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PROCEDURES FOR CALCULATION OF NOx EMISSIONS REDUCTION FROM IMPLEMENTATION OF THE 2000 IECC/IRC CONSERVATION CODE 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 NAAQS[1] 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., affected areas)[2]. In 2001, the Texas State Legislature formulated and passed Senate Bill 5 to reduce ozone levels by encouraging the reduction of emissions of NO_x by sources that are currently not regulated by the state[3]. 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 2001 IECC[4], which represents one of the first times that the EPA is considering emissions reductions credits from energy conservation – an important new development for the building simulation community, since this could pave the way for documented procedures for financial reimbursement for building energy conservation from the state's emissions reductions funding. This paper outlines the procedures that have been used to calculate the electricity savings residential construction in non-attainment and affected counties. Results are presented that show the annual electricity savings and NO_x reductions from implementation of the 2001 IECC, which use the DOE-2 simulation program.

BACKGROUND

Thirty-eight counties in Texas have been designated by the EPA as either non-attainment or affected areas. These areas are shown on the map in Figure 1[5].

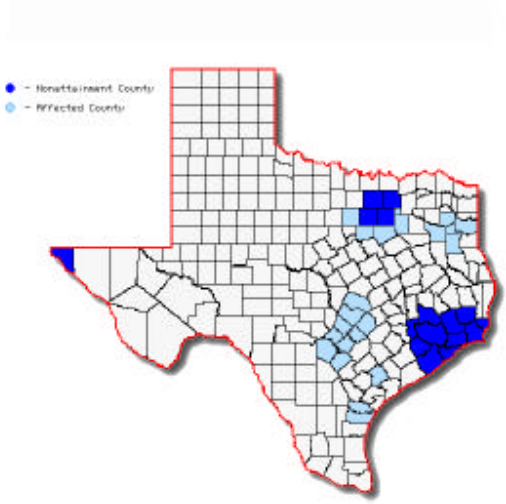

Figure 1: *EPA Non-attainment (blue) and affected counties (light blue).*

These counties represent different areas of the state that have been categorized into the different climate zones[6]

[1] The National Ambient Air Quality Standards (NAAQS) were established by the Federal Clean Air Act of 1970, which authorized the EPA to establish the maximum allowable concentrations of pollutants that are known to endanger human health, harm the environment or cause property damage. These standards include allowable limits of six primary pollutants: carbon monoxide (CO – 9 ppm, 8 hr avg.), lead (Pb -- 1.5 ppm, maximum quarterly average), oxides of nitrogen (NO_2 -- 53 ppb annual average), Ozone (O_3 -- 120 ppb, 1 hr, avg.), particulate matter (PM_{10}-- 50 micrograms/m^3 annual average), and sulfur dioxide (SO_2 -- 30 ppb annual average).

[2] The non-attainment areas include: Beaumont-Port Arthur, El Paso, Dallas-Ft. Worth, and the Houston-Galveston-Brazoria area. Affected areas include: Austin, Corpus Christi, San Antonio, and the Longview-Tyler-Marshall area.

[3] The state agency responsible for emissions reductions is the Texas Commission on Environmental Quality (TCEQ). Prior to August 2002, this agency was the Texas Natural Resources Conservation Commission (TNRCC).

[4] The "2001 IECC" notation is used to signify the 2000 International Energy Conservation Code (IECC 2000) as modified by the 2001 Supplement (IECC 2001), published by the ICC in March of 2001, as required by Senate Bill 5.

[5] 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.

contained in Chapter 3 of the 2001 IECC as shown in Figure 2. Also shown on 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). Three of these counties (i.e., Harris, Dallas, and Tarrant), are non-attainment counties. The fourth county, 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.

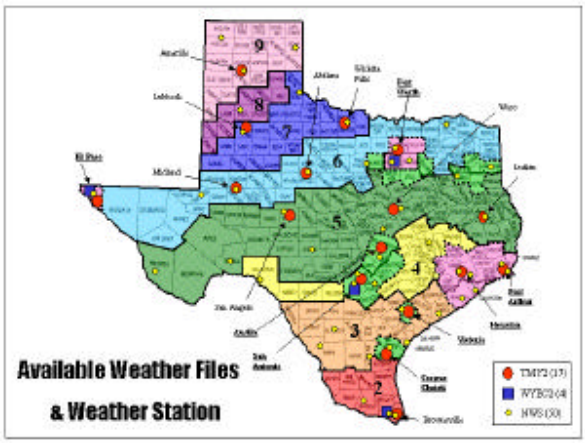

Figure 2: *Available NWS, TMY2 and WYEC2 weather files compared to the 2000 IECC weather zones for Texas.*

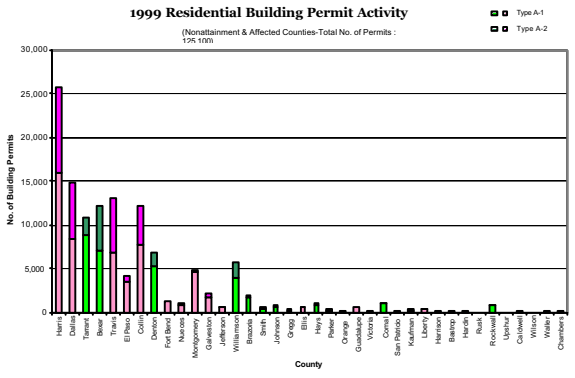

Figure 3: *1999 Residential building permits by county (Source: RECenter 2002).*

In Figure 3 the 1999 residential building permit is shown where the most activity occurred 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 3 is the significant number of new multi-family units in the counties with the largest number of building permits[7]. 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.

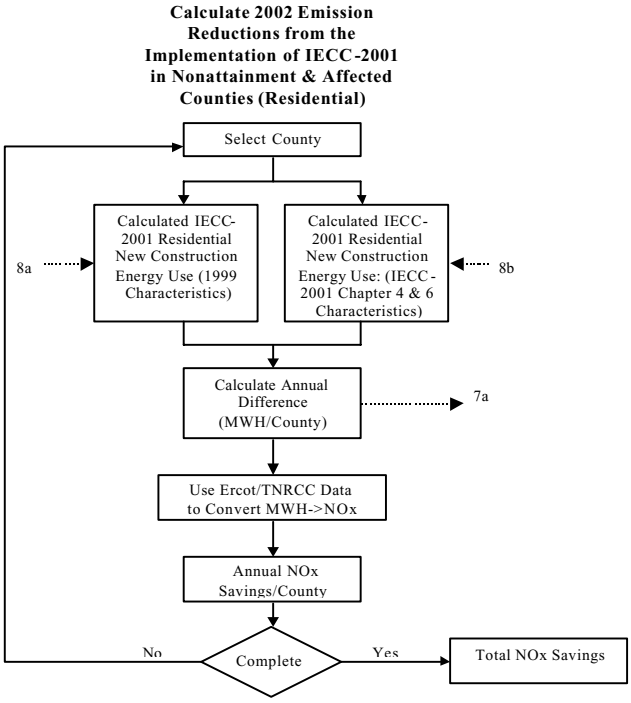

Figure 4*: Overall general flowchart for calculation of emission reductions from implementation of IECC/IRC 2001 in non-attainment and affected counties.*

[6] These climate zones include Zone 5 or Zone 6 (i.e., 2,000 to 2,999 HDD_{65}) for the Dallas-Ft. Worth and El Paso areas, and climate Zones 3 and 4 (i.e., 1,000 to 1,999 HDD_{65}) for the Houston-Galveston-Beaumont-Port Author-Brazoria area.

[7] This is indicated by the upper portion of each bar in Figure 3.

For Single Family															Total Savings		
	County	Power Control Area[1]	Climate Zone[2]	No. of projected units[3]	Floor Area (ft2)[4]	1999 Average Energy Use (KWh)[5]	IECC 2001 Energy Use (KWh)[6]	Peak Date	1999 Peak Day(KWH/House)[7]	IECC Peak Day(KWH/House)[8]	Savings per house (kWh)[9]	Total Savings (MWh) 1999-IECC w/ 20% T&D Loss [10]	lb-NOx/MWh[11]	Tons/Year[12]	Tons/Day[13]	Peak Tons/Day[14]
Affected County	Bastrop	ERCOT	4	146	2,426	16,545	13,310	31-Jul	77.96	59.66	3,236	566.77	2.68	0.7623	0.0021	0.0036
	Bexar	San Antonio Public Service Bd	4	7,168	2,426	16,681	13,332	26-Aug	71.46	55.66	3,349	28,806.76	3.24	46.6669	0.1279	0.1837
	Caldwell	ERCOT	4	101	2,426	16,545	13,310	31-Jul	77.96	59.66	3,236	392.08	2.68	0.5274	0.0014	0.0025
	Comal	ERCOT	4	1,111	2,426	16,681	13,332	26-Aug	71.46	55.66	3,349	4,464.69	2.68	6.0053	0.0165	0.0236
	Ellis	TXU	5	649	2,426	15,466	12,448	29-Jul	82.47	61.45	3,017	2,348.64	3.34	3.9039	0.0108	0.0228
	Gregg	SWEPCO	6	194	2,548	13,139	11,298	22-Jul	65.34	52.74	1,881	437.90	2.68	0.5870	0.0016	0.0033
	Guadalupe	ERCOT	4	478	2,426	16,681	13,332	26-Aug	71.46	55.66	3,349	1,920.99	2.68	2.5837	0.0071	0.0102
	Harrison	SWEPCO	6	33	2,548	13,139	11,260	22-Jul	65.34	52.74	1,881	74.49	2.68	0.0999	0.0003	0.0006
	Hays	ERCOT	6	737	2,426	16,662	13,160	31-Jul	76.63	56.26	3,502	3,097.17	2.68	4.1657	0.0114	0.0184
	Johnson	TXU	5	629	2,426	15,466	12,448	29-Jul	82.47	61.45	3,017	2,277.23	3.34	3.8030	0.0104	0.0221
	Kaufman	TXU	6	218	2,426	15,725	12,419	19-Aug	78.10	58.40	3,306	884.85	3.34	1.4443	0.0040	0.0072
	Nueces	CRI	3	841	2,548	14,354	12,851	18-Aug	63.46	56.11	1,703	1,718.67	2.68	2.3039	0.0063	0.0083
	Parker	TXU	6	302	2,426	15,725	12,419	19-Aug	78.10	58.40	3,306	1,196.09	3.34	2.0009	0.0055	0.0099
	Rockwall	TXU	6	1,111	2,426	15,725	12,419	19-Aug	78.10	58.40	3,306	4,407.56	3.34	7.3606	0.0202	0.0366
	Rusk	SWEPCO	5	17	2,548	13,139	11,253	22-Jul	65.34	52.97	1,886	38.47	2.68	0.0516	0.0001	0.0003
	San Patricio	CRI	3	218	2,548	14,354	12,851	18-Aug	63.46	56.11	1,703	445.50	2.68	0.5972	0.0016	0.0021
	Smith	TXU	5	466	2,548	13,139	11,253	22-Jul	65.34	52.97	1,886	1,052.39	3.34	1.7575	0.0048	0.0096
	Travis	Austin Energy	5	5,822	2,426	16,662	13,160	31-Jul	76.63	56.26	3,502	24,006.61	1.44	17.2804	0.0491	0.0791
	Upshur	SWEPCO	6	17	2,548	13,139	11,253	22-Jul	65.34	52.74	1,881	38.37	2.68	0.0514	0.0001	0.0003
	Victoria	CRI	3	166	2,548	13,823	12,261	8-Sep	67.25	60.21	1,672	313.00	2.68	0.4196	0.0011	0.0015
	Williamson	TXU	6	4,111	2,426	16,662	13,160	31-Jul	76.63	56.26	3,502	17,276.07	2.68	23.1586	0.0634	0.1022
	Wilson	ERCOT	4	18	2,426	16,681	13,332	26-Aug	71.46	55.66	3,349	84.30	2.68	0.0865	0.0002	0.0003
Nonattainment County	Brazoria	Reliant Energy HL & P	3	2,008	2,548	13,740	11,899	29-Jul	66.52	55.988	1,881	4,532.46	1.88	4.2605	0.0117	0.0207
	Chambers	EGS	4	318	2,548	12,913	11,297	1-Sep	59.02	49.96	1,616	616.67	2.68	0.8266	0.0023	0.0039
	Collin	TXU	5	9,639	2,426	15,725	12,419	19-Aug	78.10	58.40	3,306	38,238.64	3.34	63.8605	0.1750	0.3172
	Dallas	TXU	5	8,595	2,426	15,466	12,448	29-Jul	82.47	61.45	3,017	31,117.34	3.34	51.9660	0.1424	0.3017
	Denton	TXU	6	5,339	2,426	15,725	12,419	19-Aug	78.10	58.40	3,306	21,176.91	3.34	35.3664	0.0969	0.1757
	El Paso	EL PASO Electric Company	6	3,089	2,426	16,095	12,684	12-Jul	78.74	56.62	3,401	12,643.56	2.68	16.9487	0.0464	0.0839
	Fort Bend	Reliant Energy HL & P	4	1,049	2,548	13,099	11,467	29-Jul	61.75	51.80	1,626	2,046.81	1.88	1.9240	0.0053	0.0098
	Galveston	Reliant Energy HL & P	3	2,338	2,548	13,740	11,899	29-Jul	66.52	55.988	1,881	5,277.33	1.88	4.9607	0.0136	0.0241
	Hardin	EGS	4	19	2,548	12,913	11,297	1-Sep	59.02	49.96	1,616	36.84	2.68	0.0494	0.0001	0.0002
	Harris	Reliant Energy HL & P	4	19,103	2,548	13,080	11,467	29-Jul	61.75	51.80	1,626	37,428.67	1.88	35.1841	0.0964	0.1795
	Jefferson	EGS	4	610	2,548	12,913	11,297	1-Sep	59.02	49.96	1,616	1,182.91	2.68	1.5867	0.0043	0.0074
	Liberty	EGS	4	213	2,548	12,913	11,297	1-Sep	59.02	49.96	1,616	413.05	2.68	0.5537	0.0015	0.0026
	Montgomery	EGS	4	4,030	2,548	13,099	11,467	29-Jul	61.75	51.80	1,626	7,867.24	2.68	10.5480	0.0289	0.0538
	Orange	EGS	4	172	2,548	12,913	11,297	1-Sep	59.02	49.96	1,616	333.54	2.68	0.4471	0.0012	0.0021
	Tarrant	TXU	5	10,368	2,426	15,466	12,448	29-Jul	82.47	61.45	3,017	37,500.10	3.34	62.6252	0.1716	0.3636
	Waller	Reliant Energy HL & P	4	22	2,548	13,099	11,467	29-Jul	61.75	51.80	2,047	54.04	1.88	0.0508	0.0001	0.0002
	TOTAL										2,517	297,160.32		417.4298	1.1436	2.0947

Page 1

Notes:
1. The Power Control Area is classified from Texas Electric Retail Service Area Map published by the Texas Public Utilities Commission.
2. The climate zones are from the IECC 2000 Chapter 3
3. No. of Projected Units: The data from Real Estate Center of TAMU and U.S. Census.
4. Floor Area: From NAHB Survey Data
5,6. 1999 & IECC 2000 Energy use: From the DOE-2 simulation (BEPS report).
7,8. Peak day electricity use (kWh/Day): From the DOE-2 ps-f report and the corresponding hourly report of DOE-2.1e simulation. (i.e., Find the date of the peak day from the ps-f report and the peak day use from hourly report for that day).
9. Savings per house: 1999 average energy use - IECC 2000 energy use
10.Total Savings: Savings per house x No. of Projected Unit
11. lb-NOx/MWH: From the June 2002 TNRCC published values (EGRID). The average lb-NOx/MWH of Texas is 2.68
12.Tons/year: (Total Savings x lb-NOx/MWH)/2000
13.Tons/day: (Tons/year)/365
14. Peak Tons/day: (((1999 peak day use-IECC peak day use)/2000) x No. of Projected Unit x lb-NOx/MWH)/2000
15. TMY2: Classified from the map of available weather files & weather station
16. Division (East and West Texas): From NAHB survey data.
17. AFUE (%),SEER and Water Heater Efficiency for 1999 standard and IECC 2000 house are 80%, 11 and 76%, respectively.

Table 1: *2002 NOx emissions reductions from implementation of the 2000 IECC to single-family residences in non-attainment and affected counties.*

METHODOLOGY

The TCEQ is currently working with the EPA, through the Senate Bill 5 Legislation to obtain emissions reduction credits for reductions in electricity use and peak summertime electric demand that are attributable to the adoption of the International Energy Conservation Code (IECC 2001) 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 (E-GRID)[8]. The methodology to accomplish this for residential buildings is presented in Figure 4, additional detailed information can be found in Haberl et al. (2002a, 2002b, 2003). This methodology is composed of

[8] E-GRID, Ver. 2, is the EPA's Emissions and Generation Resource Integrated Database . This publicly available database can be found at www.epa.gov/airmarkets/egrid/.

several procedures that calculate and verify savings using different sources of information.

These procedures include:

1. The calculation of electricity savings and peak day electricity use reductions from the implementation of the IECC 2001 in new residences in non-attainment and affected counties as compared against 1999 housing characteristics using calibrated simulation.
2. A cross-check of the calculated energy use against the published average energy use found in the USDOE's Residential Energy Characteristics Survey[9] (RECS 1999) and other data sources.
3. A cross-check of energy savings using monthly utility billing data from a sample of houses analyzed with the Princeton Scorekeeping Method (PRISM) (Fels 1986; Fels et al. 1995),
4. A cross-check of construction data using on-site visits.

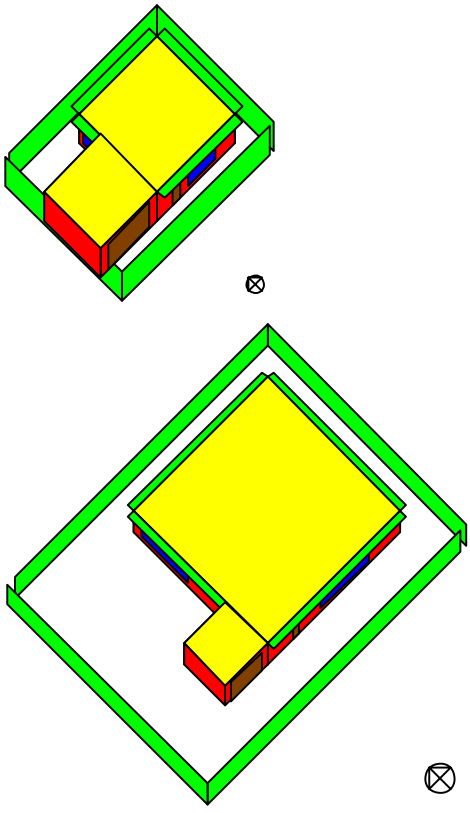

Figure 5: *Architectural rendering of the prototypical 2000 IECC single-family residence (Upper: 1,000 ft^2, Lower: 5,000 ft^2).*

[9] The energy use reported by RECS represents the total energy use, which would include electricity use and natural gas use.

Calculation of NOx Emissions Reductions

For each county, 1999 and 2002 residential housing characteristics were ascertained, then using simulation, these characteristics are entered into a code-traceable DOE-2 simulation to calculate the annual energy use of two average-sized residences, one representing the house with the average 1999 characteristics, and one representing the appropriate characteristics from the 2001 IECC. For each county the 1999 single-family residential housing characteristics were obtained from the annual builder's survey performed by the National Association of Home Builders (NAHB 2002)[10]. The average 1999 air-conditioner efficiencies (i.e., SEER 11) were obtained from ARI (2002) statewide sales. Average furnace efficiencies and domestic water heater efficiencies were assumed to meet the Federal Standards of 80% and 76%, respectively. The 2001 IECC code-compliant housing characteristics were then determined for a house with an equivalent floor area and an equivalent window-to-wall area[11]. 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 2001 IECC[12]. To accommodate

[10] The NAHB characteristics divided the state into east (E), and west (W) divisions: window-to-wall area E=15.28%, W=20.6%, glazing U-value E=1.11, W=0.87, SHGC E=0.66, W=0.71, roof R-value E=27.01, W=26.75, wall R-value E=13.99, W=14.18.

[11] These were determined using the appropriate IECC climate zone for each county and the window-to-wall area that corresponded to the NAHB survey data. For more information see the Texas Builder's Prescriptive Compliance Form located at "eslsb5.tamu.edu". The code-traceable simulation can be viewed at "eslsb5ec.tamu.edu". For example, in Harris County, the IECC-compliant house has 15.28% window-to-wall area, 0.75 glazing U-value, SHGC = 0.40, roof R-value of 27.08 (i.e., the same as the NAHB house), wall R-value of 13.99, SEER = 10, AFUE = 0.80, and DHW = 0.76. Additional information about these characteristics can be found in Haberl et al. (2003).

[12] The standard house is a one story square house facing west with an uninsulated slab on grade foundation. Interior walls are 8 feet in height. There are no exterior shading devices, moveable windows shades or adjacent buildings or shade trees. A garage is attached on the north side of the house, and the house has two exterior doors (front and back). The solar absorptance is assumed to be 0.55 for the exterior walls and 0.50 for the roof. The window frames are aluminum w/o thermal break, no dividers. The edge of glass U-factor is not included in the calculation. The roof is flat with no penalty for duct loss. The heating and cooling equipment are automatically sized by the DOE-2.1e, Version 119 simulation. The thermostat is programmable with customized settings according to IECC 2001 with 68F for heating and 78F for cooling and 5F setback for 6 hours. Water heating is natural

the simulation of varying floor areas, a scaleable simulation file was created as shown in Figure 5, which shows a 1,000 ft^2 house in the upper portion of the figure and a 5,000 ft^2 house in the lower portion of the figure[13].

The procedure for linking the county-wide electricity reductions calculated with the DOE-2 simulations to the EPA's E-GRID program (E-GRID 2002) are shown in Figure 6, additional details can be found in Haberl et al. (2003). 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 2001 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

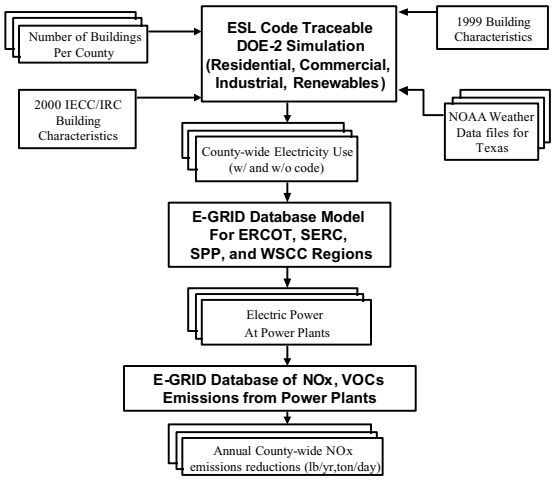

Figure 6: *Overall general flowchart for calculation of emission reductions from implementation of IECC/IRC 2001 in non-attainment and affected counties.*

gas. Total daily consumption is given by: gal/day= (30xa)+(10xb), where a = number of living units in the standard and proposed design, b = number of bedrooms in each living. Infiltration is calculated according to ASHRAE Standard 136. Equipment efficiency for the 1999 and 2001 IECC standard house assumed to be AFUE = 80%, SEER= 11, and the Water Heater Efficiency = 76% (i.e., According to the NAHB the existing housing stock already contained equipment in compliance with the 2001 IECC).

[13] In this figure, rendered with the DrawBDL program (Huang 2002), two potential types of shading area shown, shading from the eaves of the house and shading from nearby structures (i.e., the fence-like structure surrounding the house). In the calculations performed for this study, the transmittance of these shades were set equal to unity (i.e., transparent).

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

Results: 2002 Emissions Reductions From the Implementation of the 2001 IECC to Single-Family Residential

Calculated NOx emissions reductions from the implementation of 2001 IECC to single-family residences in 2002 can be seen in Table 1 and Figure 7. Each row in Table 1 represents an affected or non-attainment county, and contains information by column about the Power Control Area[14], the designated 2001 IECC Climate zone[15], the number of projected housing units[16], the simulated 1999 electricity use for an average house, the simulated electricity use of a house that is compliant with the 2001 IECC, the peak date of the electricity use on the TMY2 file used for the simulation, the daily electricity use on the peak day for the 1999 house and the 2001 IECC code-compliant house, the annual kWh savings for an average house, the total county-wide electricity savings for all houses built in the county, the PCA-average NOx/MWh emissions factor assigned to the primary utility supplier for each county, and the NOx savings for each year (tons/year and tons/peak-day). Electricity savings from the 2001 IECC code implementation average 11% to 20% of the annual electricity use, and of importance to ozone-plagued cities, a 11% to 23% reduction in peak daily electricity use[17], which equates to about 2 tons of NOx/peak-day for single-family residential. Figure 7 shows the geographic distribution of the calculated electricity savings (upper map, MWh/day), and E-GRID calculated emissions reductions (lower map, peak tons-NOx/day).

[14] The Power Control Area represents the primary utility supplier to a particular county, secondary and tertiary suppliers are not listed. Counties listed as ERCOT were counties that were not assigned to a Power Control Area.

[15] The IECC climate zone shown include, climate zone 2 (500 – 999 HDD_{65F}) , zone 3 (1,000 – 1,499 HDD_{65F}), zone 4 (1,500 – 1,999 HDD_{65F}), zone 5 (2,000 – 2,499 HDD_{65F}), and zone 6 (2,500 – 2,999 HDD_{65F}).

[16] The number of projected single-family housing units for 2002 was determined using a linear projection of the housing growth for the three previous years.

[17] The majority of these savings appear to be related to the improved windows.

Several features are worth noting in Figure 7. First, in the upper map, as expected, the counties that experience the largest reductions in electricity use correspond to the counties with the most construction. However, of importance to emissions reductions, the reductions of NOx reductions at the power plant occur in counties that may not be

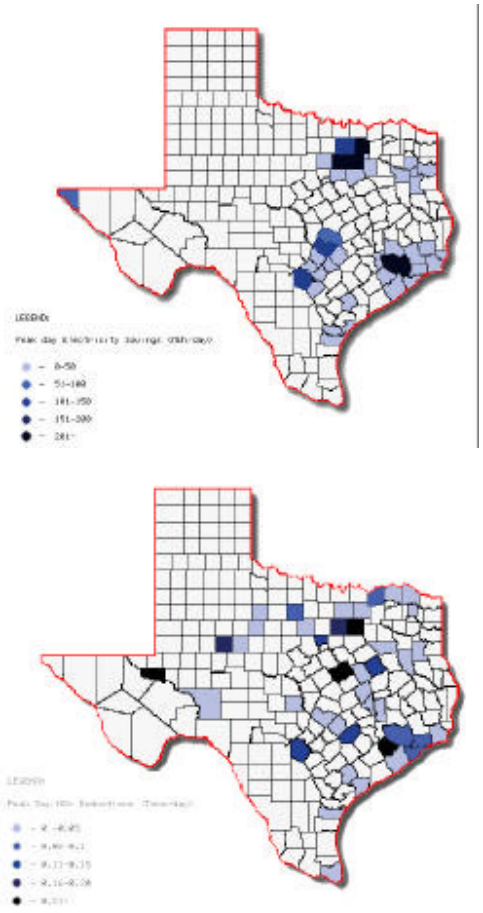

Figure 7: *Distribution of annual electricity reductions (upper map) and the associated NOx reductions (lower map) from implementation of the 2000 IECC.*

experiencing the most construction. For example, in the Houston area, Ft. Bend county is calculated to have 0.23 tons NOx/peak-day reduction because of this county contains a very large power plant for the major utility that serves this region. However, Ft. Bend county has only modest construction growth. In contrast to this is the Dallas/Ft. Worth area contains two counties (i.e., Dallas and Tarrant) that contain power plants and significant new construction activity. Therefore, the combined DOE-2/E-GRID analysis provides the state's pollution decision makers with a new tool for deciphering not only where the pollution reductions are coming from but also where the electricity reductions are coming from – important information for rule-making legislators as well.

SUMMARY

In 2001, the Texas State Legislature formulated and passed Senate Bill 5 to reduce ozone levels by encouraging the reduction of emissions of NO_x. This paper has outlined the methodology that was developed to report the electricity savings associated with the adoption of the 2001 IECC in single-family residential construction in non-attainment and affected counties. These electricity savings were converted to NO_x reductions using the EPA's E-GRID database, which contains a state-wide, utility grid conversion model. This methodology is composed of several procedures that calculate and verify savings using several different sources of information. These procedures include the calculation of electricity savings from the implementation of the IECC 2001 in new residences in non-attainment and affected counties using code-traceable DOE-2 simulation, and the EPA's E-GRID database for assigning the reduced electricity use to power plants and the associated emissions reductions. Results were presented for application of the methodology to single-family residential construction in 2002. The results from the application of the methodology to the projected 2002 residential construction data have yielded valuable information for the state's environmental pollution control planners.

Future work includes the development of fuel-neutral, multi-family and commercial code-traceable DOE-2 simulations and the development of procedures to feed the county-by-county, simulated hourly outputs of emissions reductions into the state's photochemical model for modeling the reductions during the 2000 episode day[18].

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[18] Currently, the TCEQ is using the Comprehensive Air Quality Model with extensions (CAMx) model for simulating the photochemical reactions that produce ozone on the states non-attainment and affected counties (Nobel et al. 2001).

Thesis contains a detailed description of the procedures outlined in this paper.

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