Statewide Electricity and Demand Capacity Savings from the Implementation of IECC Code in Texas: Analysis for Single-Family Residences

Hyojin Kim
Research Associate

Juan-Carlos Baltazar
Assc. Research Engineer

Jeff S. Haberl
Professor/Assc. Director

Cynthia Lewis
TERP Manager

Bahman Yazdani, P.E.
Assc. Director

Energy Systems Laboratory, Texas A&M University System, College Station, TX.

ABSTRACT

This paper presents estimates of the statewide electricity and electric demand savings achieved from the adoption of the International Energy Conservation Code (IECC) for single-family residences in Texas and includes the corresponding increase in construction costs over the eight-year period from 2002 through 2009. Using the Energy Systems Laboratory's International Code Compliance Calculator (IC3) simulation tool, the annual statewide electricity savings in 2009 are estimated to be $161 million. The statewide peak electric demand reductions in 2009 are estimated to be 694 MW for the summer and 766 MW for the winter periods. Since 2002, the cumulative statewide electricity and electric demand savings over the eight year period from 2002 to 2009 are $1,803 million ($776 million from electricity savings and $1,027 million from electric demand savings) while the total increased costs are estimated to be $670 million.

INTRODUCTION

In September 2001, Texas adopted the 2000 International Energy Conservation Code (IECC), including the 2001 Supplement as the first statewide energy code. During this period, several improved versions of IECC have been published and adopted by individual jurisdictions. The analysis shows 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. This paper presents an analysis of the statewide electricity and electric demand savings achieved from the adoption of the different IECC versions for single-family residences in Texas, including the corresponding construction cost increases over the eight-year period from 2002 through 2009.

METHODOLOGY

The analysis consists of two parts: a building-level analysis and a state-level analysis.

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. 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[1] (i.e., a house with a heat pump for space heating, and electric

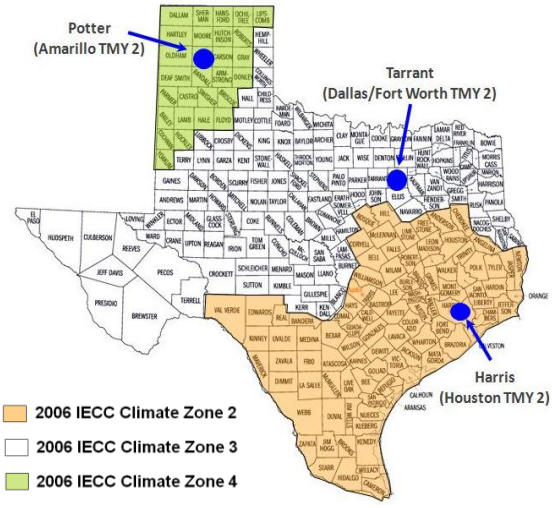


Figure 1. 2006 IECC Climate Zone Classification and Three Selected Counties in Texas

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

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.

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 IECC codes adoption in Texas. To calculate the statewide electricity savings, the annual MWh savings from code-compliant, new single-family housing in Texas for years 2002 through 2009 reported in the Laboratory's Annual Reports submitted to the Texas Commission on Environmental Quality (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 (i.e., avoided construction cost of a peaking plant), 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). Figure **3** shows the ratio of the single family residences in Texas by type of heating system for Climate Zone 2 (CZ 2) and for Climate Zones 3 and 4 (CZ 3&4 combined). 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)

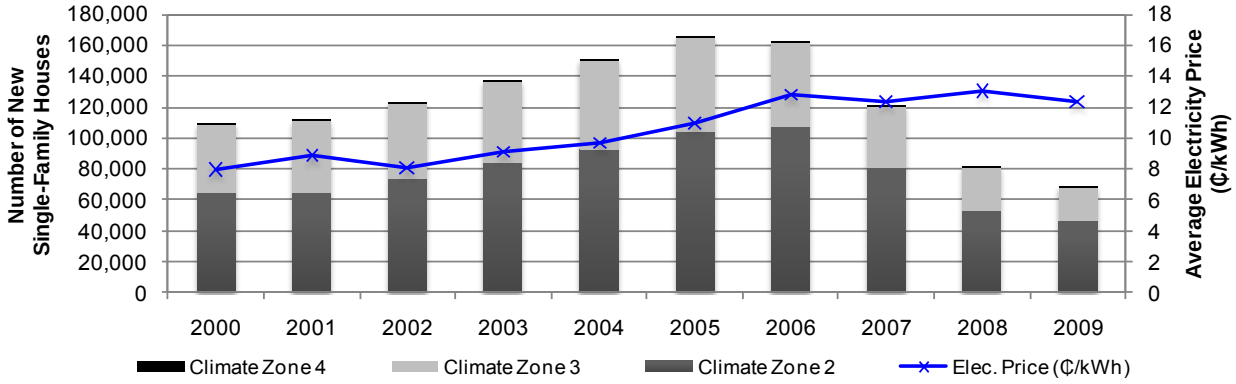


Figure 2. Number of Building Permits for New Single-Family Construction in Texas by Climate Zone and Annual Average Price of Electricity for Residential Customers in Texas

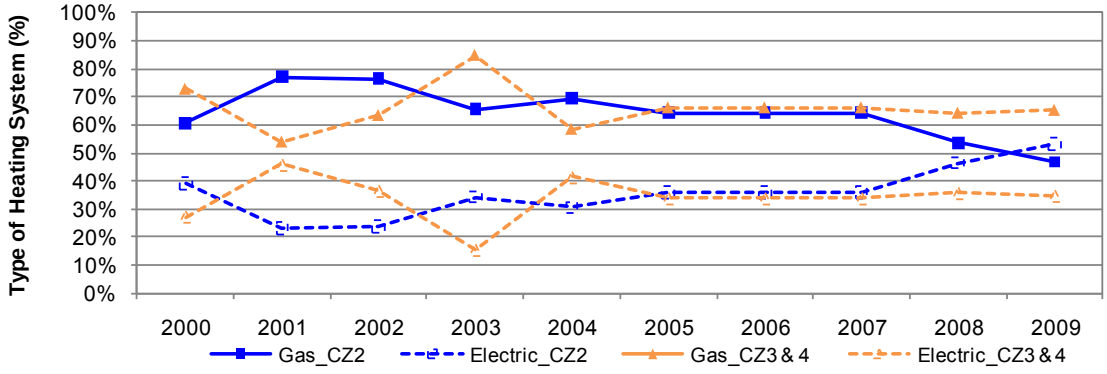


Figure 3. Type of Heating System of New Single-Family Construction in Texas

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).

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.

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[2]. For the 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[3].

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. The results are also graphically represented in Figure 4 through Figure 8.

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

[2] 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.

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

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.

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)

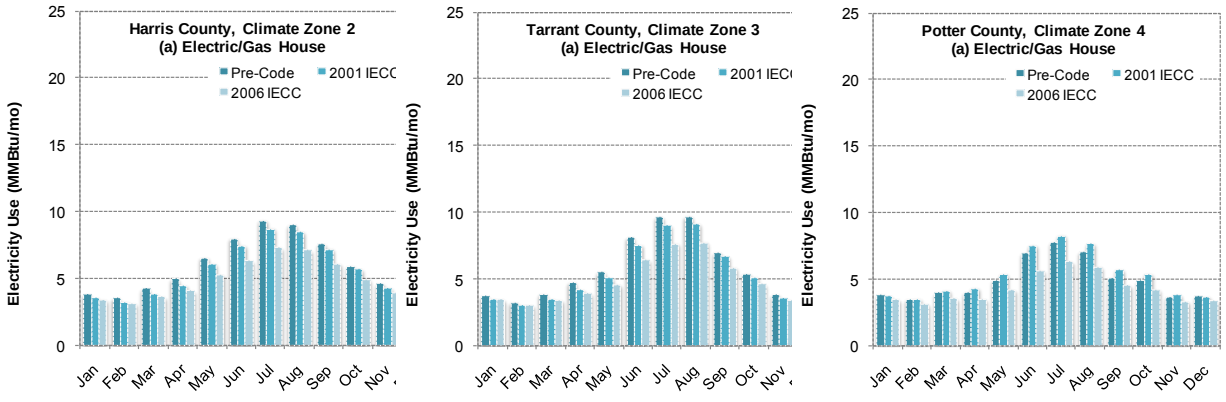


Figure 4. Monthly Electricity Use for a Pre-Code and Code-Compliant, Electric/Gas House in Texas

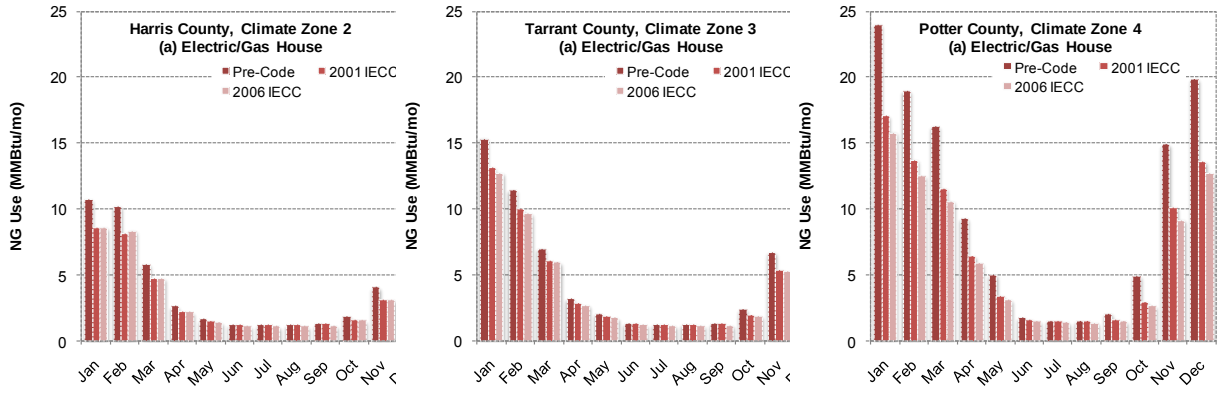


Figure 5. Monthly Natural Gas Use for a Pre-Code and Code-Compliant, Electric/Gas House in Texas

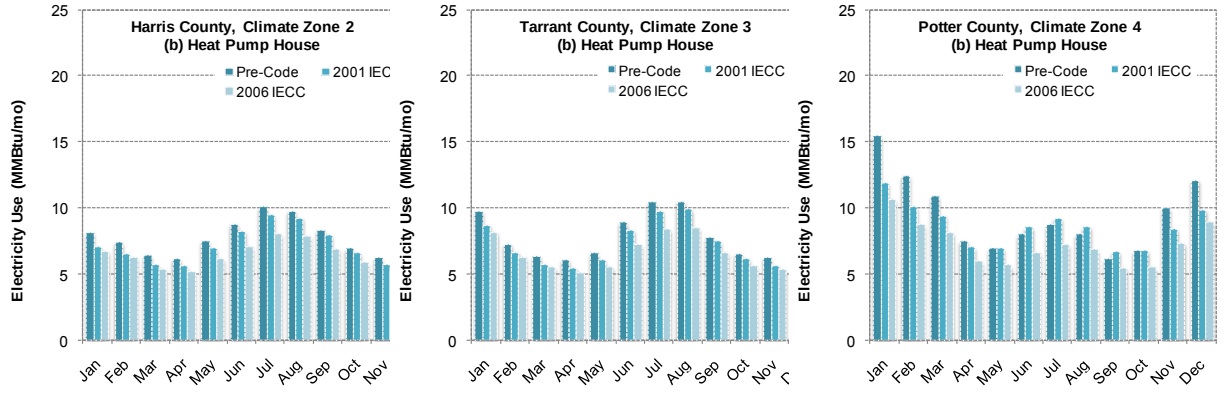


Figure 6. Monthly Electricity Use for a Pre-Code and Code-Compliant, Heat Pump House in Texas

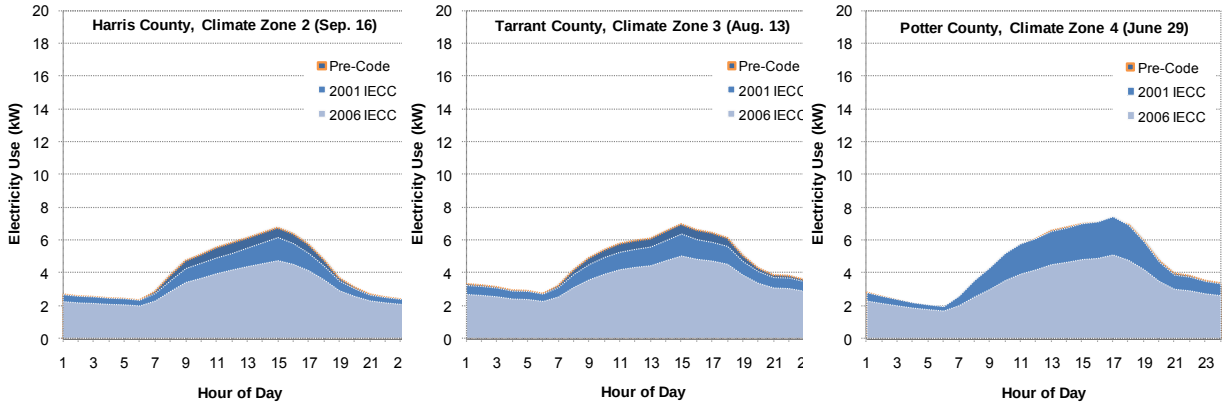


Figure 7. Peak Summer Day Hourly Electricity Use for a Pre-Code and Code-Compliant, House in Texas

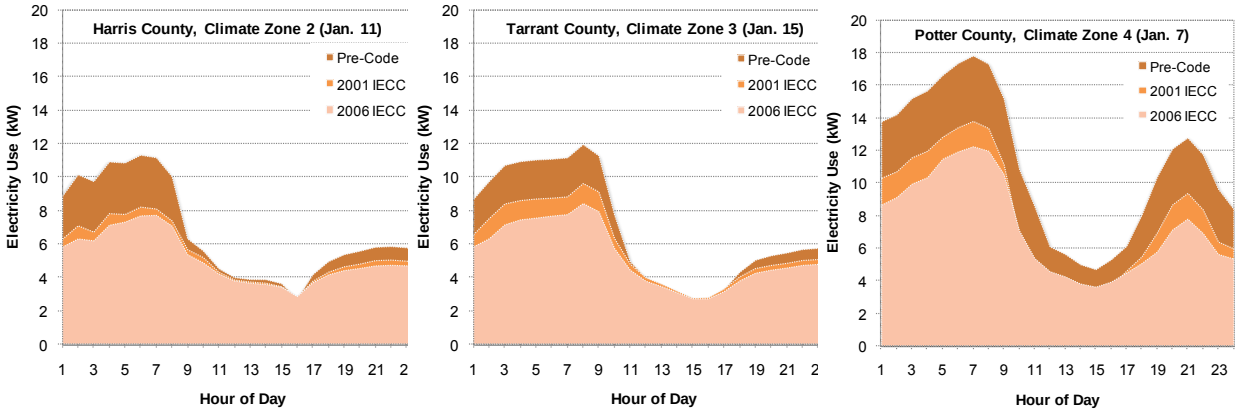


Figure 8. Peak Winter Day Hourly Electricity Use for a Pre-Code and Code-Compliant, Heat Pump House in Texas

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. Alternatively, 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[4] 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 rather than electricity. 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

[4] 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).

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 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

Table 4 presents the estimated per-house increased costs for upgrading major building components and systems to comply with the 2001 IECC and the 2006 IECC for each climate zone. 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 9 presents the annual and cumulative statewide electricity savings from code-compliant new single-family housing in Texas for years 2002 through 2009. Figure 10 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 $1,027 million from 2002 to 2009.

Figure 11 shows the annual increased costs and the statewide electricity savings by the year the house was constructed. The annual statewide increased costs are estimated to range between $60 million and $113 million. For the houses built between 2002 and 2006, the cumulative electricity savings alone exceed the initial increased construction costs. If both electricity and electric demand savings are considered, the expected savings will be much higher. Figure 12 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. The cumulative statewide costs over the eight year period from 2002 to 2009 are estimated to be $670 million

Table 4. Per-House Increased Construction Costs

Components	Pre-Code	2001 IECC	2006 IECC	Increased Costs Per Unit 2001 IECC	Increased Costs Per Unit 2006 IECC	Sq. Ft /Linear Ft	Total Increased Costs 2001 IECC	Total Increased Costs 2006 IECC	References
Climate Zone 2									
Ceiling Insulation	R-27	R-30	R-30	$ 0.09	$ 0.11	2,548	$ 229	$ 280	R.S. Means 2002 and 2007
Window U/SHGC	1.11/0.71	0.52/0.40	0.75/0.40	$ 1.50	$ 1.00	247	$ 371	$ 247	Malhotra et al. 2008; Kim et al. 2010
Wall Insulation	R-14	R-11	R-13	$ -	$ -	1,778	$ -	$ -	-
Slab Insulation	NR	NR	NR	$ -	$ -	202	$ -	$ -	-
AC SEER	11	10	13	$ -	$ -	-	$ -	$ 300	10% of AC Cost (R.S. Means 2007)
Gas DHW EF	0.54	0.54	0.59	$ -	$ -	-	$ -	$ 175	ACEEE Guide (Amann et al. 2007)
Electric DHW EF	0.86	0.86	0.90	$ -	$ -	-	$ -	$ 75	ACEEE Guide (Amann et al. 2007)
(a) Electric/Gas House Total							**$ 600**	**$ 1,002**	
(b) All Electric House Total							**$ 600**	**$ 902**	
Climate Zone 3									
Components	Pre-Code	2001 IECC	2006 IECC	Increased Costs Per Unit 2001 IECC	Increased Costs Per Unit 2006 IECC	Sq. Ft /Linear Ft	Total Increased Costs 2001 IECC	Total Increased Costs 2006 IECC	References
Ceiling Insulation	R-27	R-30	R-30	$ 0.09	$ 0.11	2,426	$ 218	$ 267	R.S. Means 2002 and 2007
Window U/SHGC	0.87/0.66	0.50/0.40	0.65/0.40	$ 1.50	$ 1.00	373	$ 560	$ 373	Malhotra et al. 2008; Kim et al. 2010
Wall Insulation	R-14	R-11	R-13	$ -	$ -	1,814	$ -	$ -	-
Slab Insulation	NR	NR	NR	$ -	$ -	197	$ -	$ -	-
AC SEER	11	10	13	$ -	$ -	-	$ -	$ 300	10% of AC Cost (R.S. Means 2007)
Gas DHW EF	0.544	0.544	0.594	$ -	$ -	-	$ -	$ 175	ACEEE Guide (Amann et al. 2007)
Electric DHW EF	0.86	0.86	0.90	$ -	$ -	-	$ -	$ 75	ACEEE Guide (Amann et al. 2007)
(a) Electric/Gas House Total							**$ 778**	**$ 1,115**	
(b) All Electric House Total							**$ 778**	**$ 1,015**	
Climate Zone 4									
Components	Pre-Code	2001 IECC	2006 IECC	Increased Costs Per Unit 2001 IECC	Increased Costs Per Unit 2006 IECC	Sq. Ft /Linear Ft	Total Increased Costs 2001 IECC	Total Increased Costs 2006 IECC	References
Ceiling Insulation	R-27	R-38	R-38	$ 0.27	$ 0.19	2,426	$ 655	$ 461	R.S. Means 2002 and 2007
Window U/SHGC	0.87/0.66	0.37/NR	0.40/NR	$ 1.50	$ 1.50	373	$ 560	$ 560	Malhotra et al. 2008; Kim et al. 2010
Wall Insulation	R-14	R-11	R-12/3 c.i.	$ -	$ -	1,814	$ -	$ -	-
Slab Insulation	R-6, 2ft	R-6, 2ft	R-10, 2ft	$ -	$ 1.26	197	$ -	$ 248	BCAP report (Paquette et al. 2010)
AC SEER	11	10	13	$ -	$ -	-	$ -	$ 300	10% of AC Cost (R.S. Means 2007)
Gas DHW EF	0.544	0.544	0.594	$ -	$ -	-	$ -	$ 175	ACEEE Guide (Amann et al. 2007)
Electric DHW EF	0.86	0.86	0.90	$ -	$ -	-	$ -	$ 75	ACEEE Guide (Amann et al. 2007)
(a) Electric/Gas House Total							**$ 1,215**	**$ 1,744**	
(b) All Electric House Total							**$ 1,215**	**$ 1,644**	

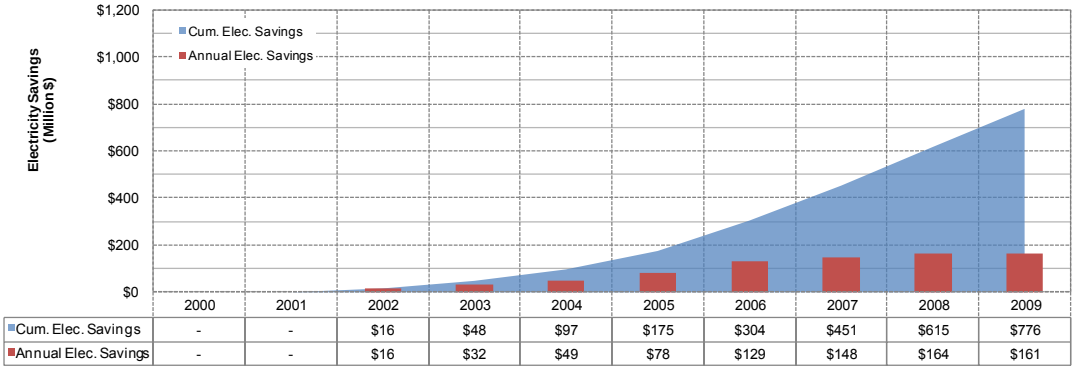
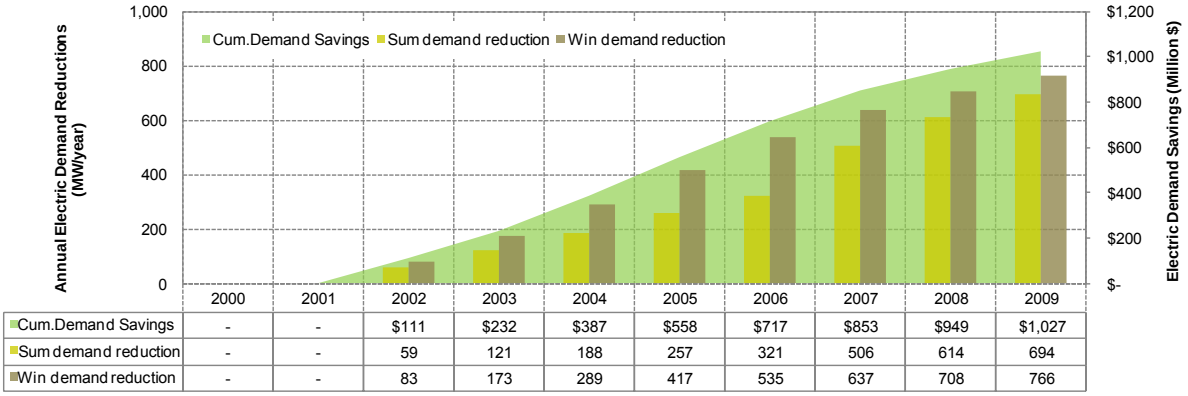


Figure 9. Annual and Cumulative Statewide Electricity Savings from the IECC Code Adoption for New Single-Family Residences in Texas: 2002-2009



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

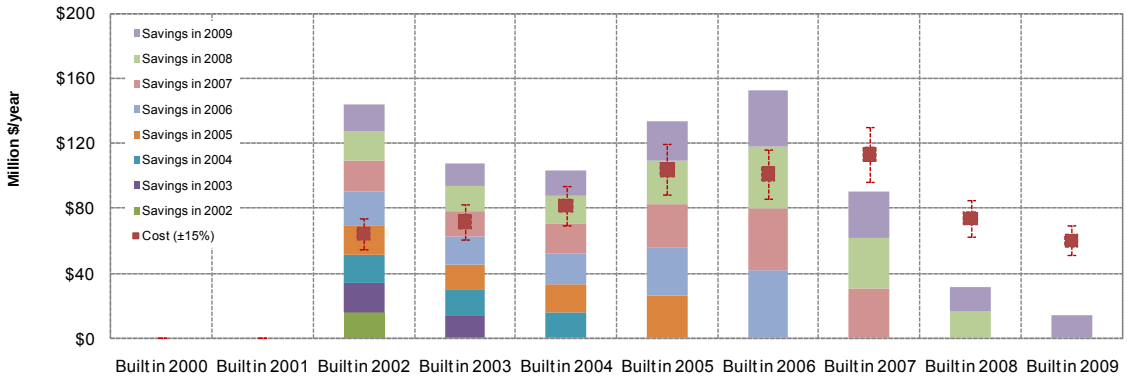


Figure 11. Annual Increased Costs and Statewide Electricity Savings by Construction Year of Houses

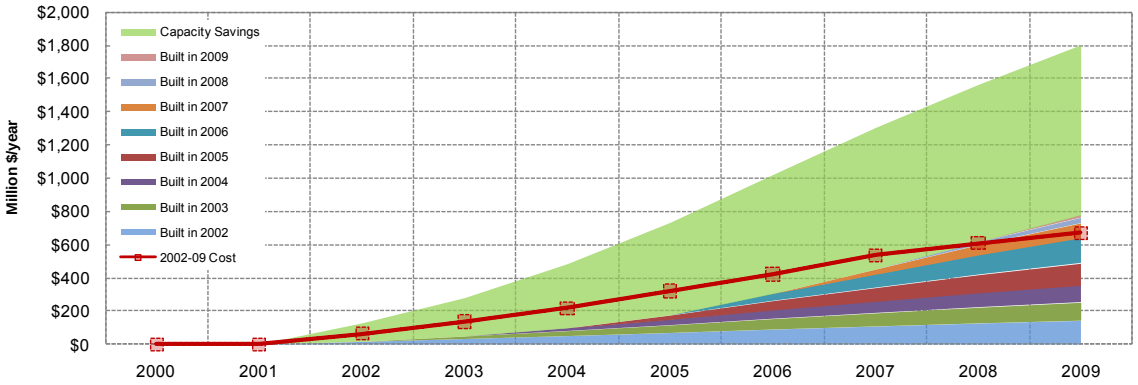


Figure 12. Cumulative Increased Costs, Statewide Electricity and Electric Demand Savings Associated with the IECC Code Adoption for Single-Family Residences in Texas: 2002-2009

while the cumulative electricity and demand savings are $1,803 million: $776 million from electricity savings and $1,027 million from demand savings.

SUMMARY

Statewide electricity savings and peak electric demand reductions achieved from the International Energy Conservation Code (IECC) 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 report. In the first part of the analysis, the impact of different versions of IECC (2001 IECC and 2006 IECC) 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.

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.

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REFERENCES

Amann, J.T., A. Wilson, and K. Ackerly. 2007. *Consumer Guide to Home Energy Savings: 9th Edition*. Washington, D.C.: American Council for an Energy-Efficient economy.

Atmos Energy. 2010a. *Atmos Energy Tariffs for Mid-Tex: September 2010 Mid-Tex GCR Rates*. Dallas, TX: Atmos Energy. Retrieved September 30, 2010, from http://www.atmosenergy.com/about/tariffs.html?st=mtx&pass=1

Atmos Energy. 2010b. *Atmos Energy Tariffs for West Texas: September 2010 Texas (West) GCA Rates*. Dallas, TX: Atmos Energy. Retrieved September 30, 2010, from http://www.atmosenergy.com/about/tariffs.html?st=TX&pass=1

ASHRAE. 1993. *ANSI/ASHRAE Standard 136-1993 (RA 2006) - A Method of Determining Air Change Rates in Detached Dwellings.* Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

ASHRAE. 2001. *ANSI/ASHRAE Standard 62-2001 Ventilation for Acceptable Indoor Air Quality.* Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

ASHRAE. 2003. *ASHRAE Handbook - HVAC Applications.* Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

CPS Energy. 2010. *Fuel and Regulatory Charges*. San Antonio, TX: CPS Energy. Retrieved November 9, 2010, from http://www.cpsenergy.com/Residential/Billing_Payments/Fuel_and_Regulatory_Charges/index.asp

Faruqui, A., R. Hledik, S. Newell, and H. Pfeifenberger. 2007. The Power of 5 Percent. *The Electricity Journal*. 20(8):68-77.

Haberl, J., C. Culp, B. Yazdani, T. Fitzpatrick, and D. Turner. 2002. *Texas's Senate Bill 5 Legislation for Reducing Pollution in Non-attainment and Affected Areas*. Annual Report to the Texas Natural Resource Conservation Commission. ESL-TR-02/07-01. College Station, TX: Energy Systems Laboratory, Texas A&M University System.

Haberl, J., C. Culp, B. Yazdani, T. Fitzpatrick, J. Bryant, and D. Turner. 2003. *Energy Efficiency/Renewable Energy Impact in the Texas Emissions Reduction Plan (TERP), Volume II – Technical Report*. Annual Report to the Texas Commission on Environmental Quality, September 2002 to August 2003. ESL-TR-03/12-04. College Station, TX: Energy Systems Laboratory, Texas A&M University System.

Haberl, J., C. Culp, B. Yazdani, D. Gilman, T. Fitzpatrick, S. Muns, M. Verdict, M. Ahmed, B. Liu, J.C. Baltazar-Cervantes, J. Bryant, L. Degelman, and D. Turner. 2004. *Energy Efficiency/Renewable Energy Impact in the Texas Emissions Reduction Plan (TERP), Volume II – Technical Report*. Annual Report to the Texas Commission on Environmental Quality, September 2003 to August 2004. Report ESL-TR-04/12-04. College Station, TX: Energy Systems Laboratory, Texas A&M University System.

Haberl, J., C. Culp, B. Yazdani, D. Gilman, T. Fitzpatrick, S. Muns, M. Verdict, M. Ahmed, B. Liu, J.C. Baltazar-Cervantes, J. Bryant, L. Degelman, and D. Turner. 2006. *Energy Efficiency/Renewable Energy Impact in the Texas Emissions Reduction Plan (TERP), Volume II – Technical Report.* Annual Report to the Texas Commission on Environmental Quality, September 2004 to December 2005. ESL-TR-06-06-08. College Station, TX: Energy Systems Laboratory, Texas A&M University System.

Haberl, J., C. Culp, B. Yazdani, D. Gilman, T. Fitzpatrick, S. Muns, M. Verdict, M. Ahmed, Z. Liu, J.C. Baltazar-Cervantes, J. Mukhopadhyay, L. Degelman, and D. Turner. 2007. *Energy Efficiency/Renewable Energy Impact in the Texas Emissions Reduction Plan (TERP), Volume II – Technical Report. Annual Report to the Texas Commission on Environmental Quality*, January 2006 to June 2007. ESL-TR-07-12-02. College Station, TX: Energy Systems Laboratory, Texas A&M University System.

Haberl, J., C. Culp, B. Yazdani, D. Gilman, T. Fitzpatrick, S. Muns, Z. Liu, J.C. Baltazar-Cervantes, J. Mukhopadhyay, L. Degelman, and D. Claridge. 2008. *Energy Efficiency/Renewable Energy Impact in the Texas Emissions Reduction Plan (TERP), Volume II—Technical Report.* Annual Report to the Texas Commission on Environmental Quality, January 2007 – December 2007. ESL-TR-08-12-02. College Station, TX: Energy Systems Laboratory, Texas A&M University System.

Haberl, J., C. Culp, B. Yazdani, D. Gilman, S. Muns, Z. Liu, J.C. Baltazar-Cervantes, J. Mukhopadhyay, L. Degelman, and D. Claridge. 2009. *Energy Efficiency/Renewable Energy Impact in the Texas Emissions Reduction Plan (TERP), Volume II—Technical Report.* Annual Report to the Texas Commission on Environmental Quality, January 2008 – December 2008. ESL-TR-09-12-02. College Station, TX: Energy Systems Laboratory, Texas A&M University System.

Haberl, J., C. Culp, B. Yazdani, C. Lewis, Z. Liu, J.C. Baltazar-Cervantes, J. Mukhopadhyay, D. Gilman, L. Degelman, K. McKelvey, and D. Claridge. 2010. *Energy Efficiency/Renewable Energy Impact in the Texas Emissions Reduction Plan (TERP), Volume II—Technical Report.* Annual Report to the Texas Commission on Environmental Quality, January 2009 – December 2009. ESL-TR-10-12-02. College Station, TX: Energy Systems Laboratory, Texas A&M University System.

ICC. 1999. *2000 International Energy Conservation Code.* Falls Church, VA: International Code Council, Inc.

ICC. 2001. *2001 Supplement to the International Energy Conservation Code.* Falls Church, VA: International Code Council, Inc.

ICC. 2006. *2006 International Energy Conservation Code.* Falls Church, VA: International Code Council, Inc.

ICC. 2009. *2009 International Energy Conservation Code.* Falls Church, VA: International Code Council, Inc.

Kaplan, S. 2008. *Power Plants: Characteristics and Costs*. CRS Report for Congress. RL34746. Washington, DC: Congressional Research Service.

Kats, G.H. et al. 1996. Energy Efficiency as a Commodity. *ACEEE Summer Study on Energy Efficiency in Buildings*.

Kim, H., Z. Liu, J.C. Baltazar, J. Haberl, C. Culp, B. Yazdani, and C. Montgomery. 2010. *Recommendations for 2009 IECC 15% Above Code Energy Efficiency Measures for Residential Buildings*. ESL-TR-10-11-01. College Station, TX: Energy Systems Laboratory, Texas A&M University System.

LBL. 1993. *DOE-2 BDL Summary Version 2.1E.* LBL Report No. 349346. Berkley, CA: Lawrence Berkeley Laboratory.

Malhotra, M., J. Mukhopadhyay, Z. Liu, J. Haberl, C. Culp, B. Yazdani, and C. Montgomery. 2008. *Recommendations for 15% Above-Code Energy Efficiency Measures for Residential Buildings*. ESL-TR-07-09-01. College Station, TX: Energy Systems Laboratory, Texas A&M University System.

NAECA. 2006. *National Appliance Energy Conservation Act*.

NAHB. 2000. *Builders Practices Report 1999*. National Association of Home Builders. Upper Marlboro, MD: NAHB Research Center.

NAHB. 2001. *Builders Practices Report 2000*. National Association of Home Builders. Upper Marlboro, MD: NAHB Research Center.

NAHB. 2002. *Builders Practices Report 2001*. National Association of Home Builders. Upper Marlboro, MD: NAHB Research Center.

NAHB. 2003. *Builders Practices Report 2002*. National Association of Home Builders. Upper Marlboro, MD: NAHB Research Center.

NAHB. 2004. *Builders Practices Report 2003*. National Association of Home Builders. Upper Marlboro, MD: NAHB Research Center.

NAHB. 2005. *Builders Practices Report 2004*. National Association of Home Builders. Upper Marlboro, MD: NAHB Research Center.

NAHB. 2009. *Builders Practices Report 2008.* National Association of Home Builders. Upper Marlboro, MD: NAHB Research Center.

NAHB. 2010. *Builders Practices Report 2009.* National Association of Home Builders. Upper Marlboro, MD: NAHB Research Center.

NREL. 2001. *Building America House Performance Analysis Procedures*. (NREL/TP-550-27754) Golden, CO: National Renewable Energy Laboratory. p.34

Paquette, Z., J. Miller, and M. DeWein. 2010. *Incremental Construction Cost Analysis for New Homes: Building to the 2009 IECC*. Washington, D.C.: Building Codes Assistance Project.

PUCT. 2010. *Average Annual Rate Comparison for Residential Electric Service: July 2010*. Austin, TX: Public Utility Commission of Texas. Retrieved September 30, 2010, from http://www.puc.state.tx.us/electric/rates/RESrate.cfm

RECenter. 2011. Building Permits Texas, Real Estate Center, Texas A&M University, College Station, Texas. Retrieved January 25, 2011, from http://recenter.tamu.edu/data/bp/bps/st31.asp#

R.S. Means. 2002. *Residential Cost Data: 21st Annual Edition*. Kingstone, MA: R.S. Means Company, Inc.

R.S. Means. 2007. *Residential Cost Data: 26th Annual Edition*. Kingstone, MA: R.S. Means Company, Inc.

US DOE EIA. 2011. State Data for Prices: *Current and Historical Monthly Retail Sales, Revenues, and Average Retail Price by Sector*. Energy Information Administration, U.S. Department of Energy. Retrieved February 16, 2011, from http://www.eia.gov/cfapps/state/SEP_MorePrices.cfm