Statewide Emissions Reduction, Electricity and Demand Savings from the Implementation of Building-Energy-Codes in Texas

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ABSTRACT

This paper presents estimates of the statewide emissions reduction, electricity and electric demand savings achieved in 2002-2009, the first eight years following the adoption of building-energy-codes in new construction in Texas. The paper focuses on the estimates of the electricity and electric demand savings from the adoption of energy codes for single-family residences in Texas, as well as the corresponding increase in construction costs over the eight-year period from 2002 through 2009, and the estimates of the statewide emissions reduction.

Using the Energy Systems Laboratory's International Code Compliance Calculator (IC3) simulation tool, the cumulative statewide electricity and electric demand savings over the eight year period from 2002 to 2009 are $1,706 million for the summer ($776 million from electricity savings and $929 million from demand savings) and $1,803 million for the winter periods ($776 million from electricity savings and $1,027 million from demand savings), while the total increased costs of construction are estimated to be $670 million.

In 2009, the estimated Ozone Season Day (OSD) NOx emissions reduction from energy code-compliant single-family residential construction in Texas was 4.8 tons-NOx/day. This accounts for 11.1% of the estimated total NOx emissions reduction from all of the energy efficiency and renewable energy (EE/RE) programs of the Texas Emissions Reduction Plan (TERP) that focus on stationary sources of emissions. In 2009, the annual NOx emissions reduction from energy-code-compliant residential construction built since 2002 was 879 tons-NOx/year, which is 5.7% of the estimated annual total NOx savings achieved from all of the EE/RE stationary programs of the Texas Emissions Reduction Plan. This annual amount of emissions reduced from energy-code-compliant residential construction is equal to removing NOx emissions from about 46,000 cars for an entire year.

INTRODUCTION

In 2001, the Texas Emissions Reduction Plan (TERP) was established by the 77th Texas Legislature through the enactment of Senate Bill (SB) 5. The Plan was devised to provide the Texas Natural Resource Conservation Commission – later renamed as the Texas Commission on Environmental Quality (TCEQ) – with tools that will help achieve important environmental and economic goals, which include making the air in Texas safer to breathe and meeting the minimum federal ambient air quality standards.

One of the TERP's energy efficiency programs to reduce emissions from stationary sources was the establishment of the Texas Building Energy Performance Standards (TBEPS) that define the building energy codes for all new residential and commercial construction statewide. The original TBEPS were based on the energy efficiency chapter of the 2000 International Residential Code (IRC), including the 2001 Supplement, for single-family residences, (i.e., one- and two-family residences of three stories or less above grade) and the 2000 International Energy Conservation Code (IECC), including the 2001 Supplement, for commercial, industrial and residential buildings over three stories. Over the years since the establishment of the TERP, newer editions of the IRC and the IECC have been published. The Energy Systems Laboratory has reviewed the stringency of the new code editions and provided recommendations to the State on whether to upgrade the TBEPS to the new editions. In the time frame of 2002-2009, the State of Texas did not adopt any of the newer editions of the energy efficiency codes as the TBEPS. During this timeframe, several individual jurisdictions did adopt the newer editions of the IRC and the IECC.

The analysis shows that the building energy code has substantially improved the energy efficiency of housing in Texas, resulting in reduced annual heating/cooling, which is reflected in the reduced utility bills for residential customers, reduced demand on Texas' electric grid, and reduced emissions at the power plants. This paper presents an analysis of the statewide emissions reduction resulted from the implementation of the TBEPS in single-family residential construction during the period 2002-2009, the first eight years following the initiation of the TERP, and the statewide electricity and electric demand savings achieved, including corresponding construction cost increases over the eight-year period.

METHODOLOGY

Building-Level Analysis

At the building-level analysis, the energy savings and peak demand reductions per house were calculated using the IC3 simulation program (BDL version 4.01.07 of IC3), which is based on the DOE-2.1e simulation program and the appropriate TMY2 weather files for the corresponding location. The IC3 uses a performance method of compliance.[1]
To perform the analysis, counties in Texas representing three 2006 IECC Climate Zones across Texas were selected: Harris County for Climate Zone 2, Tarrant County for Climate Zone 3, and Potter County for Climate Zone 4 (Figure 1.). For each representative county, a total of six simulations that represent pre-code 1999 conditions and code-compliant conditions meeting the requirements of the 2001 IECC and the 2006 IECC were simulated for the appropriate periods: three runs for (a) an electric/gas house (i.e., a gas-fired furnace for space heating, and a gas-fired water heater for domestic water heating) and the next three runs for (b) a heat pump house[2] (i.e., a house with a heat pump for space heating, and electric water heater for domestic water heating). Using these models, the energy savings and peak demand reductions per house compared to the pre-code building were calculated for each climate zone.

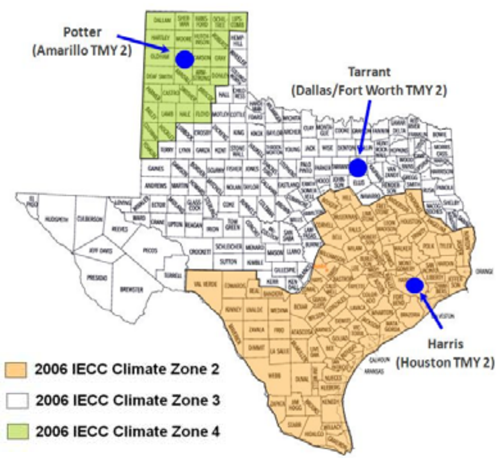


Figure 1. 2006 IECC Climate Zone Classification and Three Selected Counties in Texas

State-Level Analysis

At the state-level analysis, two different approaches were applied to calculate the statewide annual electricity and electric demand savings associated with the energy codes implementation in Texas. To calculate the statewide electricity savings in 2002-2009 from code-compliant, new single-family housing in Texas, the annual MWh savings, reported in the Laboratory's Annual Reports submitted to the TCEQ, were used (Haberl et al. 2002-2010). For the years 2002 through 2004, the annual electricity savings (MWh/year) were calculated for the 41 non-attainment and affected counties. From 2005 to 2009, the savings were calculated for all the counties in Electric Reliability Council of Texas (ERCOT) region, which includes the 41 non-attainment and affected counties. These annual electricity savings were then multiplied by the annual average electric prices in Texas published by the US DOE EIA (2011) shown in Figure 2.

To compute the statewide electric demand savings, the peak demand reductions per house calculated in the building-level analysis were multiplied by the number of new single-family houses built in each climate zone of each year (RECenter 2011) and aggregated to annual totals using an annual degradation factor of 5%. Figure 2 shows the building permits per year for new single-family residences in Texas by climate zone as well as the average statewide electricity price (□/kWh). The ratio of electric/gas and heat pump houses constructed in Texas was determined using the annual surveys, National Association of Home Builders (NAHB) (NAHB 2001–2005 and 2009-2010). The 2001 IECC and 2006 IECC were assumed to be adopted across Texas in 2002 and 2007, respectively in the analysis. A 20% initial discount factor and a 7% transmission and distribution loss factor were applied to the calculations.

To estimate electric demand savings, the calculated statewide electric demand savings (MW) were then multiplied by the average capital cost of a natural gas combined cycle power plant, $1,165 per kW (Kaplan, 2008) using a 15% reserve margin (Faruqui et al. 2007).

[1] The performance method of compliance is one of the two methods of compliance detailed by the IECC. The IRC, which is the prescriptive TBEPS for single-family construction, allows following the compliance requirements of the IECC.

[2] To estimate the heating savings, heat pump systems were selected for space heating of all-electric houses instead of electric-resistance heaters.

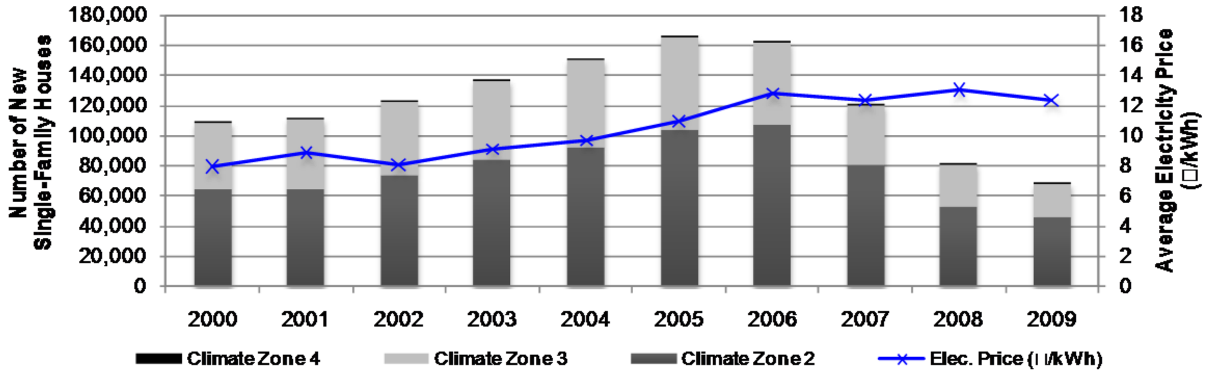


Figure 2. Number of Building Permits for New Single-Family Construction in Texas by Climate Zone and Annual Average Price of Electricity for Residential Customers in Texas

Incremental Cost Analysis

Finally, an incremental cost analysis was conducted to determine if the savings are sufficient to justify the increased construction costs for upgrading to the IECC. The increased costs for upgrading major residential building components and systems to comply with the 2001 IECC and the 2006 IECC were examined using R.S. Means Residential Cost Data (R. S. Means 2002 and 2007), the Building Codes Assistance Project (BCAP) Incremental Construction Cost Analysis for New Homes (Paquette et al. 2010), the American Council for an Energy-Efficient Economy (ACEEE) Consumer Guide to Home Energy Savings (Amann et al. 2007), and the similar incremental cost analysis studies in Texas (Malhotra et al. 2008; Kim et al. 2010). The construction characteristics published by the NAHB (2000) were used to define pre-code house conditions. The calculated per-house costs of implementation of the IECC were then multiplied by the number of new single-family houses in the ERCOT region (41 non-attainment and affected counties from 2002 to 2004 and all the counties in the ERCOT region from 2005 to 2009) and aggregated to cumulative total increased costs over the eight year period from 2002 to 2009. The 2001 IECC and 2006 IECC were assumed to be adopted across Texas in 2002 and 2007 for new single-family residences, respectively.

Annual and Ozone Season Day (OSD) Emissions Reduction Calculations

The statewide NOx emissions reductions from the electricity reductions achieved by implementing the building-energy-codes in new construction in Texas were calculated based on the US EPA's Emissions and Generation Resource Integrated Database (eGrid) for Texas[3] for both annual and Ozone Season Day (OSD) periods. For an annual estimation, the total MWh electricity savings were calculated for each Power Control Authorities (PCA) and input in the eGrid to calculate the annual emissions reduction for the corresponding PCA. The calculated NOx emissions savings for each PCA were then aggregated to compute the statewide annual NOx emissions reductions. For an OSD estimation, the daily average of the OSD period electricity savings calculated for each PCA were input in the eGrid, which were then aggregated to compute the statewide OSD NOx emissions reductions.

BASE-CASE BUILDING DESCRIPTION

The base-case building used for a simulation in the building-level analysis is a 2,325 sq. ft., square-shape, one story, single-family, detached house with a floor-to-ceiling height of 8 feet. The house has an attic with a roof pitched at 23 degrees. The wall construction is light-weight wood frame with 2x4 studs at 16" on center with a slab-on-grade-floor, which is typical construction according to the NAHB survey (NAHB 2003). The pre-code building envelope and system characteristics were determined based on the construction characteristics published by the NAHB (2000) for typical residential construction in East and West Texas for 1999. The code-compliant building envelope and system characteristics were determined from the general characteristics and the climate-specific characteristics as specified in the 2001 IECC and the 2006 IECC. Table 1 summarizes the base-case building characteristics used in the simulation model for each climate zone.

To facilitate a more accurate and realistic comparison between the codes, several modifications were applied to the simulations as follows[4]. For the

[3] The emissions savings were calculated using the 2007 eGRID database which was specially prepared for Texas by Mr. Art Diem at the US EPA using a 1999 base year.

[4] These unifying modifications to the simulation inputs were necessary because the comparisons between the pre-code, 2001 and 2006 simulations could not be performed if different values were used.

Table 1. Base Case Building Description

Characteristics	Pre-Code 1999			2001 IECC			2006 IECC		
	CZ 2	CZ 3	CZ 4	CZ 2	CZ 3	CZ 4	CZ 2	CZ 3	CZ 4
	Harris	Tarrant	Potter	Harris	Tarrant	Potter	Harris	Tarrant	Potter
Building									
Building Type	Single family, detached house								
Gross Area[2]	2,325 sq. ft. (48.21 ft. x 48.21 ft.)								
Number of Floors	1								
Floor to Floor Height (ft.)[2]	8								
Orientation	South facing								
Construction									
Construction	Light-weight wood frame with 2x4 studs spaced at 16" on center								
Floor	Slab-on-grade floor								
Roof Configuration	Unconditioned, vented attic								
Roof Absorptance	0.75								
Ceiling Insulation (hr-sq.ft.-°F/Btu)[1]	R-27.08	R-26.75		R-30	R-38		R-27.84		R-32.51
Wall Absorptance	0.75 (Assuming brick facia exterior)								
Wall Insulation (hr-sq.ft.-°F/Btu)[1]	R-13.99	R-14.18		R-11		R-12/3 c.i.	R-11.8		
Slab Perimeter Insulation	None		R-6	None		R-6	None		R-10
Ground Reflectance	0.24 (Assuming grass)								
U-Factor of Glazing (Btu/hr-sq.ft.-°F)[1]	1.11	0.87		0.47		0.41	0.75	0.65	0.40
Solar Heat Gain Coefficient (SHGC)[1]	0.71	0.66		0.40		0.68	0.40		
Window Area[2]	18% of conditioned floor area								
Interior Shading	Sum 0.7 Win 0.85			Sum 0.7 Win 0.9 (Simulation adjustment[3]: Sum 0.7, Win 0.85)			Summer 0.7, Winter 0.85		
Exterior Shading	None								
Roof Radiant Barrier	No								
Slope of Roof	5:12 (= 23 degrees)								
Space Conditions									
Space Temperature Set point	72°F Heating, 75°F Cooling			68°F Heating, 78°F Cooling, 5F setback/setup			68°F Heating, 78°F Cooling		
				(Simulation adjustment[3]: Heating 72F, Cooling 75F)					
Internal Heat Gains	1.095 kW			0.88 kW (Simulation adjustment[3]: 1.095 kW)			1.095 kW (0.547 kW for lighting and 0.547 kW for equipment)		
Number of Occupants	None (Assuming internal gains include heat gain from occupants)								
Mechanical Systems									
HVAC System Type	(a) Electric/Gas House: Electric cooling (air conditioner) and natural gas heating (gas fired furnace)								
	(b) Heat Pump House: Electric cooling and heating (air conditioner with heat pump)								
HVAC System Efficiency[1]	(a) Electric/Gas House: SEER 11 AC, 0.80 AFUE			(a) Electric/Gas House: SEER 10 AC[4], 0.78 AFUE			(a) Electric/Gas House: SEER 13 AC, 0.78 AFUE		
	(b) Heat Pump House: SEER 11 AC, 6.8 HSPF			(b) Heat Pump House: SEER 10 AC[4], 6.8 HSPF			(b) Heat Pump House: SEER 13 AC, 7.7 HSPF heat		
Cooling Capacity (Btu/hr)	55,800 (= 500 sq. ft./ton)								
Heating Capacity (Btu/hr)	55,800 (= 1.0 x cooling capacity)								
DHW System Type	(a) Electric/Gas House: 40-gallon tank type gas water heater with a standing pilot light								
	(b) Heat Pump House: 50-gallon tank type electric water heater (without a pilot light)								
DHW Heater Energy Factor	(a) Electric/Gas House: 0.544						(a) Electric/Gas House: 0.594		
	(b) Heat Pump House: 0.864						(b) Heat Pump House: 0.904		
Duct Distribution System Efficiency	0.80								
Supply Air Flow (CFM/ton)	360								
Infiltration Rate (SG)	SLA= 0.00057						SLA= 0.00036		

Note:

[1] The ceiling and wall insulation, glazing specifications, and HVAC system efficiencies for the pre-code houses were determined based on the NAHB Survey for typical residential construction in East and West Texas for 1999.

[2] For a fair comparison, the pre-code house was assumed to have the same floor area, ceiling height, and window areas as the 2001 IECC code-compliant house rather than following the NAHB survey results.

[3]To facilitate a more accurate and realistic comparison between the codes, several adjustments were applied to the 2001 and 2006 IECC codes.

[4]SEER 10 was used to comply with the 2001 IECC performance path.

2001 IECC simulation, internal heat gains and interior shading fractions for winter were adjusted to match the values required in the 2006 IECC: internal heat gains: 0.547 kW/house for lighting and 0.547 kW/house for equipment; and interior shading fraction for winter: 0.85. For all simulations, the thermostat set points were also modified to match the 2009 IECC specifications of 72°F for heating and 75°F for cooling with no set-back/set-up schedule as a more realistic estimate of savings[5].

ENERGY SAVINGS AND ELECTRIC DEMAND REDUCTIONS PER HOUSE

Table 2 summarizes the results of the energy savings analysis for Harris, Tarrant, and Potter Counties, including: the annual total site energy consumption (MMBtu/year and $/year by total and fuel types), as well as energy savings associated with the IECC code adoption. Table 3 presents summer and winter peak electric demand and reductions expected from 2001 and 2006 IECC adoption.

Annual Per-House Energy Consumption

Across all counties, the pre-code houses reported the highest consumption with a total of: (a) an electric/gas house: 122.8 MMBtu/year for Harris County, 133.9 MMBtu/year for Tarrant County, and 179.1 MMBtu/year for Potter County and (b) a heat pump house: 93.1 MMBtu/year for Harris County, 94.7 MMBtu/year for Tarrant County, and 113.0 MMBtu/year for Potter County. Conversely, the 2006 IECC code-compliant house reported the lowest site energy consumption with a total of: (a) an electric/gas house: 100.6 MMBtu/year for Harris County, 112.0 MMBtu/year for Tarrant County, and 128.9 MMBtu/year for Potter County and (b) a heat pump house: 76.7 MMBtu/year for Harris County, 79.2 MMBtu/year for Tarrant County, and 87.0 MMBtu/year for Potter County.

Similar trends were observed in the estimated annual utility bill of a house using $0.11/kWh for electricity (PUCT 2010) and $0.84/therm for natural gas (Climate Zone 2) and $0.64/therm for natural gas (Climate Zone 3 and 4) for natural gas (CPS Energy 2010, Atmos Energy 2010a and 2010b). Across the counties, the pre-code houses are expected to have the highest energy bills: (a) an electric/gas house: $2,724/year for Harris County, $2,617/year for Tarrant County, and $2,679/year for Potter County and (b) a heat pump house: $3,001/year for Harris County, $3,053/year for Tarrant County, and $3,643/year for Potter County. The 2006 IECC code-compliant houses are expected to have the lowest energy bills: (a) an electric/gas house: $2,237/year for Harris County, $2,192/year for Tarrant County, and $2,145/year for Potter County and (b) a heat pump house: $2,473/year for Harris County, $2,553/year for Tarrant County, and $2,805/year for Potter County.

Annual Per-House Energy Savings from the Adoption of the 2001 and 2006 IECC

The annual energy savings associated with the 2001 and 2006 IECC were calculated compared to the pre-code cases: (a) an electric/gas house: 14.2-22.2 MMBtu/year ($231-$487/year) for Harris County, 13.7-21.9 MMBtu/year ($209-$424/year) for Tarrant County, and 31.4-50.2 MMBtu/year ($111-$533/year) for Potter County and (b) a heat pump house: 7.5-16.4 MMBtu/year ($242-$529/year) for Harris County, 7.4-15.5 MMBtu/year ($239-$500/year) for Tarrant County, and 9.7-26.0 MMBtu/year ($313-$838/year) for Potter County. The corresponding percent savings over a pre-code house are: (a) an electric/gas house: 8.5-17.9% for Harris County, 8.0-16.2% for Tarrant County, and 4.1-19.9% for Potter County[6] and (b) a heat pump house: 8.1-17.6% for Harris County, 7.8-16.4% for Tarrant County, and 8.6-23.0% for Potter County.

For an electric/gas house, the natural gas savings (MMBtu/year) achieved from 2001 IECC is larger than electricity savings. In Potter County, the savings of all three versions of IECC codes are mainly from the savings in natural gas. However, due to the difference in the unit cost of electricity and gas, the dollar savings from electricity are higher than the savings from gas, except in Potter County. In Potter County, no electricity savings were observed from 2001 IECC code adoption. From the 2006 IECC code adoption, the savings from gas and electricity are almost the same.

Per-House Peak Electric Demand Reductions from 2001 and 2006 IECC

The pre-code houses reported the highest peak summertime demand: (a) an electric/gas house: 6.7 kW for Harris County, 7.0 kW for Tarrant County, and 7.0 kW for Potter County and (b) a heat pump house: 7.1 kW for Harris County, 7.3 kW for Tarrant County, and 7.5 kW for Potter County. Not surprisingly, the 2006 IECC code-compliant house

[5] Although the results of the 2009 IECC simulations are not reported in this report, ongoing work identified these changes to the simulation inputs.

[6] A negative electricity savings was expected for a 2001 IECC code-compliant, electric/gas house in Potter County due to the increased cooling energy consumption. This is because a lower SEER (SEER 10) A/C unit was used for a 2001 IECC code-compliant house simulation to comply with the 2001 IECC performance path requirement. For a pre-code house, a SEER 11 A/C unit was used from the NAHB survey results (2000).

Table 2. Annual Per-House Energy Savings from IECC Code-Compliant, Single Family Residences in Texas

Test Cases		Annual Total Site Energy Consumption						Annual Total Site Energy Savings						
		(MMBtu/year)			($/year)			(MMBtu/year)			($/year)			
		Total	Elec.	NG	Total	Elec.	NG	Total	Elec.	NG	Total	Elec.	NG	% Savings vs. Pre-Code
(a) Electric/Gas House														
Harris County (CZ 2)	Pre-Code 1999	122.8	71.0	51.8	$2,724	$2,289	$435	-	-	-	-	-	-	-
	2001 IECC Modified	108.6	66.3	42.3	$2,493	$2,137	$355	14.2	4.7	9.5	$231	$152	$80	**8.5%**
	2006 IECC Modified	100.6	58.4	42.2	$2,237	$1,883	$354	22.2	12.6	9.6	$487	$406	$81	**17.9%**
Tarrant County (CZ 3)	Pre-Code 1999	133.9	68.1	65.8	$2,617	$2,195	$421	-	-	-	-	-	-	-
	2001 IECC Modified	120.2	63.4	56.8	$2,407	$2,044	$364	13.7	4.7	9.0	$209	$152	$58	**8.0%**
	2006 IECC Modified	112.0	57.1	54.9	$2,192	$1,841	$351	21.9	11.0	10.9	$424	$355	$70	**16.2%**
Potter County (CZ4)	Pre-Code 1999	179.1	59.3	119.8	$2,679	$1,912	$767	-	-	-	-	-	-	-
	2001 IECC Modified	147.7	62.8	84.9	$2,568	$2,025	$543	31.4	-3.5	34.9	$111	-$113	$223	**4.1%**
	2006 IECC Modified	128.9	51.1	77.8	$2,145	$1,647	$498	50.2	8.2	42.0	$533	$264	$269	**19.9%**
(b) Heat Pump House														
Harris County (CZ 2)	Pre-Code 1999	93.1	93.1	-	$3,001	$3,001	-	-	-	-	-	-	-	-
	2001 IECC Modified	85.6	85.6	-	$2,760	$2,760	-	7.5	7.5	-	$242	$242	-	**8.1%**
	2006 IECC Modified	76.7	76.7	-	$2,473	$2,473	-	16.4	16.4	-	$529	$529	-	**17.6%**
Tarrant County (CZ 3)	Pre-Code 1999	94.7	94.7	-	$3,053	$3,053	-	-	-	-	-	-	-	-
	2001 IECC Modified	87.3	87.3	-	$2,814	$2,814	-	7.4	7.4	-	$239	$239	-	**7.8%**
	2006 IECC Modified	79.2	79.2	-	$2,553	$2,553	-	15.5	15.5	-	$500	$500	-	**16.4%**
Potter County (CZ4)	Pre-Code 1999	113.0	113.0	-	$3,643	$3,643	-	-	-	-	-	-	-	-
	2001 IECC Modified	103.3	103.3	-	$3,330	$3,330	-	9.7	9.7	-	$313	$313	-	**8.6%**
	2006 IECC Modified	87.0	87.0	-	$2,805	$2,805	-	26.0	26.0	-	$838	$838	-	**23.0%**

Table 3. Annual Per-House Peak Electric Demand Reductions from IECC Code-Compliant, Single Family Residences in Texas

Test Cases		Summer Demand (kW)			Winter Demand (kW)		
		Peak Demand[1]	Reduction	% Reduction vs. Pre-Code	Peak Demand[2]	Reduction	% Reduction vs. Pre-Code
(a) Electric/Gas House							
Harris County (CZ 2)	Pre-Code 1999	6.7	-	-	-	-	-
	2001 IECC Modified	6.2	0.5	8.1%	-	-	-
	2006 IECC Modified	4.8	2.0	29.5%	-	-	-
Tarrant County (CZ 3)	Pre-Code 1999	7.0	-	-	-	-	-
	2001 IECC Modified	6.4	0.6	8.4%	-	-	-
	2006 IECC Modified	5.1	1.9	27.2%	-	-	-
Potter County (CZ4)	Pre-Code 1999	7.0	-	-	-	-	-
	2001 IECC Modified	7.0	0.0	0.0%	-	-	-
	2006 IECC Modified	5.1	1.9	27.1%	-	-	-
(b) Heat Pump House							
Harris County (CZ 2)	Pre-Code 1999	7.1	-	-	11.3	-	-
	2001 IECC Modified	6.5	0.5	7.7%	8.2	3.1	27.6%
	2006 IECC Modified	5.1	2.0	28.4%	7.7	3.6	32.0%
Tarrant County (CZ 3)	Pre-Code 1999	7.3	-	-	12.0	-	-
	2001 IECC Modified	6.7	0.6	8.1%	9.6	2.4	19.6%
	2006 IECC Modified	5.4	1.9	26.3%	8.5	3.5	29.5%
Potter County (CZ4)	Pre-Code 1999	7.5	-	-	17.9	-	-
	2001 IECC Modified	7.5	0.0	0.0%	13.8	4.0	22.5%
	2006 IECC Modified	5.5	1.9	25.8%	12.2	5.6	31.4%

Note:

[1]Summer Peak Demand Date: (a) Electric/Gas House-September 16 (CZ 2), August 13 (CZ 3), and June 29 (CZ 4); and (b) Heat Pump House-September 16 (CZ 2), August 13 (CZ 3), and June 29 (CZ 4)

[2]Winter Peak Demand Date: (b) Heat Pump House-January 11 (CZ 2), January 15(CZ 3), and January 7 (CZ 4)

reported the lowest peak summertime demand: (a) an electric/gas house: 4.8 kW for Harris County, 5.1 kW for Tarrant County, and 5.1 kW for Potter County and (b) a heat pump house: 5.1 kW for Harris County, 5.4 kW for Tarrant County, and 5.5 kW for Potter County. In the analysis, the same peak day was used regardless of the house type: September 16 for Harris County, August 13 for Tarrant County, and June 29 for Potter County.

In the winter, the peak electric demands were estimated for a heat pump house. The peak days used in the analysis were: January 11 for Harris County, January 15 for Tarrant County, and January 7 for Potter County. As reported, the highest peak wintertime electric demands are for a pre-code house: 11.3 kW for Harris County, 12.0 kW for Tarrant County, and 17.9 kW for Potter County. The lowest wintertime demands for the 2006 IECC code-compliant house are: 7.7 kW for Harris County, 8.5 kW for Tarrant County, and 12.2 kW for Potter County.

Finally, the peak electric demand reductions associated with the 2001 and 2006 IECC were calculated for both summer and winter. For summer, the reductions in peak summertime electric demands are expected to happen in the afternoon between 3 to 5 pm for both electric/gas and heat pump houses: 0.5-2.0 kW for Harris County, 0.6-1.9 kW for Tarrant County, and 1.9 kW for Potter County. In Potter County, no demand savings are expected in summer from the 2001 IECC code adoption. For winter, the electric demand reductions were estimated to occur in early morning hours between 6 and 8 am for a heat pump house: 3.1-3.6 kW for Harris County, 2.4-3.5 kW for Tarrant County, and 4.0-5.6 kW for Potter County. The corresponding percentage summer electric demand reductions over a pre-code house are: (a) an electric/gas house: 8.1-29.5% for Harris County, 8.4-27.2% for Tarrant County, and 27.1% for Potter County and (b) a heat pump house: 7.7-28.4% for Harris County, 8.1-26.3% for Tarrant County, and 25.8% for Potter County. In winter, the percent reductions are: (b) a heat pump house: 27.6-32.0% for Harris County, 19.6-29.5% for Tarrant County, and 22.5-31.4% for Potter County.

INCREMENTAL COST ANALYSIS

The per-house increased costs for upgrading major building components and systems to comply with the 2001 IECC and the 2006 IECC were estimated for each climate zone[7]. As a result, the per-house increased construction costs for upgrading to the 2001 IECC are estimated to be $600 for Climate Zone 2, $778 for Climate Zone 3, and $1,215 for Climate Zone 4. To comply with the 2006 IECC, the per-house increased costs are estimated to be $1,002 and $ 902 for Climate Zone 2, $1,015 and $1,115 for Climate Zone 3, and $1,644 and $1,744 for Climate Zone 4 for the electric/gas and heat pump houses, respectively.

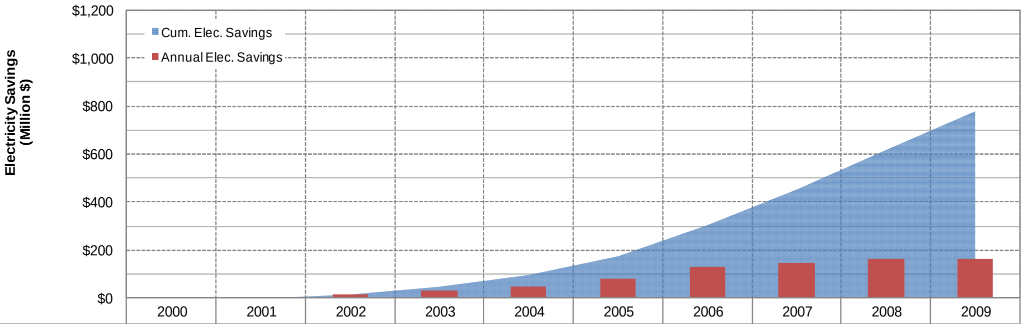
STATEWIDE ELECTRICITY AND ELECTRIC DEMAND SAVINGS

Figure 3 presents the annual and cumulative statewide electricity savings from code-compliant new single-family housing in Texas for years 2002 through 2009. Figure 4 presents the summer and winter electric demand reductions and the corresponding electric demand savings. The annual statewide electricity savings in 2009 are estimated to be $161 million, and the total cumulative electricity savings over the period from 2002 to 2009 are estimated to be $776 million. Although expected MWh savings in 2009 (1,301,063 MWh) are higher than 2008 MWh savings (1,256,764 MWh), a decrease of dollar savings in 2009 is expected because of lower electricity rates in 2009: from $0.13/kWh to $0.12/kWh. The electric demand reductions in 2009 are estimated to be 694 MW for the summer and 766 MW for the winter periods. The corresponding electric demand savings from the reduced peak demands (i.e., avoided construction cost of a peaking plant) are estimated to be $929 million for the summer and $1,027 million for the winter periods from 2002 to 2009.

Figure 5 shows the cumulative statewide increased costs with the cumulative statewide electricity and demand savings from code-compliant, single-family residences built between 2002 and 2009.[8] The cumulative statewide costs over the eight year period from 2002 to 2009 are estimated to be $670 million while the cumulative electricity and demand savings are $1,706 million for the summer ($776 million from electricity savings and $929 million from demand savings) and $1,803 million for the winter periods ($776 million from electricity savings and $1,027 million from demand savings).

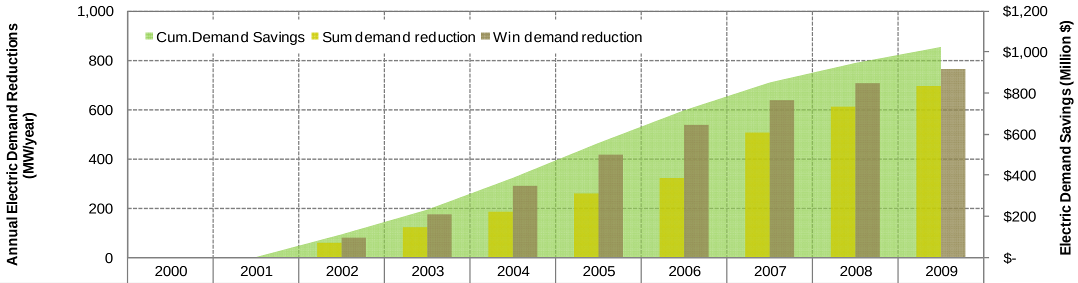
[7] Details on the results of incremental cost analysis are available in Kim et al. (2011).

[8] In the figure, for electric demand savings, the estimation for the winter periods ($1,027 million, cumulative) was displayed instead of summer ($929 million, cumulative).



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cum. Elec. Savings	-	-	$16	$48	$97	$175	$304	$451	$615	$776
Annual Elec. Savings	-	-	$16	$32	$49	$78	$129	$148	$164	$161

Figure 3. Annual and Cumulative Statewide Electricity Savings from the IECC Code Adoption for New Single-Family Residences in Texas: 2002-2009



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cum.Demand Savings	-	-	$111	$232	$387	$558	$717	$853	$949	$1,027
Sum demand reduction	-	-	59	121	188	257	321	506	614	694
Win demand reduction	-	-	83	173	289	417	535	637	708	766

Figure 4. Annual Statewide Electric Demand Reductions and Electric Demand Savings from the IECC Code Adoption for New Single-Family Residences in Texas: 2002-2009

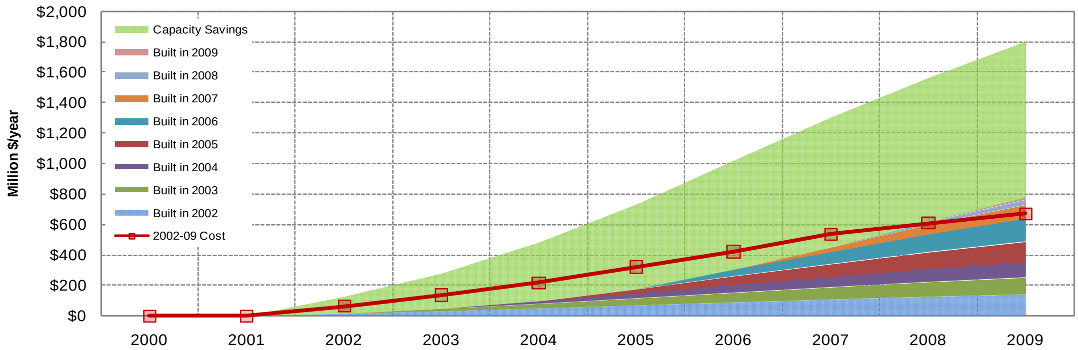


Figure 5. Cumulative Increased Costs, Statewide Electricity and Electric Demand Savings Associated with the IECC Code Adoption for Single-Family Residences in Texas: 2002-2009

Table 4. The total annual and OSD emissions reduction from energy code-compliant single-family construction in Texas and other EE/RE stationary programs under TERP, 2002-2009.

Year	Annual Emissions Reduction (tons NOx/yr)			# of cars taken off the road for 1 year equivalent to the annual emissions reduction from energy code-compliant single-family residential construction in Texas[1]	Ozone Season Day (OSD) Emissions Reduction (tons-NOx/day)		
	Energy code-compliant single-family residential construction in Texas	All EE/RE programs under TERP for stationary emissions sources[2]	% of code-compliant single-family residential construction out of stationary EE/RE programs under TERP		Energy code-compliant single-family residential construction in Texas	All EE/RE programs under TERP for stationary emissions sources	% of code-compliant single-family residential construction out of stationary EE/RE programs under TERP
2002							
2003	340	473	71.9%	17,801	2.13	2.44	87.3%
2004	301.67	346	87.2%	15,794	1.77	1.89	93.7%
2005	157.64	3,119	5.1%	8,253	0.76	8.09	9.4%
2006	707.64	6,760	10.5%	37,049	3.85	19.53	19.7%
2007	842.66	8,839	9.5%	44,118	4.50	26.24	17.1%
2008	883.34	12,727	6.9%	46,248	4.76	31.38	15.2%
2009	879.27	15,327	5.7%	46,035	4.81	43.28	11.1%
Total 2002-2009	**4112.22**	**47,591**	**8.6%**	**215,299**	**22.58**	**132.85**	**17.0%**

Note:
[1] Based on 38.2 lbs-NOx/car per year, from 2000 EPA web page
[2] TERP EE/RE programs for stationary emissions sources include: code-complaint construction, Federal buildings, the Texas Public Utility Commission (PUC) Senate Bill 7 and Senate Bill 5 programs, the EE programs managed by the Texas State Energy Conservation Office (SECO), electricity generated from wind power, and several additional statewide measures, including SEER 13 air conditioner and pilot lights.

ANNUAL AND OZONE SEASON DAY (OSD) EMISSIONS REDUCTION

Table 4 presents the annual (tons-NOx/yr) and OSD (tons-NOx/day) emissions reduction from energy code-compliant single-family construction in Texas and from all other EE/RE stationary programs under TERP.[9] The cumulative annual and OSD emissions reductions from 2002 to 2009 were also aggregated and presented in the last row of the table.

In 2009, the estimated annual NOx emissions reduction from energy code-compliant single-family residential construction in Texas was 879 tons-NOx/yr. This accounts for 5.7% of the estimated total NOx emissions reduction from all of the TERP EE/RE stationary programs, which was 15,327 tons-NOx/yr. This amount of emissions reduced from energy-code-compliant residential construction is equal to removing NOx emissions from about 46,000 cars for an entire year.

The cumulative annual NOx emissions reduction from energy-code-compliant residential construction from 2002 to 2009 was 4,112 tons-NOx/year, which is 8.6% of 47,591 tons-NOx/year - the estimated total NOx savings achieved from all of the TERP EE/RE stationary programs. This amount of emissions reduced from energy-code-compliant residential construction is equal to removing NOx emissions from about 215,300 cars for one full year over the 2002 to 2009 period.

In 2009, the estimated OSD NOx emissions reduction from energy code-compliant single-family residential construction in Texas was 4.8 tons-NOx/day. This accounts for 11.1% of the estimated total NOx emissions reduction from all of the TERP EE/RE stationary programs, which was 43.3 tons-NOx/day.

The cumulative OSD NOx emissions reduction from energy-code-compliant residential construction from 2002 to 2009 was 22.6 tons-NOx/year, which is 17.0% of 132.9 tons-NOx/year - the estimated total OSD NOx savings achieved from all of the TERP EE/RE stationary programs.

It is interesting to note that the percentage of emissions reduced that is attributed to energy-code-compliant residential construction out of all the TERP EE/RE stationary programs is greater for OSD calculations than in the annual estimation. This can be attributed to the summertime reduction in air-conditioning savings and the reduction in wind power generation, which is one of the largest emission reducing TERP EE/RE stationary programs.

[9] Details on the various TERP EE/RE stationary programs are available in Baltazar et al. 2010.

SUMMARY

Statewide emissions reduction, electricity savings and peak electric demand reductions achieved from energy code adoption for single-family residences in Texas and the corresponding increase in construction costs over the eight-year period from 2002 through 2009 are presented in this paper. In the first part of the analysis, the impact of different versions of the code (2001 and 2006) on energy savings and peak demand reductions were calculated at the individual building level using the ESL's IC3 simulation tool based on the DOE-2.1e program for three counties in Texas.

To calculate the electricity cost savings at the statewide level, the annual MWh savings from code-compliant new single-family housing in Texas for years 2002 through 2009 which were reported in the Laboratory's Annual Reports to the TCEQ, were tabulated and multiplied by the annual average prices of Texas residential electricity published by the U.S. DOE EIA. To compute the statewide annual electric demand reductions, the peak demand reductions per house calculated in the building-level analysis were multiplied by the number of new single-family houses built in each climate zone of each year, and aggregated to annual totals with an annual degradation factor of 5%. To compute the avoided construction cost of a peaking plant (i.e., electric capacity savings), the calculated statewide electric demand savings in MW were multiplied by the average capital cost of a natural gas combined-cycle power plant, $1,165 per kW, with a 15% reserve margin. The statewide NOx emissions reductions were calculated based on the US EPA's Emissions and Generation Resource Integrated Database (eGrid) for Texas. For an annual estimation, the total MWh electricity savings were calculated for each Power Control Authorities (PCA) and input in the eGrid to calculate the annual emissions reduction for the corresponding PCA. The calculated NOx emissions savings for each PCA were then aggregated to compute the statewide annual NOx emissions reductions. For an Ozone Season Day (OSD) estimation, the daily average of the OSD period electricity savings calculated for each PCA were input in the eGrid, which were then aggregated to compute the statewide OSD NOx emissions reductions.

As a result, the annual statewide electricity savings in 2009 are estimated to be $161 million, and the statewide electric demand reductions in 2009 are estimated to be 694 MW for the summer and 766 MW for the winter periods. Finally, the cumulative statewide electricity and electric capacity savings from the electric demand savings over the eight year period from 2002 to 2009 are estimated to be $1,803 million ($776 million from electricity savings and $1,027 million from capacity savings), which exceeds the increased construction costs estimated to be $670 million.

In 2009, the estimated OSD NOx emissions reduction from energy code-compliant single-family residential construction in Texas was 4.8 tons-NOx/day. This accounts for 11.1% of the estimated total NOx emissions reduction from all of the energy efficiency and renewable energy (EE/RE) programs of the Texas Emissions Reduction Plan that focus on stationary sources of emissions. In 2009, the annual NOx emissions reduction from energy-code-compliant residential construction built since 2002 was 879 tons-NOx/year, which is 5.7% of the estimated annual total NOx savings achieved from all of the EE/RE stationary programs of the Texas Emissions Reduction Plan. This annual amount of emissions reduced in 2009 from energy-code-compliant residential construction is equal to removing NOx emissions from about 46,000 cars for an entire year. The cumulative NOx emissions reduction in the years 2002-2009 combined, achieved from energy-code-compliant residential construction, is 4,112 tons-NOx. This amount of emissions is equal to removing NOx emissions from about 215,300 cars for an entire year.

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