NO_x EMISSIONS REDUCTIONS FROM IMPLEMENTATION OF THE 2000 IECC/IRC CONSERVATION CODE TO RESIDENTIAL CONSTRUCTION IN TEXAS

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ABSTRACT

Four areas in Texas have been designated by the United States Environmental Protection Agency (EPA) as non-attainment areas because ozone levels exceed the National Ambient Air Quality Standard (NAAQS) maximum allowable limits. These areas face severe sanctions if attainment is not reached by 2007. Four additional areas in the state are also approaching national ozone limits (i.e., classified as affected areas).

In 2001, the Texas State Legislature formulated and passed the Texas Emissions Reduction Plan (TERP), to reduce ozone levels by encouraging the reduction of emissions of NOx by sources that are currently not regulated by the state. An important part of this legislation is the State's energy efficiency program, which includes reductions in energy use and demand that are associated with the adoption of the 2000 IECC[1], which represents one of the first times that the EPA is considering emissions reductions credits from energy conservation – an important new development for building efficiency professionals.

This paper provides an overview of the procedures that have been developed and used to calculate the electricity savings and NOx reductions from residential construction in non-attainment and affected counties[2]. Results are presented that show the annual electricity and natural gas savings and NOx reductions from implementation of the 2000 IECC to single-family and multi-family residences in 2003, which use a code-traceable DOE-2 simulation. A second paper provides a detailed discussion of the methods used to calculate the emissions reductions using the eGRID database (Haberl et al. 2004).

BACKGROUND

The Federal Clean Air Act of 1970 authorized the United States Environmental Protection Agency (EPA) to establish the maximum allowable concentrations of pollutants that are known to endanger human health, harm the environment or cause property damage. In response to this act the EPA established NAAQS which describe the allowable maximum limits of the six primary pollutants: carbon monoxide (CO -- 9 ppm, 8 hr avg.), lead (Pb -- 1.5 ppm, maximum quarterly average), oxides of nitrogen (NO2 -- 53 ppb annual average), Ozone (O3 -- 120 ppb, 1 hr, avg.), particulate matter (PM10-- 50 micrograms/m3 annual average), and sulfur dioxide (SO2 -- 30 ppb annual average). In Texas the Texas Commission on Environmental Quality (TCEQ) has the responsibility of measuring and reporting these emissions to the EPA.

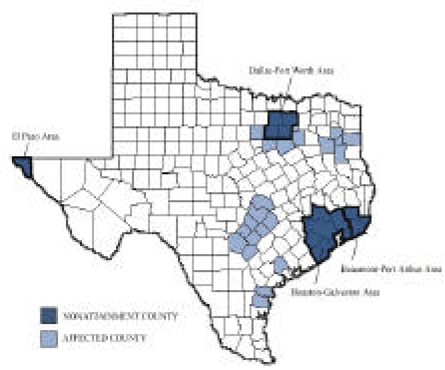

***Figure 1**: EPA Non-attainment (blue) and affected counties (light blue).*

Nationally, areas that exceed safe levels of Ozone are carefully monitored by the U.S.E.P.A. Ozone is formed when oxides of nitrogen (NOx), volatile organic compounds (VOCs), and oxygen (O_2) combine in the presence of strong sunlight. Hence, controlling NOx emissions is fast becoming a priority for many areas of the United

[1] This includes the 2001 Supplement to the 2000 IECC and 2000 IRC (IRC 2000, IECC 2001).

[2] The procedures outlined in this paper were developed and used in the Laboratory's 2002 and 2003 Annual Report to the TCEQ to satisfy the requirements of the Senate Bill 5 Legislation. In 2003 the Laboratory was awarded a grant from the EPA, which is administered through the TCEQ, to expand the development of these procedures into a web-based tool that would provide state and local authorities with accurate emissions reductions for use in preparing State Implementation Plans.

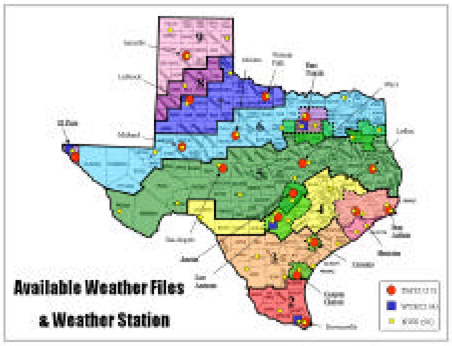

Figure 2: *Available NWS, TMY2 and WYEC2 weather files compared to the 2000 IECC weather zones for Texas.*

States. 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 TNRCC (now the TCEQ), including area sources (e.g., residential emissions,etc.), on-road mobile sources (e.g., all types of motor vehicles), and non-road mobile sources (e.g., aircraft, locomotives, etc.)[3]. 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 2000). In 2001, thirty-eight counties in Texas were designated by the EPA as either non-attainment or affected areas. These areas are shown on the map[4] in Figure 1. In 2003, three additional counties were classified as affected counties[5], bringing the total to forty-one counties (sixteen non-attainment and twenty-five affected counties). Analyses reported in this paper, however, were conducted over the past year and focused on the original 38 counties.

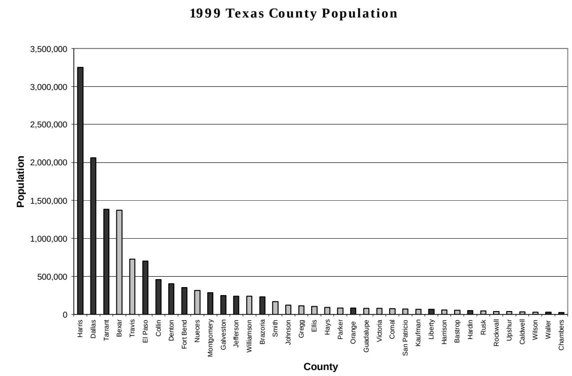

Figure 3: *1999 Texas county population for non-attainment (dark shade) and affected (light shade) counties (Source: U.S. Census Bureau).*

These counties represent different areas of the state that have been categorized into the different climate zones contained in Chapter 3 of the 2000 IECC as shown in Figure 2. Also shown in Figure 2 are the locations of the various weather data sources, including the seventeen Typical Meteorological Year (TMY2) (NREL 1995), and four Weather Year for Energy Calculations (WYEC2) (Stoffel 1995) weather stations, as well as the forty-nine National Weather Service weather stations, (NWS) (NOAA 1993). To no surprise, these thirty-eight counties represent some of the most populated counties in the state, and contained 13.9 million residents in 1999, which represents 69.5% of the state's 20.0 million total population (U.S. Census 1999). As shown in Figure 3, three of these counties (i.e., Harris, Dallas, and Tarrant), are non-attainment counties. The fourth county,

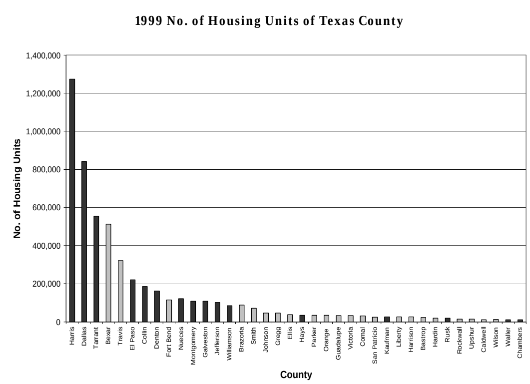

Figure 4: *1999 Housing units by county (Source: RECenter 2002).*

Bexar county, is classified as an affected county. These four counties contain 8.0 million residents, or 40.0% of the state's total population. In the rankings of the remaining counties it is clear to

[3] 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 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.

[4] The sixteen counties designated as non-attainment counties include: Brazoria, Chambers, Collin, Dallas, Denton, El Paso, Fort Bend, Hardin, Harris, Jefferson, Galveston, Liberty, Montgomery, Orange, Tarrant, and Waller counties. The twenty-two counties designated as affected counties include: Bastrop, Bexar, Caldwell, Comal, Ellis, Gregg, Guadalupe, Harrison, Hays, Johnson, Kaufman, Nueces, Parker, Rockwall, Rusk, San Patricio, Smith, Travis, Upshur, Victoria, Williamson, and Wilson County.

[5] These counties are Henderson, Hood and Hunt counties in the Dallas – Fort Worth area.

see that the most populated counties also represent the majority of the non-attainment regions.

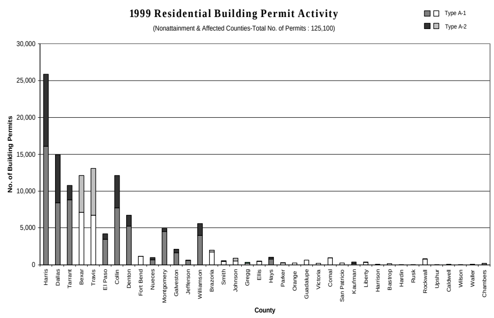

Figure 5: *1999 Residential building permits by county (Source: RECenter 2002). Type A-1 houses are single family residential. Type A-2 houses are multifamily residential.*

In Figure 4 the total housing units in the non-attainment and affected counties is shown to closely follow the county populations, with Harris, Dallas, Tarrant, and Bexar counties containing 3.2 million housing units, or 40.0% of the state's total 8.0 million households (U.S. Census 1999). However, in Figure 5 the 1999 residential building permit activity is shown that differs from the population and total housing unit trends, with the most activity occurring in Harris county (25,862 units), followed by significantly less construction in the five counties in the 10,000 to 15,000 unit range, including Dallas, Travis, Bexar, Collin and Tarrant counties. These six counties represented 88,833 housing starts, or 71% of the total 125,100 residential building permits in the 38 counties classified as non-attainment or affected by the EPA. Also of interest in Figure 5 is the significant number of new multi-family units in the counties with the largest number of building permits . In the six largest counties (i.e., Harris, Dallas, Travis, Bexar, Collin and Tarrant) there were 34,038 new multi-family units, or 38% of the 88,833 housing starts in these counties.

METHODOLOGY

The TCEQ is currently working with the EPA, through the Texas Emissions Reduction Plan (TERP) to determine how SIP emissions reduction credits can be obtained from the reductions in electricity use from energy efficiency and renewable energy (EE/RE) projects, with an emphasis on peak summertime electric demand[6], that are attributable to the adoption of the International Energy Conservation Code (IECC 2000) in non-attainment and affected counties. In order for the TCEQ to accomplish this, county-wide reductions in electricity use must be calculated by the Energy Systems Laboratory and presented to the TCEQ in a suitable format for calculating emissions reductions using the EPA's Emissions and Generation Resource Integrated Database (eGRID)[7]. The methodology to accomplish this for residential buildings is presented in Figure 6, additional detailed information can be found in Haberl et al. (2002a, 2002b, 2003a, 2003b, 2003c) and Im (2003). This methodology is composed of several procedures that calculate and verify savings using different sources of information.

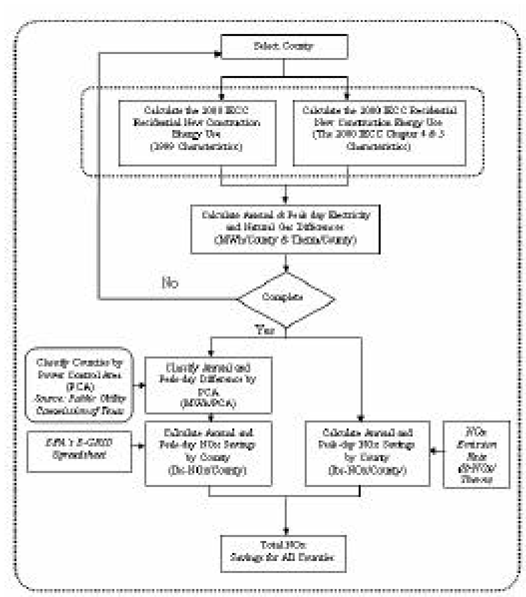

Figure 6: *Overall general flowchart for calculation of emission reductions from implementation of IECC/IRC 2001 in non-attainment and affected counties.*

[6] The peak day for the 2002 and 2003 Annual reports were determined from the nearest TMY2 weather files that were used for the simulations. The same peak days were used for the 2002 and 2003 simulations. Current work for the EPA includes the modification to the methodology to use actual 1999 NOAA weather data for the ozone episode period that occurred during August-September of 1999.

[7] The use of the eGRID database, which includes a simplified utility grid model based on annual sales of electricity data, was proposed by the TNRCC for use in calculating the emissions reductions from energy efficiency and renewable energy projects in 2001. Although this method is not as accurate as more sophisticated electricity dispatch models, its use is acceptable to the EPA because it is based on public domain data, and uses procedures that were developed and the database maintained for this purpose by the EPA.

These procedures include:

1. The calculation of electricity and natural gas savings and peak-day electricity and natural gas use reductions from the implementation of the IECC 2000 in new single-family and mult-ifamily residences in non-attainment and affected counties as compared against 1999 single-family and mult-ifamily housing characteristics using a code-traceable, calibrated DOE-2 simulation.
2. A cross-check of electricity and natural gas savings using a utility bill analysis method.
3. A cross-check of pre-code and post –code construction data using on-site visits.

Calculation of NOx Emissions Reductions

For each county, 1999 and 2003 residential housing characteristics for single and multifamily homes were ascertained, then using simulation, these characteristics were entered into the DOE-2 simulation to calculate the annual energy use of four average-sized residences, two representing a prototypical single-family and multi-family house with the average 1999 characteristics, and two representing the same houses with specific new energy-conserving characteristics from the 2000 IECC. For each county, the 1999 single-family and multi-family residential housing characteristics were obtained from the annual builder's survey performed by the National Association of Home Builders[8] as shown in Table 1 (single-family) and Table 2 (multi-family) (NAHB 2002). The average 1999 air-conditioner efficiencies (i.e., SEER 11) were obtained from the American Refrigeration Institute state-wide sales data for Texas ARI (2002). Average furnace efficiencies and domestic water heater efficiencies were assumed to meet the Federal Standards of 80% and 76%, respectively. The 2000 IECC code-compliant housing characteristics were then determined for a house with an equivalent floor area and an equivalent window-to-wall area. In this analysis, it was assumed that all houses have air conditioning, and natural gas heating and DHW, which represents the most common single-family house according to the 1999 NAHB survey. All other characteristics in the simulation were carefully chosen to match the requirements of Chapter 4 of the 2000 IECC. To accommodate the simulation of varying floor areas, a scaleable simulation file was created as shown in Figure 7, which shows a 1,000 ft2 house in the upper portion of the figure and a 5,000 ft2 house in the lower portion of the figure[9].

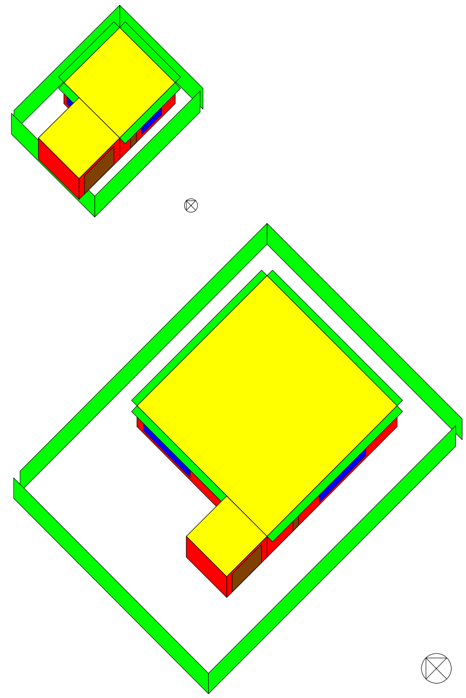

Figure 7: *Architectural rendering[10] of the prototypical 2000 IECC single-family residence (Upper: 1,000 ft^2, Lower: 5,000 ft^2).*

The procedure for linking the county-wide electricity reductions calculated with the DOE-2 simulations to the EPA's eGRID program (E-GRID 2002) are shown in Figure 8, additional details can be found in Haberl et al. (2003c). In this procedure, the code-traceable DOE-2 simulation is used to calculate the annual electricity savings (kWh/yr) and peak-day electricity savings (kWh/day) from the implementation of the 2000 IECC for all houses built in a county. The utility supplier for each county is then assigned according to data published by the Texas Public Utilities

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[8] In 2004 these characteristics will be expanded to include a diversified building stock that more closely tracks the NAHB survey data.

[9] The 2003 version of the DOE-2 simulation (LBNL 2000) includes a single-story residential simulation with slab-on-grade construction. In 2004 the simulation is being expanded to accommodate the simulation of fuel-neutral (i.e., electric, natural gas or heat pump heating, air-conditioning, and electric or natural gas DHW), 1 or 2 story residence with varying floor types (i.e., crawlspace, slab).

[10] These images were rendered with DrawBDL (Huang 2002).

	County	TMY2	Division (East or West)	1999 Average Area %	1999 Average Glazing U-value (Btu/hr-ft2-F)	1999 Average SHGC	1999 Average Roof Insulation (hr-ft2-F/Btu)	1999 Average Wall Insulation (hr-ft2-F/Btu)	2000 IECC Area %	2000 IECC Glazing U-value (Btu/hr-ft2-F)	2000 IECC SHGC	2000 IECC Roof Insulation (hr-ft2-F/Btu)	2000 IECC Wall Insulation (hr-ft2-F/Btu)
Non-attainment	Brazoria	Houston	East	13.8	1.11	0.71	27.08	13.98	13.8	0.75	0.40	19.00	11.00
	Chambers	Port Arthur	East	13.8	1.11	0.71	27.08	13.98	13.8	0.75	0.40	26.00	13.00
	Collin	Fort Worth	West	20.6	0.87	0.66	36.75	14.18	20.6	0.46	0.40	38.00	16.00
	Dallas	Fort Worth	West	20.6	0.87	0.66	36.75	14.18	20.6	0.50	0.40	38.00	13.00
	Denton	Fort Worth	West	20.6	0.87	0.66	36.75	14.18	20.6	0.46	0.40	38.00	16.00
	El Paso	El Paso	West	20.6	0.87	0.66	36.75	14.18	20.6	0.46	0.40	38.00	16.00
	Fort Bend	Houston	East	13.8	1.11	0.71	27.08	13.98	13.8	0.75	0.40	26.00	13.00
	Galveston	Houston	East	13.8	1.11	0.71	27.08	13.98	13.8	0.75	0.40	19.00	11.00
	Hardin	Port Arthur	East	13.8	1.11	0.71	27.08	13.98	13.8	0.75	0.40	26.00	13.00
	Harris	Houston	East	13.8	1.11	0.71	27.08	13.98	13.8	0.75	0.40	26.00	13.00
	Jefferson	Port Arthur	East	13.8	1.11	0.71	27.08	13.98	13.8	0.75	0.40	26.00	13.00
	Liberty	Port Arthur	East	13.8	1.11	0.71	27.08	13.98	13.8	0.75	0.40	26.00	13.00
	Montgomery	Houston	East	13.8	1.11	0.71	27.08	13.98	13.8	0.75	0.40	26.00	13.00
	Orange	Port Arthur	East	13.8	1.11	0.71	27.08	13.98	13.8	0.75	0.40	26.00	13.00
	Tarrant	Fort Worth	West	20.6	0.87	0.66	36.75	14.18	20.6	0.50	0.40	38.00	13.00
	Waller	Houston	East	13.8	1.11	0.71	27.08	13.98	13.8	0.75	0.40	26.00	13.00
Affected	Bastrop	Austin	West	20.6	0.87	0.66	36.75	14.18	20.6	0.52	0.40	30.00	13.00
	Bexar	San Antonio	West	20.6	0.87	0.66	36.75	14.18	20.6	0.52	0.40	30.00	13.00
	Caldwell	Austin	West	20.6	0.87	0.66	36.75	14.18	20.6	0.52	0.40	30.00	13.00
	Comal	San Antonio	West	20.6	0.87	0.66	36.75	14.18	20.6	0.52	0.40	30.00	13.00
	Ellis	Fort Worth	West	20.6	0.87	0.66	36.75	14.18	20.6	0.50	0.40	38.00	13.00
	Gregg	Lufkin	East	13.8	1.11	0.71	27.08	13.98	13.8	0.60	0.40	30.00	13.00
	Guadalupe	San Antonio	West	20.6	0.87	0.66	36.75	14.18	20.6	0.52	0.40	30.00	13.00
	Harrison	Lufkin	East	13.8	1.11	0.71	27.08	13.98	13.8	0.60	0.40	30.00	13.00
	Hays	Austin	West	20.6	0.87	0.66	36.75	14.18	20.6	0.50	0.40	38.00	13.00
	Johnson	Fort Worth	West	20.6	0.87	0.66	36.75	14.18	20.6	0.50	0.40	38.00	13.00
	Kaufman	Fort Worth	West	20.6	0.87	0.66	36.75	14.18	20.6	0.46	0.40	38.00	16.00
	Nueces	Corpus Christi	East	13.8	1.11	0.71	27.08	14.18	13.8	0.75	0.40	19.00	11.00
	Parker	Fort Worth	West	20.6	0.87	0.66	36.75	14.18	20.6	0.46	0.40	38.00	16.00
	Rockwall	Fort Worth	West	20.6	0.87	0.66	36.75	14.18	20.6	0.46	0.40	38.00	16.00
	Rusk	Lufkin	East	13.8	1.11	0.71	27.08	13.98	13.8	0.65	0.40	30.00	13.00
	San Patricio	Corpus Christi	East	13.8	1.11	0.71	27.08	14.18	13.8	0.75	0.40	19.00	11.00
	Smith	Lufkin	East	13.8	1.11	0.71	27.08	13.98	13.8	0.65	0.40	30.00	13.00
	Travis	Austin	West	20.6	0.87	0.66	36.75	14.18	20.6	0.50	0.40	38.00	13.00
	Upshur	Lufkin	East	13.8	1.11	0.71	27.08	13.98	13.8	0.60	0.40	30.00	13.00
	Victoria	Victoria	East	20.6	1.11	0.71	27.08	14.18	20.6	0.75	0.40	19.00	11.00
	Williamson	Austin	West	13.8	0.87	0.66	36.75	14.18	13.8	0.50	0.40	38.00	13.00
	Wilson	San Antonio	West	20.6	0.87	0.66	36.75	14.18	20.6	0.52	0.40	30.00	13.00

Table 1: *1999 and 2000 IECC code-compliant building characteristics used in the DOE-2 simulation for single-family residential.*

	County	Climate Zone	TMY2	1999 Average Area %	1999 Average Glazing U-value (Btu/hr-ft2-F)	1999 Average SHGC	1999 Average Roof Insulation (hr-ft2-F/Btu)	1999 Average Wall Insulation (hr-ft2-F/Btu)	2000 IECC Area %	2000 IECC Glazing U-value (Btu/hr-ft2-F)	2000 IECC SHGC	2000 IECC Roof Insulation (hr-ft2-F/Btu)	2000 IECC Wall Insulation (hr-ft2-F/Btu)
Non-attainment	Brazoria	3	Houston	7.5%	0.75	0.61	36.08	21.41	7.5%	any	0.40	19.00	11.00
	Chambers	4	Port Arthur	7.5%	0.75	0.61	36.08	21.41	7.5%	0.85	0.40	19.00	11.00
	Collin	5	Fort Worth	7.5%	0.75	0.61	36.08	21.41	7.5%	0.70	0.40	19.00	11.00
	Dallas	5	Fort Worth	7.5%	0.75	0.61	36.08	21.41	7.5%	0.70	0.40	19.00	11.00
	Denton	6	Fort Worth	7.5%	0.75	0.61	36.08	21.41	7.5%	0.55	0.40	30.00	13.00
	El Paso	6	El Paso	7.5%	0.75	0.61	36.08	21.41	7.5%	0.55	0.40	30.00	13.00
	Fort Bend	4	Houston	7.5%	0.75	0.61	36.08	21.41	7.5%	0.85	0.40	19.00	11.00
	Galveston	3	Houston	7.5%	0.75	0.61	36.08	21.41	7.5%	any	0.40	19.00	11.00
	Hardin	4	Port Arthur	7.5%	0.75	0.61	36.08	21.41	7.5%	0.85	0.40	19.00	11.00
	Harris	4	Houston	7.5%	0.75	0.61	36.08	21.41	7.5%	0.85	0.40	19.00	11.00
	Jefferson	4	Port Arthur	7.5%	0.75	0.61	36.08	21.41	7.5%	0.85	0.40	19.00	11.00
	Liberty	4	Port Arthur	7.5%	0.75	0.61	36.08	21.41	7.5%	0.85	0.40	19.00	11.00
	Montgomery	4	Houston	7.5%	0.75	0.61	36.08	21.41	7.5%	0.85	0.40	19.00	11.00
	Orange	4	Port Arthur	7.5%	0.75	0.61	36.08	21.41	7.5%	0.85	0.40	19.00	11.00
	Tarrant	5	Fort Worth	7.5%	0.75	0.61	36.08	21.41	7.5%	0.70	0.40	19.00	11.00
	Waller	4	Houston	7.5%	0.75	0.61	36.08	21.41	7.5%	0.85	0.40	19.00	11.00
Affected	Bastrop	4	Austin	7.5%	0.75	0.61	36.08	21.41	7.5%	0.85	0.40	19.00	11.00
	Bexar	4	San Antonio	7.5%	0.75	0.61	36.08	21.41	7.5%	0.85	0.40	19.00	11.00
	Caldwell	4	Austin	7.5%	0.75	0.61	36.08	21.41	7.5%	0.85	0.40	19.00	11.00
	Comal	4	San Antonio	7.5%	0.75	0.61	36.08	21.41	7.5%	0.85	0.40	19.00	11.00
	Ellis	5	Fort Worth	7.5%	0.75	0.61	36.08	21.41	7.5%	0.70	0.40	19.00	11.00
	Gregg	6	Lufkin	7.5%	0.75	0.61	36.08	21.41	7.5%	0.55	0.40	30.00	13.00
	Guadalupe	4	San Antonio	7.5%	0.75	0.61	36.08	21.41	7.5%	0.85	0.40	19.00	11.00
	Harrison	6	Lufkin	7.5%	0.75	0.61	36.08	21.41	7.5%	0.55	0.40	30.00	13.00
	Hays	5	Austin	7.5%	0.75	0.61	36.08	21.41	7.5%	0.70	0.40	19.00	11.00
	Johnson	5	Fort Worth	7.5%	0.75	0.61	36.08	21.41	7.5%	0.70	0.40	19.00	11.00
	Kaufman	6	Fort Worth	7.5%	0.75	0.61	36.08	21.41	7.5%	0.55	0.40	30.00	13.00
	Nueces	3	Corpus Christi	7.5%	0.75	0.61	36.08	21.41	7.5%	any	0.40	19.00	11.00
	Parker	6	Fort Worth	7.5%	0.75	0.61	36.08	21.41	7.5%	0.55	0.40	30.00	13.00
	Rockwall	6	Fort Worth	7.5%	0.75	0.61	36.08	21.41	7.5%	0.55	0.40	30.00	13.00
	Rusk	5	Lufkin	7.5%	0.75	0.61	36.08	21.41	7.5%	0.70	0.40	19.00	11.00
	San Patricio	3	Corpus Christi	7.5%	0.75	0.61	36.08	21.41	7.5%	any	0.40	19.00	11.00
	Smith	5	Lufkin	7.5%	0.75	0.61	36.08	21.41	7.5%	0.70	0.40	19.00	11.00
	Travis	5	Austin	7.5%	0.75	0.61	36.08	21.41	7.5%	0.70	0.40	19.00	11.00
	Upshur	6	Lufkin	7.5%	0.75	0.61	36.08	21.41	7.5%	0.55	0.40	30.00	13.00
	Victoria	3	Victoria	7.5%	0.75	0.61	36.08	21.41	7.5%	any	0.40	19.00	11.00
	Williamson	5	Austin	7.5%	0.75	0.61	36.08	21.41	7.5%	0.70	0.40	19.00	11.00
	Wilson	4	San Antonio	7.5%	0.75	0.61	36.08	21.41	7.5%	0.85	0.40	19.00	11.00

Table 2: *1999 and 2000 IECC code-compliant building characteristics used in the DOE-2 simulation for multi-family residential.*

County	Single Family Houses: Total Annual Electricity Savings per County w/ 20% T&D Loss (MWh/County)	Annual NOx Reductions (Tons)	Peak-day Electricity Savings per County w/ 20% T&D Loss (MWh/County)	Peak-day NOx Reductions (Tons)	Multifamily Houses: Total Annual Electricity Savings per County w/ 20% T&D Loss (MWh/County)	Annual NOx Reductions (Tons)	Peak-day Electricity Savings per County w/ 20% T&D Loss (MWh/County)	Peak-day NOx Reductions (Tons)	Natural Gas: Total Annual N.G. Savings (Therm/County)	Annual NOx Reductions (Tons)	Total Peak-day N.G. Savings (Therm/County)	Peak-day NOx Reductions (Tons)	Combined: Total Annual Electricity Savings per County w/ 20% T&D Loss (MWh/County)	Annual NOx Reductions (Tons)	Peak-day Electricity Savings per County w/ 20% T&D Loss (MWh/County)	Peak-day NOx Reductions (Tons)
Harris	40,540.36	14.55	202.1034	0.0848	4,740.54	1.39	21.5221	0.0059	1,401,306	17.38	3,044.88	0.0480	45,280.93	33.22	253.6299	0.1107
Tarrant	31,373.86	20.80	221.0010	0.1284	1,494.88	1.07	8.2081	0.0007	1,236,201	15.08	1,881.48	0.0230	33,078.94	37.02	228.8287	0.1641
Collin	26,355.41	1.59	169.0070	0.0103	293.35	0.16	1.5179	0.0005	1,101,042	14.62	1,240.36	0.0155	26,648.76	15.72	170.5050	0.0260
Dallas	22,609.26	31.38	164.8062	0.2087	2,936.08	1.66	16.1083	0.0086	1,061,786	13.17	1,009.26	0.0231	20,966.88	46.17	170.8863	0.3406
Bexar	21,742.88	25.19	190.6882	0.1080	1,191.27	1.31	4.6447	0.0055	862,063	8.21	1,226.79	0.0152	22,933.96	32.72	195.8050	0.1300
Travis	13,860.36	3.44	89.4765	0.0218	2,362.13	0.00	10.6265	0.0026	624,339	7.74	1,220.26	0.0151	16,338.48	11.73	100.1000	0.0396
Denton	13,515.72	0.59	86.7381	0.0046	583.52	0.04	2.8158	0.0002	620,360	7.89	764.94	0.0095	14,083.24	8.40	89.5538	0.0143
Williamson	12,258.64	0.00	79.8873	0.0000	137.79	0.00	0.6289	0.0000	360,026	4.48	644.80	0.0080	12,383.43	4.48	79.1373	0.0080
El Paso	10,308.44	0.00	81.4719	0.0000	186.82	0.00	0.8881	0.0000	411,059	8.10	430.68	0.0054	10,837.47	8.10	82.8370	0.0054
Montgomery	7,970.87	0.00	48.8627	0.0000	228.13	0.00	1.0226	0.0000	306,306	2.58	573.66	0.0071	8,208.84	2.58	48.8858	0.0071
Galveston	4,818.18	10.97	27.9881	0.0614	21.84	1.22	0.1023	0.0068	114,086	1.42	213.82	0.0039	4,837.53	16.60	27.6704	0.0910
Brazoria	4,411.42	1.40	25.2564	0.0084	144.05	0.14	0.6746	0.0006	117,095	1.45	325.34	0.0040	4,555.48	3.08	25.9311	0.0131
Comal	3,207.33	0.00	18.4302	0.0000	79.99	0.00	0.3288	0.0000	97,864	1.21	110.04	0.0021	3,316.32	1.21	16.7110	0.0021
Rockwall	3,395.58	0.00	21.7851	0.0000	0.00	0.00	0.0000	0.0000	142,044	1.76	149.52	0.0019	3,395.58	1.76	21.7851	0.0019
Hays	2,863.28	0.00	17.8803	0.0000	101.93	0.00	0.8187	0.0000	94,047	1.17	159.88	0.0020	2,964.76	1.17	17.8771	0.0020
Nueces	2,588.48	3.05	16.1645	0.0190	119.40	0.23	0.4584	0.0011	55,419	0.70	151.30	0.0019	2,218.89	4.29	13.9239	0.0229
Fort Bend	1,958.76	36.00	11.3143	0.2192	0.00	3.17	0.0000	0.0046	43,062	0.67	126.16	0.0016	1,958.76	39.83	11.3143	0.2353
Ellis	1,908.65	0.00	11.3862	0.0000	336.67	0.00	1.8813	0.0000	90,947	1.24	166.48	0.0020	2,245.32	1.24	13.2476	0.0020
Johnson	1,854.86	0.00	13.0173	0.0000	0.01	0.00	0.0076	0.0000	65,026	0.83	84.48	0.0010	1,866.88	0.83	13.0848	0.0010
Guadalupe	1,831.82	0.00	8.8547	0.0000	0.00	0.00	0.0000	0.0000	41,350	0.58	77.32	0.0010	1,831.82	0.58	8.8547	0.0010
Kaufman	1,398.26	0.00	7.8481	0.0000	0.00	0.00	0.0041	0.0000	46,020	0.57	48.50	0.0006	1,398.86	0.57	7.8682	0.0006
Jefferson	1,378.88	0.00	6.9700	0.0000	38.83	0.00	0.1508	0.0000	20,244	0.35	82.68	0.0010	1,318.67	0.35	6.7739	0.0010
Parker	940.15	0.00	6.6330	0.0000	1.00	0.00	0.0081	0.0000	39,466	0.48	41.88	0.0005	941.00	0.48	6.6403	0.0005
Smith	833.87	0.00	8.1712	0.0000	33.87	0.00	0.1733	0.0000	12,006	0.15	70.68	0.0009	866.84	0.15	6.4034	0.0009
Bastrop	592.37	3.05	3.7771	0.0179	55.55	0.26	0.1588	0.0013	19,295	0.24	36.35	0.0005	651.76	3.58	3.9465	0.0195
Chambers	648.33	12.25	3.8183	0.0711	0.00	1.09	0.0000	0.0060	12,265	0.15	35.76	0.0004	648.33	15.40	3.8183	0.0765
Gregg	492.13	0.00	3.2800	0.0000	0.00	0.00	0.0000	0.0000	17,152	0.21	30.72	0.0004	492.13	0.21	3.2804	0.0004
San Patricio	474.96	0.00	2.3861	0.0000	143.21	0.00	0.5548	0.0000	25,003	0.39	64.28	0.0008	618.06	0.39	2.9845	0.0008
Liberty	409.16	0.00	2.1133	0.0000	0.00	0.01	0.0000	0.0000	9,104	0.11	20.80	0.0003	409.16	0.11	2.1133	0.0003
Victoria	362.37	1.14	1.9181	0.0067	0.00	0.00	0.0000	0.0004	7,854	0.08	21.38	0.0003	362.37	1.38	1.9181	0.0074
Orange	307.38	0.00	1.6070	0.0000	0.00	0.00	0.0000	0.0000	9,077	0.15	23.64	0.0003	307.38	0.15	1.6070	0.0003
Caldwell	355.42	0.00	2.2683	0.0000	0.00	0.00	0.0000	0.0000	9,417	0.12	15.48	0.0002	355.42	0.12	2.2683	0.0002
Wilson	152.04	0.00	0.4738	0.0000	0.00	0.00	0.0000	0.0000	2,030	0.03	4.32	0.0001	152.04	0.03	0.4738	0.0001
Hardin	85.22	0.00	0.4412	0.0000	0.00	0.00	0.0000	0.0000	1,027	0.02	5.84	0.0001	85.22	0.02	0.4412	0.0001
Harrison	88.74	0.00	0.3383	0.0000	0.00	0.00	0.0000	0.0000	2,014	0.03	6.84	0.0001	88.74	0.03	0.3383	0.0001
Waller	40.18	0.00	0.3473	0.0000	78.88	0.00	0.3485	0.0000	6,032	0.10	24.72	0.0003	120.05	0.10	0.5962	0.0003
Upshur	34.66	0.00	0.2367	0.0000	0.00	0.00	0.0000	0.0000	1,206	0.01	2.18	0.0000	34.66	0.01	0.2367	0.0000
Rusk	28.53	4.19	0.1886	0.0200	0.00	0.33	0.0041	0.0012	354	0.00	2.16	0.0000	38.33	4.48	0.2637	0.0202
WARD		21.09		0.2073		1.83		0.0087					0.00	22.72	0.0000	0.2160
MCLENNAN		26.45		0.1526		1.39		0.0080					0.00	27.74	0.0000	0.1606
MITCHELL		23.80		0.1350		1.21		0.0067					0.00	25.13	0.0000	0.1457
FAYETTE		14.74		0.0865		1.39		0.0061					0.00	16.13	0.0000	0.0926
KNOX		13.30		0.0888		0.76		0.0004					0.00	14.05	0.0000	0.0926
FREESTONE		13.30		0.0808		0.76		0.0027					0.00	14.05	0.0000	0.0835
TITUS		10.41		0.0694		0.55		0.0029					0.00	10.96	0.0000	0.0723
YOUNG		9.83		0.0600		0.53		0.0028					0.00	10.36	0.0000	0.0603
CHEROKEE		5.97		0.0389		0.31		0.0016					0.00	6.28	0.0000	0.0416
ECTOR		5.97		0.0399		0.31		0.0005					0.00	6.28	0.0000	0.0416
LLANO		1.90		0.0118		0.16		0.0006					0.00	2.06	0.0000	0.0118
PALO PINTO		1.11		0.0110		0.11		0.0006					0.00	1.82	0.0000	0.0116
HENDERSON		1.70		0.0110		0.09		0.0005					0.00	1.07	0.0000	0.0124
LIMESTONE		1.49		0.0084		0.14		0.0006					0.00	1.63	0.0000	0.0094
RED RIVER		1.16		0.0079		0.06		0.0003					0.00	1.22	0.0000	0.0081
GRIMES		1.04		0.0064		0.07		0.0003					0.00	1.09	0.0000	0.0057
CALHOUN		0.90		0.0053		0.05		0.0003					0.00	0.96	0.0000	0.0056
HASKELL		0.86		0.0053		0.05		0.0002					0.00	0.91	0.0000	0.0055
ROBERTSON		0.84		0.0054		0.03		0.0003					0.00	0.89	0.0000	0.0056
JONES		0.78		0.0049		0.05		0.0002					0.00	0.83	0.0000	0.0051
CROCKETT		0.70		0.0049		0.03		0.0002					0.00	0.83	0.0000	0.0051
CAMERON		0.70		0.0040		0.03		0.0002					0.00	0.93	0.0000	0.0041
BRAZOS		0.69		0.0040		0.04		0.0001					0.00	0.74	0.0000	0.0045
LAMAR		0.50		0.0036		0.03		0.0002					0.00	0.61	0.0000	0.0040
NOLAN		0.56		0.0036		0.03		0.0002					0.00	0.59	0.0000	0.0040
WHARTON		0.26		0.0015		0.02		0.0001					0.00	0.28	0.0000	0.0016
HIDALGO		0.19		0.0009		0.02		0.0001					0.00	0.21	0.0000	0.0010
FRIO		0.12		0.0006		0.01		0.0000					0.00	0.13	0.0000	0.0006
WEBB		0.09		0.0004		0.01		0.0000					0.00	0.10	0.0000	0.0005
COKE		0.04		0.0002		0.00		0.0000					0.00	0.08	0.0000	0.0003
COLEMAN		0.03		0.0001		0.00		0.0000					0.00	0.03	0.0000	0.0002
HARDEMAN		0.01		0.0001		0.00		0.0000					0.00	0.02	0.0000	0.0001
TAYLOR		0.01		0.0000		0.00		0.0000					0.00	0.02	0.0000	0.0001
Total	236,965.39	360.43	1,453.19	2.13	15,272.71	22.16	70.71	0.11	8,075,264	118.08	15,269.48	0.1676	252,237.41	412.06	1,526.11	2.44

Table 3: *2003 Annual and peak-day NOx reductions from electricity and natural gas savings due to the 2000 IECC for single-family and multi-family residences by county.*

Commission (TPUC 2003, Haberl et al. 2003c). For each utility supplier eGRID then calculates, on average, which utility plant supplied electricity including which counties those plants were located in, and the associated NOx, SO_2, CO_2 and mercury emissions. The emissions from the different power plants in each county are then totaled to give the total county-wide emissions.

Results: 2003 Emissions Reductions From the Implementation of the 2000 IECC to Single-family and Multi-family Residential In Table 3 the combined NOx emissions reduction are listed from single-family electricity savings, multi-family electricity savings, and natural gas savings (single-family and multi-family). In Figure 9 and Figure 10 the annual and peak-day electricity savings are shown for the combined single-family and multi-family savings. Figure 11 and Figure 12 present the combined total NOx reductions from electricity and natural gas savings in single-family and multi-family households in the 38 non-attainment and affected counties, and those counties calculated by eGRID to have electricity power production facilities.

In Table 3 the electricity and natural gas savings for single-family and multi-family are shown. For all counties the total annual electricity savings is 252,238 MWh/yr[11], which is comprised of 236,965 MWh/yr (93.9%) from single-family residences, and 15,272 MWh/yr (6.1%) from multi-family residences. The total

[11] This includes an estimated 20% transmission and distribution loss.

peak-day electricity savings from all counties is calculated to be 1,526 MWh/day, which is comprised of 1,452 MWh/peak-day (95.2%) from single-family and 73.73 MWh/peak-day (4.8%) from multi-family. N.G. savings are calculated to be 8,875,694 therms/year (i.e., 887,569 MMBtu/yr) from single-family and multi-family residences and 15,965 therms/peak-day[12] (i.e., 1,596.5 MMBtu/day). Figure 9 and Figure 10 provide graphical presentations of the data provided in Table 3.

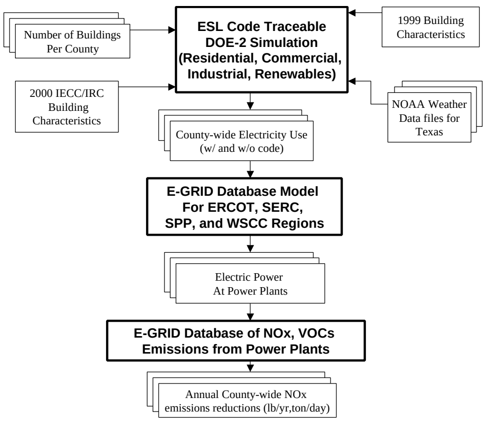


Figure 8: *Overall general flowchart for calculation of emission reductions from implementation of IECC/IRC 2001 in non-attainment and affected counties.*

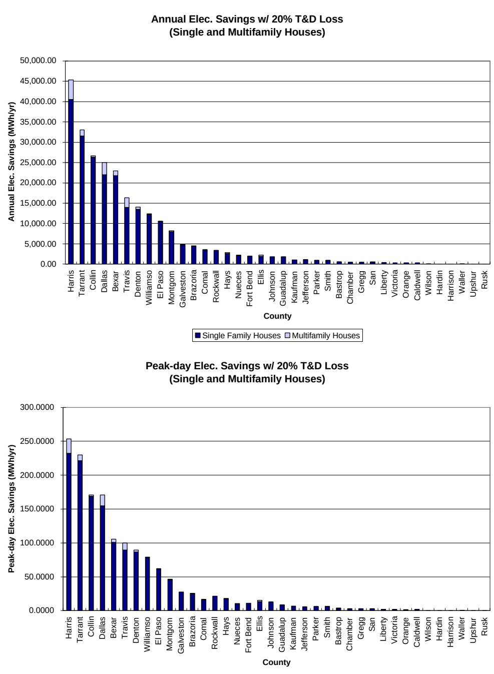


Figure 9: *2003 Annual and peak-day electricity reductions from 2000 IECC by PCA for single-family and multi-family residences by county using eGRID.*

The total NOx reductions from electricity and natural gas savings from new construction in 2003 are calculated to be 472.67 tons NOx/year, which represents 340.43 tons NOx/year (72.0%) from single-family residential electricity savings, 22.18 tons NOx/year (4.7%) from multi-family residential electricity savings, and 110.06 tons NOx/year (23.3%) from natural gas savings from single-family and multifamily residential. On a peak summer day the NOx reductions in 2003 are calculated to be 2.44 tons of NOx/day, which represents 2.13 tons NOx/day (72.0%) from single-family residential electricity savings, 0.11 tons NOx/day (4.5%) from multi-family residential electricity savings, and 0.198 tons NOx/day (8.1%) from natural gas savings from single-family and multifamily residential.

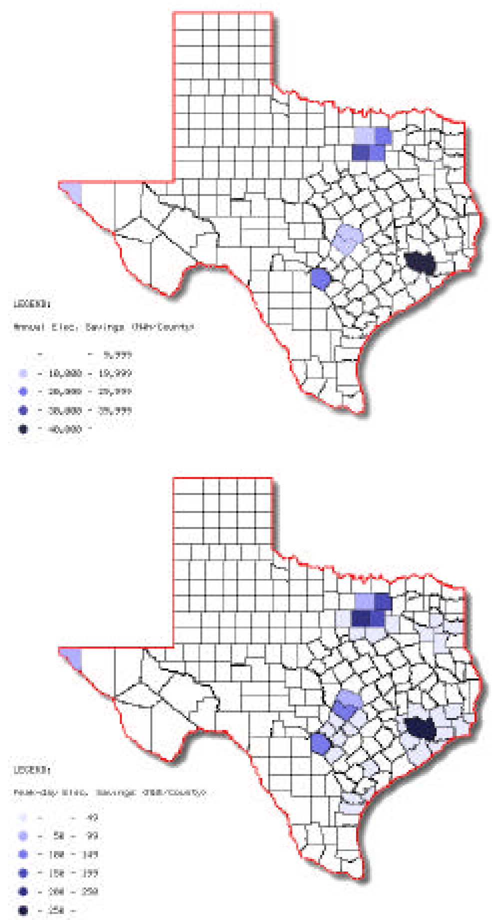
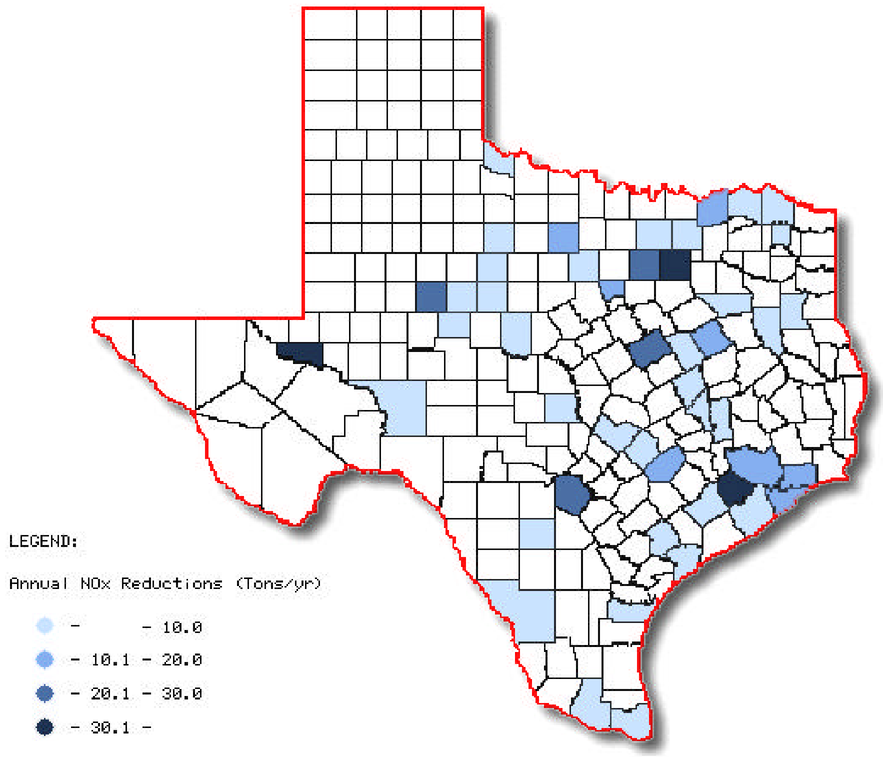


Figure 10: *2003 Annual and peak-day electricity reductions from 2000 IECC by PCA for single-family and multi-family residences by county using eGRID.*

[12] This is the summer-time peak day for electricity use.



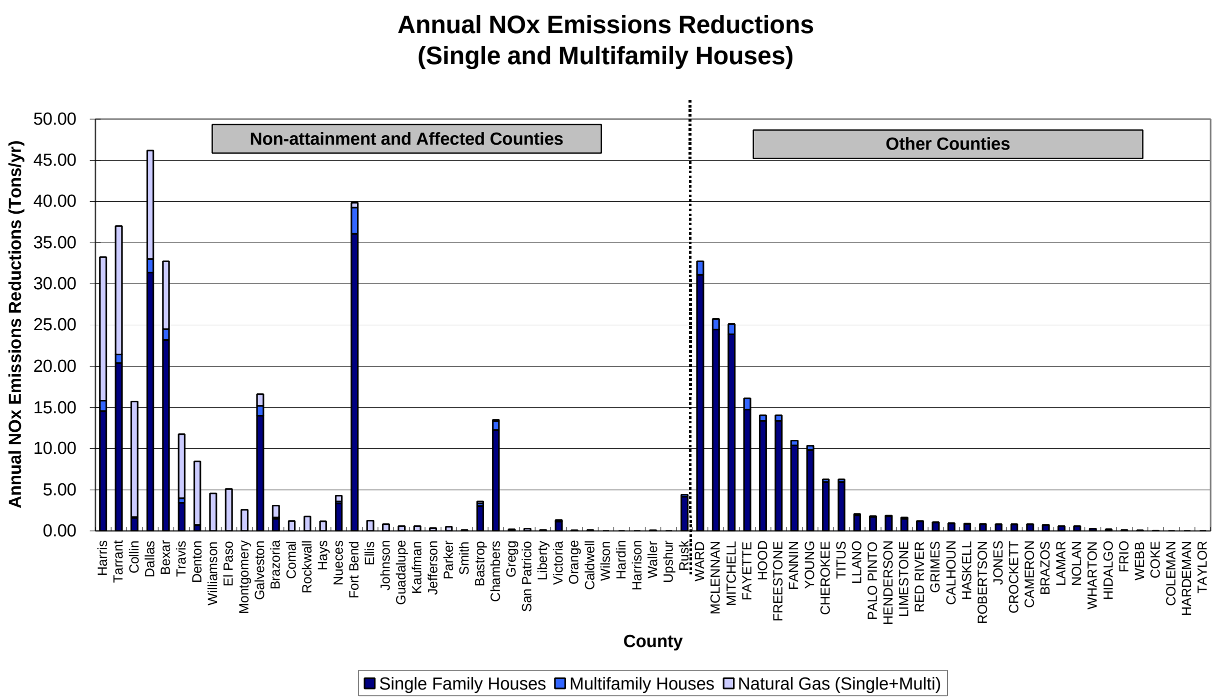


Figure 11: *2003 Annual NOx reductions from electricity and natural gas savings due to the 2000 IECC for single-family and multi-family residences by county.*

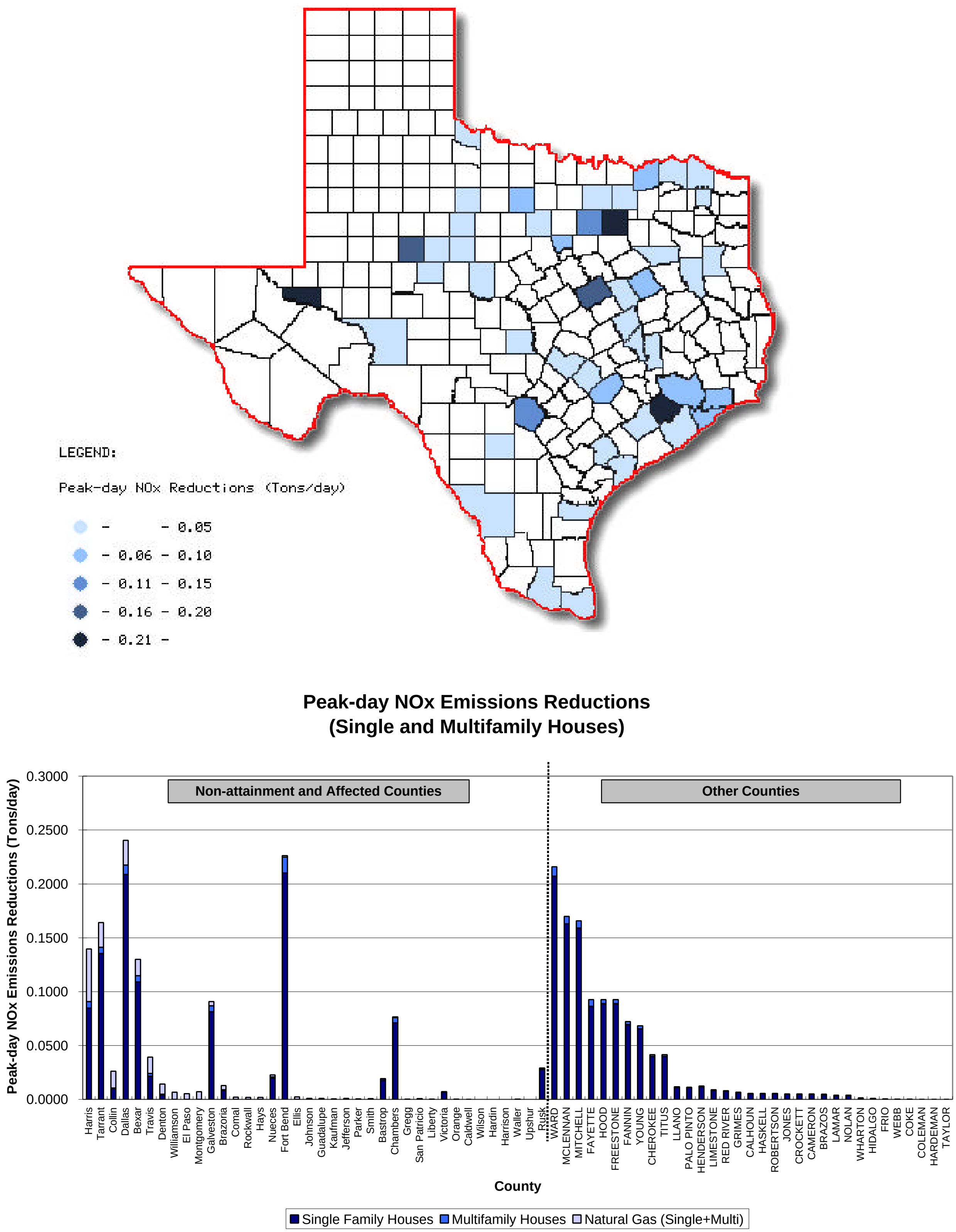


Figure 12: *2003 peak day NOx reductions from electricity and natural gas savings due to the 2000 IECC for single-family and multi-family residences by county.*

In Figure 11 and Figure 12 it is worth pointing out that the comparative magnitude of the annual and peak-day NOx emissions reduction from natural gas compared to savings from electricity vary significantly, as is expected since the annual savings include heating period NOx emissions reduction, and the peak-day (i.e., cooling) savings include only those savings associated with the elimination of pilot lights. This can be identified by comparing the size of the natural gas portion of the stacked-bar figure for each county. In the annual NOx reduction graph (Figure 11) this portion is about the same size as the contribution from electricity savings in non-attainment and affected counties. Whereas, the natural gas portion of the peak-day savings (Figure 12) is significantly smaller. Furthermore, the savings from the natural gas reductions remain in the counties where the houses are built, whereas the electricity savings are distributed to the counties containing the utility power plants using the eGRID database.

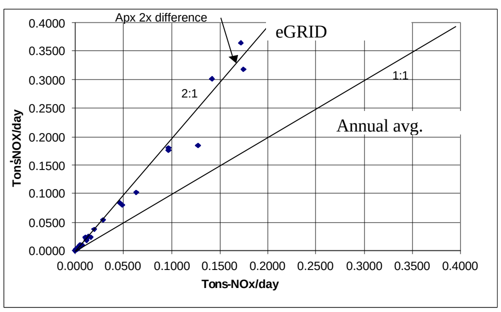


Figure 13: *Comparison of peak day versus average daily NOx reductions from electricity savings for the 38 non-attainment and affected Counties.*

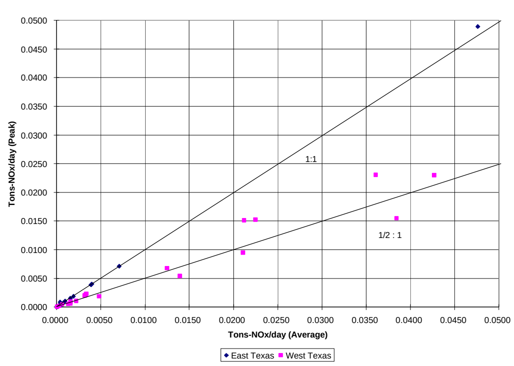


Figure 14: *Comparison of peak day versus average daily NOx reductions from natural gas savings for the 38 non-attainment and affected counties.*

A comparison of Figure 10 with Figure 11 and Figure 12 shows the importance of the use of the eGRID database for determining the location of the county in which the power generation facility is located. In Figure 10 the counties with the largest electricity savings are primarily non-attainment and affected counties with the largest housing growths. In comparison, in Figure 11 and Figure 12 some of the counties with the largest NOx emissions reductions are not non-attainment or affected counties.

The importance of the use of peak-day electricity savings for calculating NOx emissions is made clear in Figure 13 , which shows a 2:1 increase in NOx reductions calculated using peak-day electricity savings[13] versus NOx reductions calculated with average daily values[14]. The reason for this difference is due to the fact that the electricity use is reduced most during the peak cooling periods of the year, which is not reflected by an average daily calculation. In contrast to this, Figure 14 shows an opposite 1:2 ratio when one compares the NOx reductions from peak cooling use of natural gas versus NOx reductions calculated from average daily natural gas use[15]. This 1:2 ratio is indicating the equal importance of properly accounting for the peak cooling day natural gas use in a residence, which primarily represents the gas use by the domestic water heating and any pilot lights.

SUMMARY

This paper has presented procedures that have been used to calculate the electricity savings from residential construction in non-attainment and affected counties. Results are presented that show the annual electricity and natural gas savings and NOx reductions from implementation of the 2000 IECC to single and multi family residences in 2003, which use the

[13] Peak day NOx reductions are calculated using the peak day savings with the DOE-2 simulation of the 1999 and code-compliant house characteristics.

[14] The average daily NOx reductions for electricity use are calculated by dividing the total annual NOx reductions by 365, which is indicated as "annual avg.". The values indicated as "eGRID" are the peak day simulations from DOE-2 for each county.

[15] NOx reductions from average daily values are calculated by dividing the annual natural gas use by 365. The west Texas data points are for those houses classified by the NAHB as being located roughly west of I-35. These show that peak day calculated from averaging the annual gas savings overstates the summertime gas reductions, which mostly include the elimination of the pilot lights in the furnaces.

DOE-2 simulation program. Energy savings from energy code-compliant new residential construction in 2003 were 252,238 MWh/year of electricity and 887,564 MBtu/year of natural gas in the 38 original, non-attainment and affected counties. The resultant annual NO_x reductions were calculated to be 473 tons NO_x/year which include:

- 340 tons NO_x/year (72.0%) from single-family residential (236,965 MWh/year saved),
- 22 tons NO_x/year (4.7%) from multi-family residential (15,272 MWh/year saved), and
- 110 tons NO_x/year (23.3%) from natural gas savings from single-family and multi-family residential (887,564 MBtu/year saved).

On a peak summer day, the NOx reductions in 2003 are calculated to be 2.44 tons of NO_x/day, which represents:

- 2.13 tons NOx/day (87.3%) from single-family residential (1,452 MWh/day saved),
- 0.11 tons NO^x/day (4.5%) from multi-family residential (73.73 MWh/day saved), and
- 0.20 tons NO_x/day (8.2%) from natural gas savings from single-family and multi-family residential (1,595 MBtu/day saved).

The comparative magnitude of the annual and peak-day NO_x reductions from natural gas compared to the savings from electricity vary significantly. This is because the annualized savings include heating period NO_x reductions, and the peak-day (i.e., cooling) natural gas savings include only those savings associated with the elimination of pilot lights. Additional details of the analysis are reported in Haberl et al. (2003c)

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