64	269	138	25
GREGG	14	0	195	52	131	40	44
GUADALUPE, TX	42	469	89	24	0	87	30
HARDIN, TX	21	0	135	36	0	0	0
HARRIS, TX	1452	4316	3353	895	2265	4284	5571
HARRISON, TX	24	0	121	32	0	0	19
HAYS, TX	94	140	41	11	11	16	40
HENDERSON, TX	0	0	126	34	0	5	0
HOOD, TX	48	0	16	4	0	10	0
HUNT, TX	59	148	0	0	0	30	50
JEFFERSON, TX	49	121	463	123	636	83	43
JOHNSON, TX	1	93	107	29	0	1	0
KAUFMAN, TX	42	351	0	0	0	11	590
LIBERTY, TX	1	161	6	2	30	15	0
MONTGOMERY, TX	248	1443	1177	314	192	377	233
NUECES, TX	314	59	350	93	773	74	600
ORANGE, TX	17	257	1	0	0	13	2
PARKER, TX	17	97	5	1	106	0	0
ROCKWALL, TX	0	425	3	1	0	38	200
RUSK, TX	0	0	0	0	0	0	0
SAN PATRICIO, TX	10	4	0	0	0	8	0
SMITH, TX	99	113	247	66	115	32	3
TARRANT, TX	954	1964	1780	475	980	3224	1828
TRAVIS, TX	229	244	1593	425	669	812	305
UPSHUR, TX	30	0	0	0	0	0	0
VICTORIA, TX	4	17	132	35	2	20	0
WALLER, TX	107	52	0	0	0	0	914
WILLIAMSON, TX	191	758	646	172	119	183	30
WILSON, TX	0	26	0	0	0	1	0

statistics for each county, and aggregated to state-wide totals.

A commercial, code-compliant simulation model based on DOE-2 was used to create a web-based simulation tool that can be utilized to check how much energy can be savings if the building construction is at or above the ASHRAE Standard 90.1-1999 requirements (ecalc.tamu.edu). Upgraded simulation models are being created to take into account the effect of thermal mass, improved equipment selection and sizing. For the above mentioned results, published savings numbers based on nation wide analyses were used to predict the energy savings for new commercial construction in Texas.

Table 8: Difference in energy use between ASHRAE Standard 90.1-1989 and ASHRAE Standard 90.1-1999 (PNNL. 2002).

	Electric (kWh/sf-yr)			Gas (mBtu/sf-yr)		
	1989	1999	Diff. (%)	1989	1999	Diff. (%)
Assembly	17.87	16.18	-9.49	0.0322	0.0339	5.28278434
Education	10.35	9.17	-11.39	0.0189	0.0201	6.30965005
Food	29.50	29.84	1.16	0.0355	0.0349	-1.71734234
Lodging	12.43	11.92	-4.11	0.0176	0.0159	-9.48324815
Office	14.47	12.94	-10.61	0.0056	0.0063	12.6559715
Retail	16.59	13.98	-15.75	0.0040	0.0052	30.8860759
Warehouse	3.03	5.20	71.72	0.0082	0.0091	11.2332112

Table 9: Calculated ASHRAE Standard 90.1 -1989 and 1999 Annual Electricity and Natural Gas Savings for Assembly, Education, Retail, and Food Types (USDOE 2004). A decrease in energy use is negative (i.e., savings), a positive value represents an energy use increase (+).

Counties	Assembly		Education		Retail		Food		Lodging	
	kWh/yr	mBtu/yr	kWh/yr	mBtu/yr	kWh/yr	mBtu/yr	kWh/yr	mBtu/yr	kWh/yr	mBtu/yr
BASTROP, TX	0	0	-320073	323	-34865	16	1219	-2	0	0
BEXAR, TX	-667623	669	-3807631	3843	-5606113	2617	196060	-349	-783342	-2560
BRAZORIA, TX	-252669	253	-544537	550	-537216	251	18788	-33	-1022	-3
CALDWELL, TX	0	0	-54230	55	-3920	2	137	0	0	0
CHAMBERS, TX	-6783	7	0	0	-6189	3	216	0	0	0
COLLIN, TX	-862976	865	-1182915	1194	-3032054	1415	106039	-189	-895211	-2925
COMAL, TX	-8140	8	-36310	37	-73857	34	2583	-5	-21720	-71
DALLAS, TX	-2371021	2377	-2785520	2812	-5724531	2672	200202	-356	-309034	-1010
DENTON, TX	-539254	541	-2038683	2058	-1428657	667	49964	-89	-413544	-1351
EL PASO, TX	-598097	600	-961988	971	-984690	460	34437	-61	-146366	-478
ELLIS, TX	-66135	66	-70734	71	-32183	15	1126	-2	-20442	-67
FORT BEND, TX	-506186	507	-113175	114	-1622583	757	56746	-101	-92654	-303
GALVESTON, TX	-230794	231	-396702	400	-627990	293	21962	-39	-137269	-449
GREGG	-24080	24	0	0	-510603	238	17857	-32	-66999	-219
GUADALUPE, TX	-70883	71	-553143	558	-232918	109	8146	-15	0	0
HARDIN, TX	-35442	36	0	0	-352987	165	12345	-22	0	0
HARRIS, TX	-2461405	2468	-5088513	5136	-8763806	4091	306493	-546	-1157688	-3783
HARRISON, TX	-39851	40	0	0	-316471	148	11068	-20	0	0
HAYS, TX	-159402	160	-165047	167	-106453	50	3723	-7	-5724	-19
HENDERSON, TX	0	0	0	0	-329674	154	11530	-21	0	0
HOOD, TX	-81906	82	0	0	-42292	20	1479	-3	0	0
HUNT, TX	-99202	99	-174478	176	0	0	0	0	0	0
JEFFERSON, TX	-83771	84	-142766	144	-1208737	564	42273	-75	-325132	-1062
JOHNSON, TX	-1526	2	-109638	111	-280780	131	9820	-17	0	0
KAUFMAN, TX	-71053	71	-413325	417	0	0	0	0	0	0
LIBERTY, TX	-1526	2	-189922	192	-16504	8	577	-1	-15485	-51
MONTGOMERY, TX	-420211	421	-1700926	1717	-3075172	1436	107547	-191	-98224	-321
NUECES, TX	-532301	534	-69791	70	-913928	427	31962	-57	-395197	-1291
ORANGE, TX	-29167	29	-303450	306	-2888	1	101	0	0	0
PARKER, TX	-28828	29	-114000	115	-13410	6	469	-1	-54274	-177
ROCKWALL, TX	0	0	-501271	506	-8665	4	303	-1	0	0
RUSK, TX	0	0	0	0	0	0	0	0	0	0
SAN PATRICIO, TX	-16279	16	-4598	5	0	0	0	0	0	0
SMITH, TX	-168559	169	-133452	135	-644701	301	22547	-40	-58873	-192
TARRANT, TX	-1617253	1621	-2315843	2338	-4651749	2172	162684	-290	-500730	-1636
TRAVIS, TX	-389009	390	-287889	291	-4161983	1943	145555	-259	-341639	-1116
UPSHUR, TX	-50873	51	0	0	0	0	0	0	0	0
VICTORIA, TX	-7292	7	-20395	21	-344734	161	12056	-21	-1227	-4
WALLER, TX	-180938	181	-60714	61	0	0	0	0	0	0
WILLIAMSON, TX	-323552	324	-894083	902	-1686950	788	58997	-105	-60815	-199
WILSON, TX	0	0	-30652	31	0	0	0	0	0	0
TOTAL	-13003986	13036	-25586392	25827	-47380254	22119	1657010	-2950	-5902611	-19288

Table 10: Calculated ASHRAE Standard 90.1 -1989 and 1999 Annual Electricity and Natural Gas Savings for Lodging, Office, and Warehouse Building Types (USDOE 2004). A decrease in energy use is negative (i.e., savings), a positive value represents an energy use increase (+).

Counties	Office		Warehouse		Total		Total*1.07 (T&D loss) for eGrid	
	kWh/yr	mBtu/yr	kWh/yr	mBtu/yr	kWh/yr	mBtu/yr	MWh/yr	Therm/yr
BASTROP, TX	-69123	32	0	0	-422842	369	452	-3950
BEXAR, TX	-1289985	596	2372448	1005	-9586186	5822	10257	-62298
BRAZORIA, TX	-220425	102	300601	127	-1236480	1246	1323	-13334
CALDWELL, TX	0	0	0	0	-58012	56	62	-603
CHAMBERS, TX	-23041	11	0	0	-35797	20	38	-214
COLLIN, TX	-1138376	526	1344887	570	-5660606	1456	6057	-15583
COMAL, TX	-24270	11	124237	53	-37477	68	40	-723
DALLAS, TX	-3598687	1663	8549328	3621	-6039263	11780	6462	-126041
DENTON, TX	-1347895	623	4757494	2015	-960574	4463	1028	-47757
EL PASO, TX	-671259	310	1638321	694	-1689642	2495	1808	-26696
ELLIS, TX	-76189	35	1034295	438	769737	557	-824	-5962
FORT BEND, TX	-666344	308	785386	333	-2158810	1616	2310	-17292
GALVESTON, TX	-211516	98	53431	23	-1528878	558	1636	-5968
GREGG	-60982	28	95567	40	-549240	80	588	-861
GUADALUPE, TX	-133023	61	65159	28	-916661	813	981	-8696
HARDIN, TX	0	0	0	0	-376083	178	402	-1908
HARRIS, TX	-6579878	3041	12100290	5125	-11644507	15533	12460	-166206
HARRISON, TX	0	0	41268	17	-303986	185	325	-1984
HAYS, TX	-24270	11	86879	37	-370294	399	396	-4267
HENDERSON, TX	-7680	4	0	0	-325825	137	349	-1465
HOOD, TX	-15821	7	0	0	-138540	107	148	-1140
HUNT, TX	-45621	21	108599	46	-210703	343	225	-3666
JEFFERSON, TX	-127954	59	93395	40	-1752692	-247	1875	2639
JOHNSON, TX	-1843	1	0	0	-383968	227	411	-2425
KAUFMAN, TX	-17358	8	1281465	543	779731	1039	-834	-11120
LIBERTY, TX	-22580	10	0	0	-245440	160	263	-1709
MONTGOMERY, TX	-578788	268	504984	214	-5260790	3543	5629	-37908
NUECES, TX	-113669	53	1303185	552	-689739	287	738	-3070
ORANGE, TX	-19201	9	4996	2	-349610	348	374	-3720
PARKER, TX	0	0	0	0	-210043	-28	225	299
ROCKWALL, TX	-57756	27	434395	184	-132994	720	142	-7706
RUSK, TX	0	0	0	0	0	0	0	0
SAN PATRICIO, TX	-12903	6	0	0	-33780	27	36	-288
SMITH, TX	-49000	23	6950	3	-1025089	398	1097	-4256
TARRANT, TX	-4951498	2289	3971239	1682	-9903150	8175	10596	-87477
TRAVIS, TX	-1247129	576	662887	281	-5619206	2105	6013	-22526
UPSHUR, TX	0	0	0	0	-50873	51	54	-546
VICTORIA, TX	-31028	14	0	0	-392620	178	420	-1901
WALLER, TX	0	0	1985620	841	1743968	1084	-1866	-11596
WILLIAMSON, TX	-280331	130	64725	27	-3122010	1868	3341	-19983
WILSON, TX	-768	0	0	0	-31420	31	34	-335
TOTAL	-23716192	10962	43772031	18541	-70160394	68247	75072	-730244

Weather data for the hot and humid environment of Houston was used to determine the percentage of energy consumption during the Ozone period.

To take this analysis a step further, future work includes the creation of separate simulation models for the seven types of commercial buildings and the analysis of the impact of the implementation of ASHRAE Standard 90.1-1999 for all the different climate zones in Texas.

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Table 11: Calculated ASHRAE Standard 90.1 -1989 and 1999 OSD Electricity and Natural Gas Savings for Assembly, Education, Retail, and Food Types (USDOE 2004). A decrease in energy use is negative (i.e., savings), a positive value represents an energy use increase (+).

Counties	Assembly		Education		Retail		Food		Lodging	
	kWh/day	mBtu/day	kWh/day	mBtu/day	kWh/day	mBtu/day	kWh/day	mBtu/day	kWh/day	mBtu/day
BASTROP, TX	0	0	-1459	0	-144	0	-15	0	0	0
BEXAR, TX	-3248	1	-17358	6	-23183	4	-2344	-1	-5689	-4
BRAZORIA, TX	-1229	0	-2482	1	-2222	0	-225	0	-7	0
CALDWELL, TX	0	0	-247	0	-16	0	-2	0	0	0
CHAMBERS, TX	-33	0	0	0	-26	0	-3	0	0	0
COLLIN, TX	-4198	1	-5392	2	-12539	2	-1268	0	-6502	-4
COMAL, TX	-40	0	-166	0	-305	0	-31	0	-158	0
DALLAS, TX	-11534	3	-12698	4	-23673	4	-2393	-1	-2244	-1
DENTON, TX	-2623	1	-9294	3	-5908	1	-597	0	-3004	-2
EL PASO, TX	-2910	1	-4385	1	-4072	1	-412	0	-1063	-1
ELLIS, TX	-322	0	-322	0	-133	0	-13	0	-148	0
FORT BEND, TX	-2462	1	-516	0	-6710	1	-678	0	-673	0
GALVESTON, TX	-1123	0	-1808	1	-2597	0	-263	0	-997	-1
GREGG	-117	0	0	0	-2112	0	-213	0	-487	0
GUADALUPE, TX	-345	0	-2522	1	-963	0	-97	0	0	0
HARDIN, TX	-172	0	0	0	-1460	0	-148	0	0	0
HARRIS, TX	-11974	4	-23197	8	-36242	6	-3664	-1	-8408	-6
HARRISON, TX	-194	0	0	0	-1309	0	-132	0	0	0
HAYS, TX	-775	0	-752	0	-440	0	-45	0	-42	0
HENDERSON, TX	0	0	0	0	-1363	0	-138	0	0	0
HOOD, TX	-398	0	0	0	-175	0	-18	0	0	0
HUNT, TX	-483	0	-795	0	0	0	0	0	0	0
JEFFERSON, TX	-408	0	-651	0	-4999	1	-505	0	-2361	-2
JOHNSON, TX	-7	0	-500	0	-1161	0	-117	0	0	0
KAUFMAN, TX	-346	0	-1884	1	0	0	0	0	0	0
LIBERTY, TX	-7	0	-866	0	-68	0	-7	0	-112	0
MONTGOMERY, TX	-2044	1	-7754	3	-12717	2	-1286	0	-713	0
NUECES, TX	-2589	1	-318	0	-3779	1	-382	0	-2870	-2
ORANGE, TX	-142	0	-1383	0	-12	0	-1	0	0	0
PARKER, TX	-140	0	-520	0	-55	0	-6	0	-394	0
ROCKWALL, TX	0	0	-2285	1	-36	0	-4	0	0	0
RUSK, TX	0	0	0	0	0	0	0	0	0	0
SAN PATRICIO, TX	-79	0	-21	0	0	0	0	0	0	0
SMITH, TX	-820	0	-608	0	-2666	0	-270	0	-428	0
TARRANT, TX	-7867	2	-10557	3	-19237	3	-1945	0	-3637	-2
TRAVIS, TX	-1892	1	-1312	0	-17211	3	-1740	0	-2481	-2
UPSHUR, TX	-247	0	0	0	0	0	0	0	0	0
VICTORIA, TX	-35	0	-93	0	-1426	0	-144	0	-9	0
WALLER, TX	-880	0	-277	0	0	0	0	0	0	0
WILLIAMSON, TX	-1574	0	-4076	1	-6976	1	-705	0	-442	0
WILSON, TX	0	0	-140	0	0	0	0	0	0	0
TOTAL	-63261	19	-116639	38	-195935	32	-19810	-4	-42870	-28

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Table 12: Calculated ASHRAE Standard 90.1 -1989 and 1999 OSD Electricity and Natural Gas Savings for Lodging, Office, and Warehouse Building Types (USDOE 2004). A decrease in energy use is negative (i.e., savings), a positive value represents an energy use increase (+).

Counties	Office		Warehouse		Total		Total*1.07 (T&D loss) for eGrid	
	kWh/day	mBtu/day	kWh/day	mBtu/day	kWh/day	mBtu/day	MWh/day	Therm/day
BASTROP, TX	-323	0	0	0	-1941	1	2	-6
BEXAR, TX	-6025	1	6614	1	-51233	9	55	-91
BRAZORIA, TX	-1029	0	838	0	-6357	2	7	-20
CALDWELL, TX	0	0	0	0	-265	0	0	-1
CHAMBERS, TX	-108	0	0	0	-169	0	0	0
COLLIN, TX	-5317	1	3749	1	-31466	2	34	-23
COMAL, TX	-113	0	346	0	-466	0	0	-1
DALLAS, TX	-16808	2	23833	5	-45518	17	49	-185
DENTON, TX	-6295	1	13262	3	-14459	7	15	-70
EL PASO, TX	-3135	0	4567	1	-11410	4	12	-39
ELLIS, TX	-356	0	2883	1	1588	1	-2	-9
FORT BEND, TX	-3112	0	2189	0	-11962	2	13	-25
GALVESTON, TX	-988	0	149	0	-7627	1	8	-9
GREGG	-285	0	266	0	-2947	0	3	-1
GUADALUPE, TX	-621	0	182	0	-4367	1	5	-13
HARDIN, TX	0	0	0	0	-1780	0	2	-3
HARRIS, TX	-30731	4	33732	8	-80484	23	86	-244
HARRISON, TX	0	0	115	0	-1520	0	2	-3
HAYS, TX	-113	0	242	0	-1925	1	2	-6
HENDERSON, TX	-36	0	0	0	-1537	0	2	-2
HOOD, TX	-74	0	0	0	-665	0	1	-2
HUNT, TX	-213	0	303	0	-1188	1	1	-5
JEFFERSON, TX	-598	0	260	0	-9261	0	10	4
JOHNSON, TX	-9	0	0	0	-1794	0	2	-4
KAUFMAN, TX	-81	0	3572	1	1261	2	-1	-16
LIBERTY, TX	-105	0	0	0	-1166	0	1	-3
MONTGOMERY, TX	-2703	0	1408	0	-25810	5	28	-56
NUECES, TX	-531	0	3633	1	-6837	0	7	-5
ORANGE, TX	-90	0	14	0	-1614	1	2	-5
PARKER, TX	0	0	0	0	-1115	0	1	0
ROCKWALL, TX	-270	0	1211	0	-1383	1	1	-11
RUSK, TX	0	0	0	0	0	0	0	0
SAN PATRICIO, TX	-60	0	0	0	-160	0	0	0
SMITH, TX	-229	0	19	0	-5001	1	5	-6
TARRANT, TX	-23126	3	11071	2	-55298	12	59	-128
TRAVIS, TX	-5825	1	1848	0	-28614	3	31	-33
UPSHUR, TX	0	0	0	0	-247	0	0	-1
VICTORIA, TX	-145	0	0	0	-1852	0	2	-3
WALLER, TX	0	0	5535	1	4378	2	-5	-17
WILLIAMSON, TX	-1309	0	180	0	-14902	3	16	-29
WILSON, TX	-4	0	0	0	-143	0	0	0
TOTAL	-110766	16	122022	27	-427258	100	457	-1071

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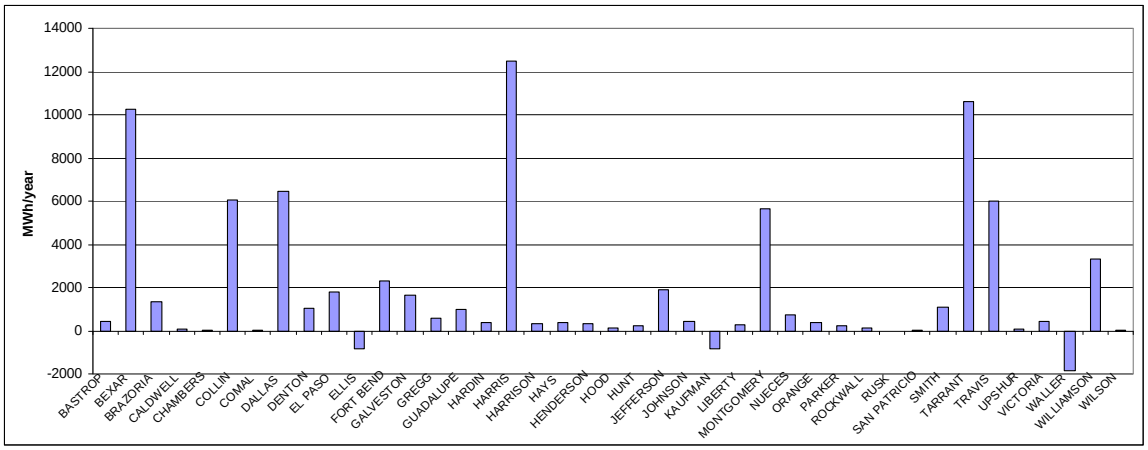

Figure 6: Annual MWh savings from new commercial construction for the 41 non-attainment and affected Counties.

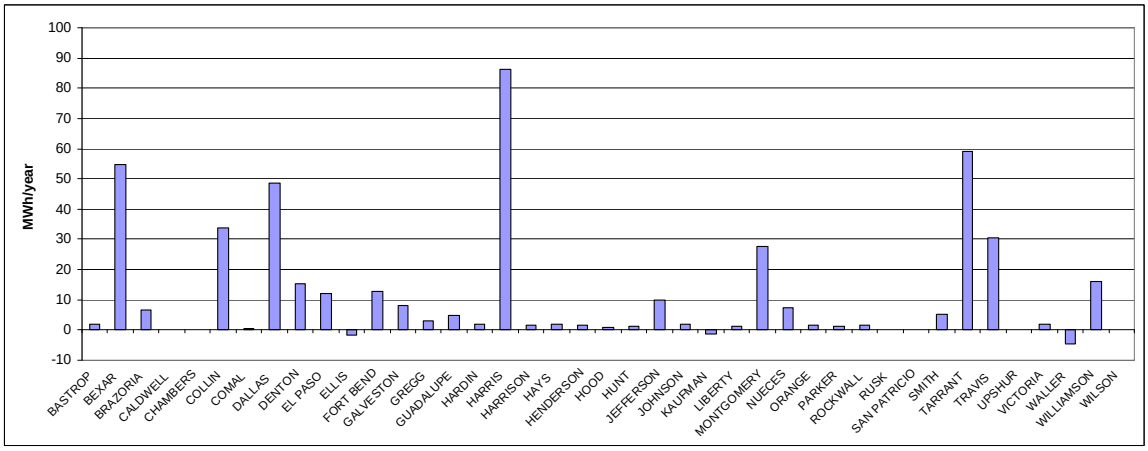

Figure 7: OSD MWh savings from new commercial construction for the 41 non-attainment and affected Counties.

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