

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 NO_x 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.

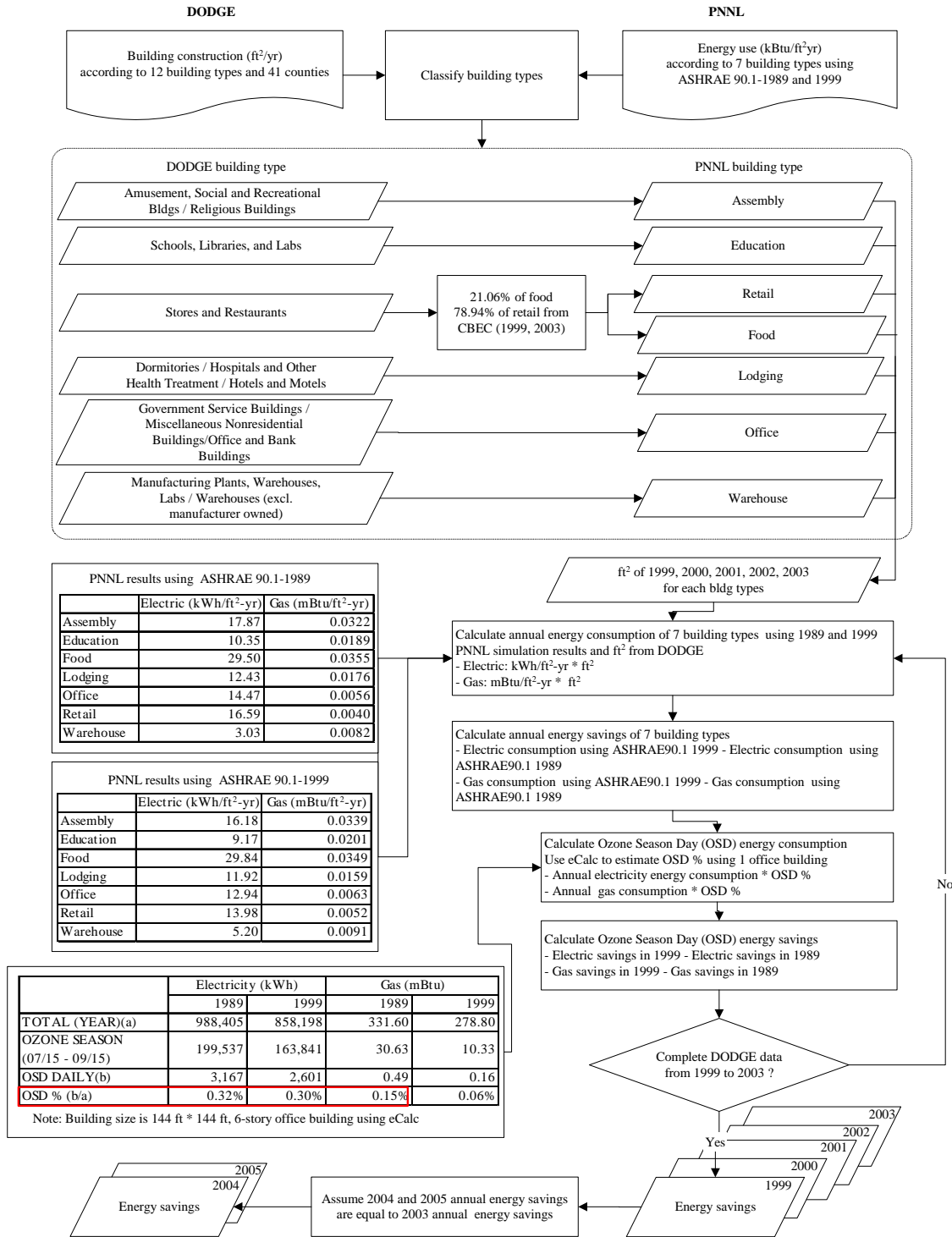


Figure1: Process flow for calculating energy savings from the implementation of ASHRAE Standard 90.1-1999.

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/ft² and MBtu/ft² 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 ft² 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

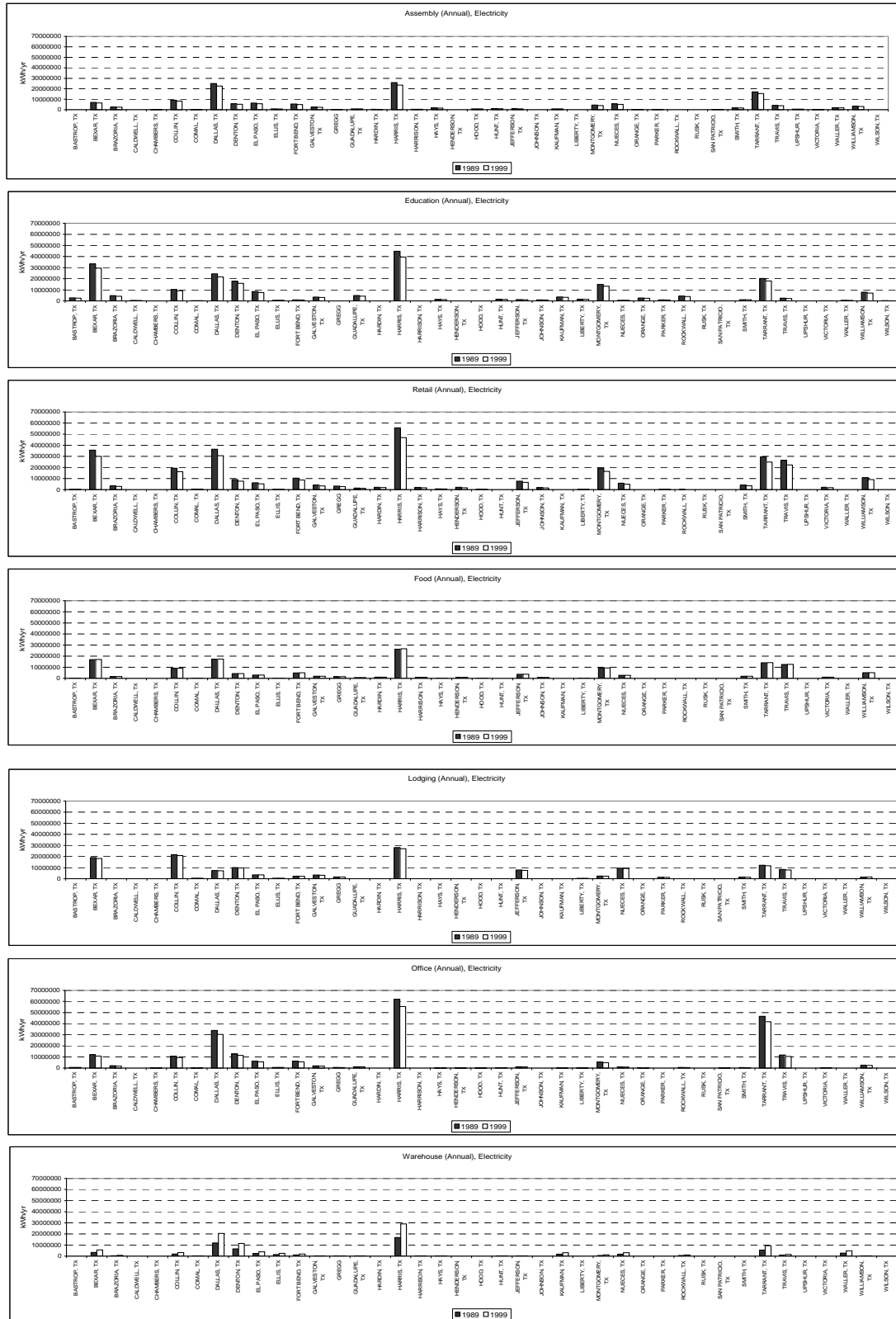


Figure 2: Calculated ASHRAE Standard 90.1 -1989 and 1999 Annual Electricity Use for Assembly, Education, Retail, Food, Lodging, Office, and Warehouse Building Types (USDOE 2004).

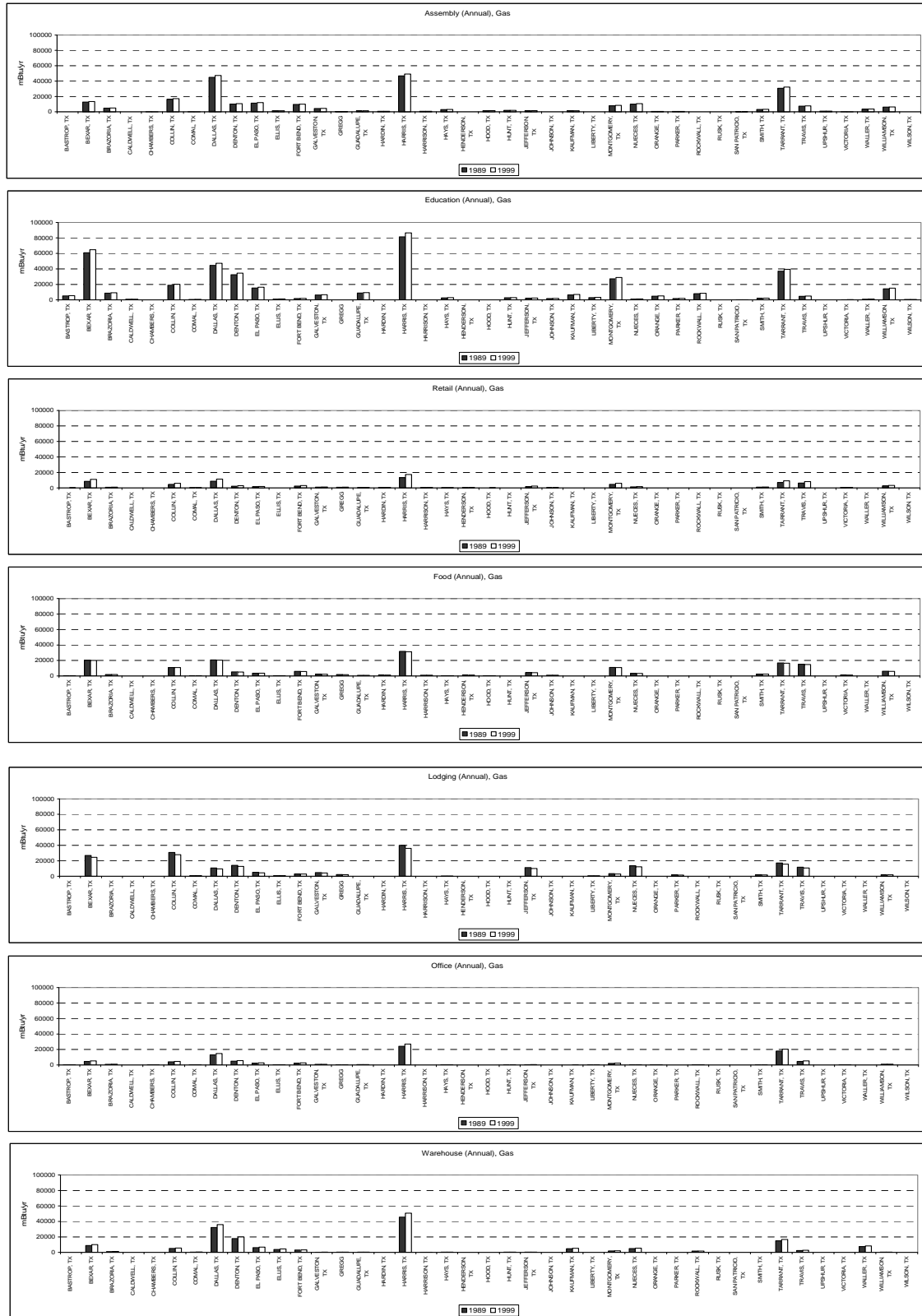


Figure 3: Calculated ASHRAE Standard 90.1 -1989 and 1999 Annual Natural Gas Use for Assembly, Education, Retail, Food, Lodging, Office, and Warehouse Building Types (USDOE 2004).

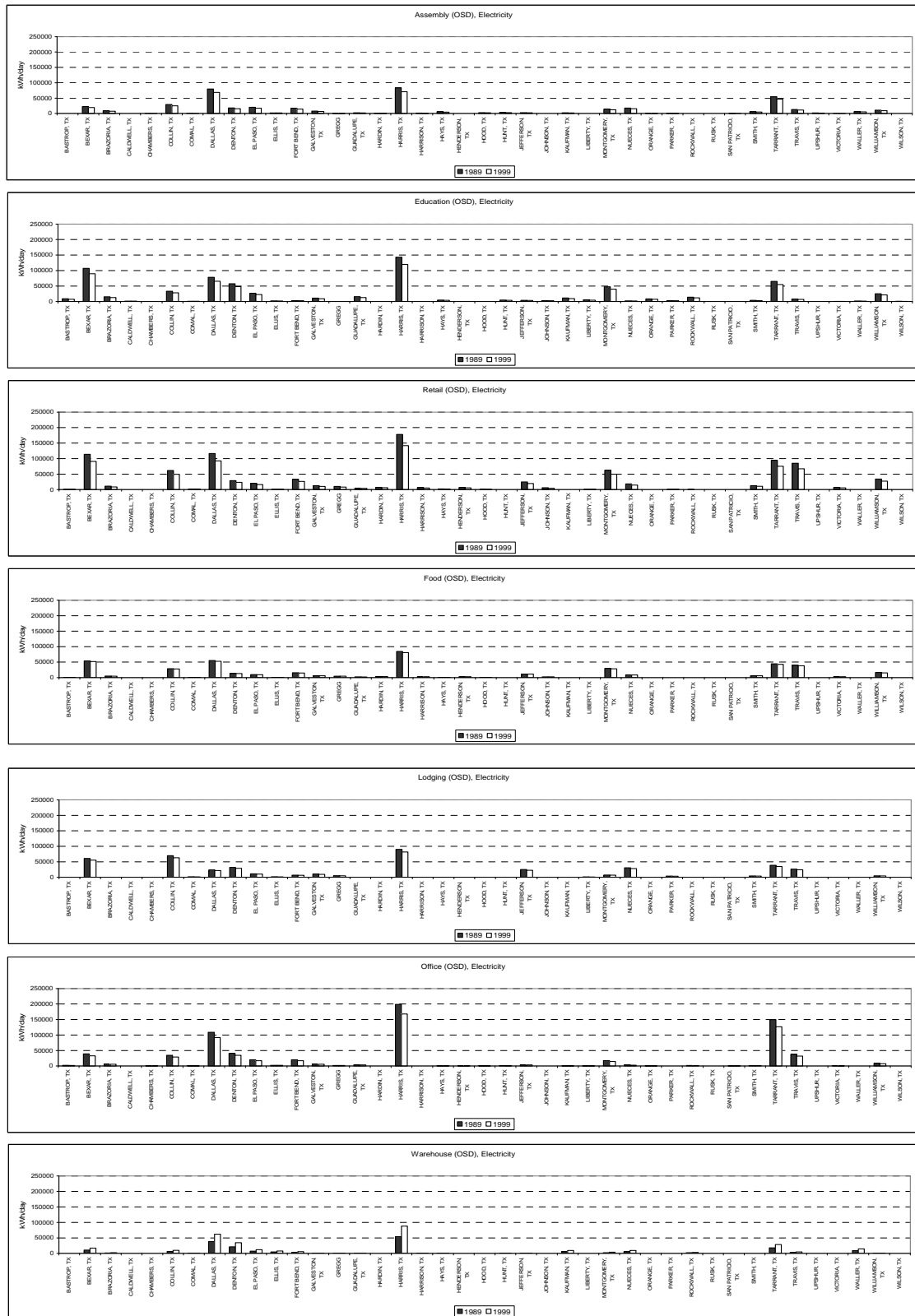


Figure 4: Calculated ASHRAE Standard 90.1 - 1989 and 1999 OSD Electricity Use for Assembly, Education, Retail, Food, Lodging, Office, and Warehouse Building Types (USDOE 2004).

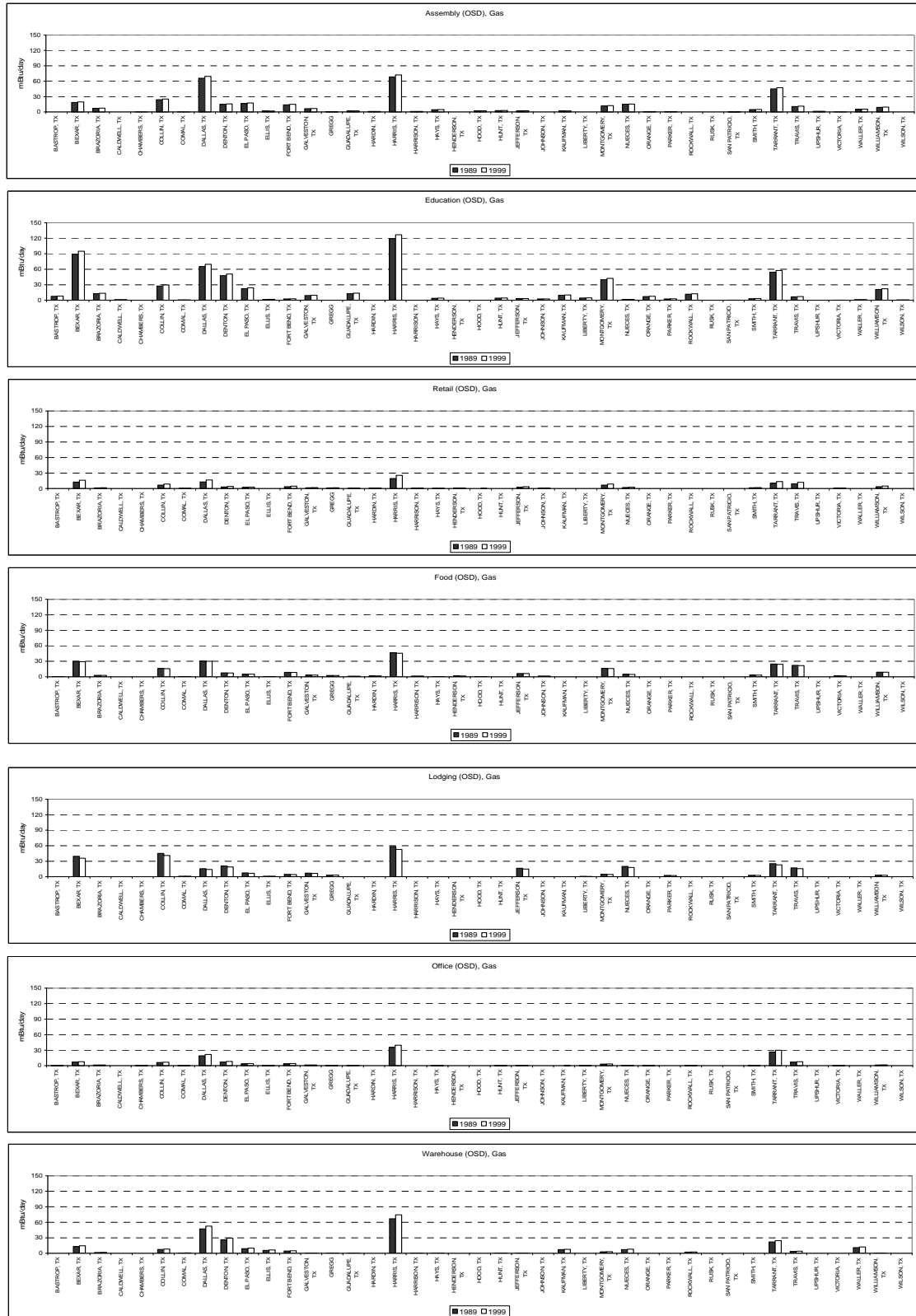


Figure 5: Calculated ASHRAE Standard 90.1 - 1989 and 1999 OSD Natural Gas Use for Assembly, Education, Retail, Food, Lodging, Office, and Warehouse Building Types (USDOE 2004).

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 | | Elec. Utilities 2 | PCA | 1998 | | |
|-------------|--------------|-----------------------|--|------------------------------------|------------|---------------------|-------------------------------|-----------------------------|------------|-----|
| | | | | Annual net Generation (MWh) | Percentage | | | 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% | Soulin | | | | |
| | 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% | SWEP/CO(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 | | Guadalupe Valley EC | | | | |
| | SPP | GREGG | SWEP/CO(AEP) | Southwestern Public Service Co/PCA | | Rusk County EC | | | | |
| | | HARRISON | SWEP/CO(AEP) | Southwestern Public Service Co/PCA | | Panola-Harrison EC | | | | |
| | | RUSK | SWEP/CO(AEP) | Southwestern Public Service Co/PCA | | ONCOR | | | | |
| | | UPSHUR | SWEP/CO(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 | 30% | Jasper-Newton EC | | | |
| | WSPC | El Paso | El Paso Electric Co/PCA | 3,086,892 | 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 | |
| | WSSC | 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 | |
| | WSPC | EL PASO | 12.21 | El Paso Electric Co/PCA | 100% | 12.21 | | | 0.00 |
| | | HARDIN | 1.90 | Entergy Electric System/PCA | 30% | 0.58 | Reliant Energy HL&P/PCA | 70% | 1.33 |
| | SERC | 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/ft ²) for office | 1.3 | User Defined | |
| sp05 | Equipment load (W/ft ²) for office | 0.75 | User Defined | |
| sp06 | Area per person (ft ² /person) for retail | 300 | User Defined | |
| sp07 | Lighting load (W/ft ²) for retail | 1.9 | User Defined | |
| sp08 | Equipment load (W/ft ²) 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 (PNL 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 or 16.6% 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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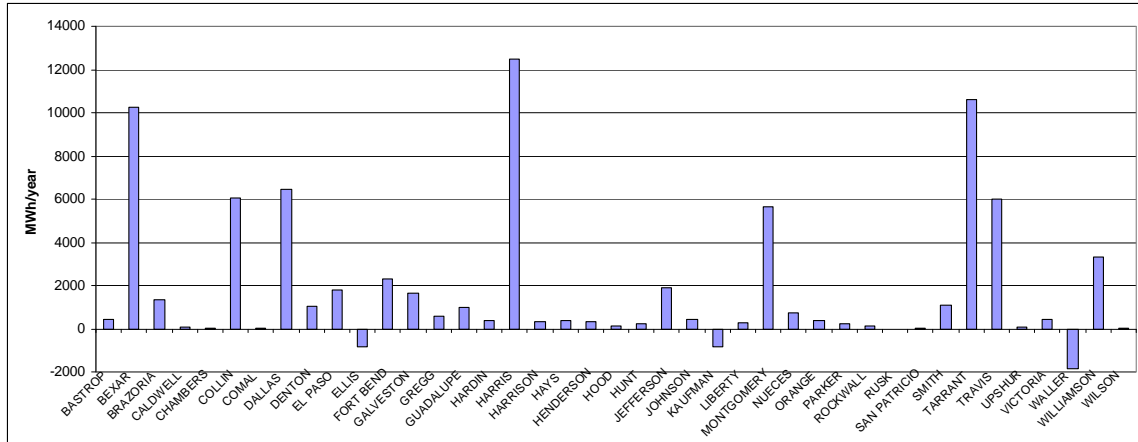


Figure 6: Annual MWh savings from new commercial construction for the 41 non-attainment and affected Counties.

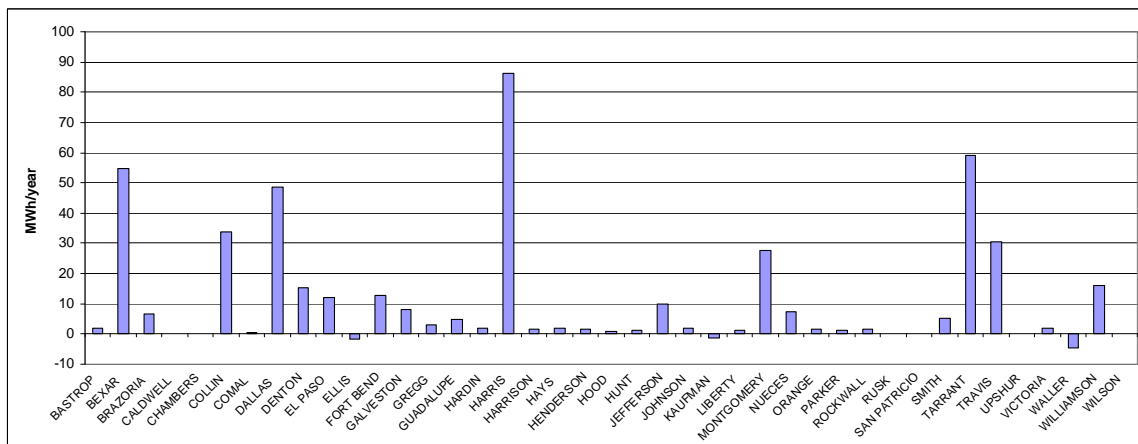


Figure 7: OSD MWh savings from new commercial construction for the 41 non-attainment and affected Counties.

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