

Analysis of Code-Compliant Construction in Texas Based on Texas Building Energy Performance Standards (TBEPS)

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ABSTRACT

This paper presents a detailed technical analysis comparing the stringency of the Texas Building Energy Performance Standards (TBEPS), based on Chapter 11 of the 2009 International Residential Code (IRC) for residential construction and Chapter 5 of the 2009 International Energy Conservation Code (IECC) for commercial construction, to the recently published editions of the IRC and IECC: 2012 IRC for residential construction and 2012 IECC for commercial construction. A series of simulations were performed using the Laboratory's single-family and large commercial office building simulation models based on the DOE-2.1e program and the appropriate TMY2 weather files for three counties representing three 2009 IECC and 2012 IECC Climate Zones across Texas: Harris County for Climate Zone 2, Tarrant County for Climate Zone 3, and Potter County for Climate Zone 4.

The analysis determined that the residential provisions of 2012 IRC are more stringent than the 2009 IRC that used the relevant 2009 IECC residential provisions, which is one of the two paths to comply with the 2009 IRC per Section N1101.2 of the code. The annual total source energy savings of the 2012 IRC ranges from 16.3% to 21.4% with the performance path and from 14.3% to 20.1% with the prescriptive path, depending on the climate zone and the heating system type of a house. The analysis for large office buildings also determined that the commercial provisions of 2012 IECC are more stringent than the 2009 IECC. The annual total site energy savings of the 2012 IECC ranges from 7.3% to 11.6% based on site energy use and from 4.1% to 7.0% based on source energy use, depending on the climate zone.

INTRODUCTION

In 2007, the 80th legislature mandated the Energy Systems Laboratory (Laboratory) to take part in Texas rule-making process. As detailed in the Health and Safety Code, Chapter 388., Texas Building Energy Performance Standards (TBEPS), Sec. 388.003 (b-1), the Laboratory is required to submit written recommendations to the State Energy Conservation Office (SECO) on whether the energy efficiency provisions of the latest published editions of the International Residential Code (IRC) or the International Energy Conservation Code (IECC) for residential or commercial energy efficiency and air quality are equivalent to or more stringent than the provisions of editions previously adopted as the TBEPS. This paper presents a detailed technical analysis comparing the stringency of the current TBEPS, based on Chapter 11 of the 2009 IRC for residential construction and Chapter 5 of the 2009 IECC for commercial construction, to the recently published editions of the IRC and IECC: Chapter 11 of the 2012 IRC for residential construction and Chapter 4 [CE] of the 2012 IECC for commercial construction.

The analysis used the relevant 2009 IECC residential (Chapters 1-4) provisions, which is one of the two paths to comply with the Chapter 11 of the 2009 IRC per Section N1101.2 of the code². The residential provisions in Chapter 11 of the 2012 IRC are identical to the 2012 IECC. For the commercial comparison the analysis used relevant provisions in the 2009 IECC for large office commercial buildings^{3,4}.

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² The energy efficiency provisions of the 2009 IRC are adopted as the energy code in Texas for single-family residential construction and become effective on January 1, 2012. Meeting the requirements of the 2009 IECC is one of the compliance options of the 2009 IRC per Section N1101.2 of the 2009 IRC.

³ The commercial sections of both the 2009 and 2012 IECC include provisions for several building types. However, for the purpose of this analysis only one building type – the large office building was selected.

⁴ In addition to the commercial simulation analysis described in this paper, a more concise desk-check was performed at the Energy Systems Laboratory comparing the all commercial provisions in the 2012 IECC with the corresponding provisions in the 2009

METHODOLOGY

The analysis was performed using the Laboratory's code-compliant single-family simulation⁵ that includes new EIR calculation models⁶ and large commercial office building simulation models based on the DOE-2.1e program and the appropriate TMY2 weather files. Three counties in Texas representing three 2009 IECC and 2012 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).

Residential Single-Family Analysis

The base-case building 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 National Association of Home Builders - survey (NAHB 2003). The mechanical systems were assumed to be in the unconditioned, vented attic, and the house was assumed to be equipped with mechanical ventilation system⁷. Since the mechanical ventilation includes the exhaust fans in bathroom and kitchen, this study determined that it would be more reasonable to simulate mechanical ventilation for both 2009 IECC and 2012 IRC/2012 IECC code-compliant houses. This assumption on the mechanical ventilation also agrees with the study by Lucas et al. (2012). Two options were considered for heating fuel type: (a) an electric/gas house (gas-fired furnace for space heating, and gas water heater for domestic water heating) and for (b) an all-electric house (heat pump for space heating, and electric water heater for domestic water heating).

Table 1 summarizes the base-case building characteristics used in the residential simulation

IECC specifically for the State of Texas. This study concluded that for most sections the 2012 IECC is more stringent than the 2009 IECC. Details of this desk-check can be found in Mukhopadhyay et al. (2011b).

⁵ The single-family analysis was performed using the International Code Compliance Calculator (IC3) developed by the Laboratory. IC3 is Residential Energy Services Network (RESNET)-accredited web-based, code-compliance software to demonstrate the performance of proposed single family residences according to the TBEPS.

⁶ Details on a new cooling EIR calculation model are available in Kim et al (2013).

⁷ A mechanical ventilation system is required to be installed for the houses that have an air infiltration rate less than 5 ACH50 per Section R403.5 of 2012 IECC and Section R 303.4 of 2012 IRC. Since the 2012 IECC requires the tested air leakage rate of not exceeding 5 ACH50 in Climate Zones 1 and 2, and 3 ACH50 in Climate Zones 3 through 8 to comply with the 2012 IECC, the

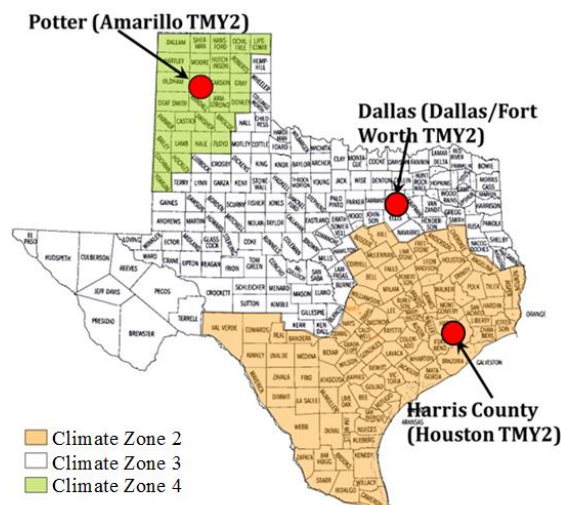


Figure 1. 2009 IECC/2012 IECC Climate Zone Classification and Three Selected Counties in Texas

model for a performance path analysis and a prescriptive path analysis⁸: 2009 IECC versus 2012 IRC/2012 IECC. To facilitate a better comparison between the two codes, both interior shading fractions specified in the 2009 IECC performance path were adjusted to match the values provided in the 2012 IRC/2012 IECC: 0.87 for Climate Zones 2 and 3 and 0.84 for Climate Zone 4. In addition, a second set of simulations for the 2012 IRC/2012 IECC performance path were created and labeled '2012 IRC and 2012 IECC Performance Modified' in the table. In this modification, internal heat gains of the 2012 IRC and 2012 IECC performance path were adjusted to include 75% of high-efficacy lamps for 2012 IRC/2012 IECC⁹.

Several changes were made in the 2012 IRC and 2012 IECC performance path analysis. Specifically, the building envelope and systems components that have different specifications from the 2009 IECC performance path are highlighted in light orange in

houses need to be provided with appropriate ventilation rate based on the Table M1507.3.3(1) of the 2012 IRC.

⁸ Unlike the performance path, the prescriptive path analysis does not provide specifications for a number of components that are needed for simulations. Hence, this analysis assumed that the components that are not specified in the prescriptive path provision are same as performance path specifications.

⁹ The provision of high-efficacy lamps becomes mandatory per Sec. R404.1 of the 2012 IECC, which requires a minimum of 75 percent of the lamps to be high-efficacy lamps. To take account of this provision, a modification was applied to the 2012 IECC Performance Path. In this modification, the internal heat gains of a house without high-efficacy lamps was assumed to be 1.095 kW (i.e., 0.547 kW for lighting and 0.547 kW for equipment) per Table 405.5.2(1) of 2009 IECC and Table R405.5.2(1) of 2012 IECC. Then the reduced internal heat gains by replacing the 75 percent of the existing lighting fixtures with high-efficacy lamps were calculated as 0.239 kW by assuming that the high-efficacy lamp uses 75 percent less energy than the existing lamp.

Table 1. Base Case Building Description for Residential Single-Family Analysis

Building Component	Performance Path Analysis									Prescriptive Path Analysis					
	2009 IECC			2012 IRC/ 2012 IECC			2012 IRC/ 2012 IECC Modified			2009 IECC			2012 IRC/ 2012 IECC		
	CZ 2	CZ 3	CZ 4	CZ 2	CZ 3	CZ 4	CZ 2	CZ 3	CZ 4	CZ 2	CZ 3	CZ 4	CZ 2	CZ 3	CZ 4
Envelope															
Exterior Walls	Type	Light-weight wood frame with 2x4 studs spaced at 16" on center													
	U-Factor	0.082	0.082	0.057	0.082	0.057	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.057
	Absorptance	0.75													
Roof	Type	Light-weight wood frame, Unconditioned, vented attic													
	U-Factor	0.035	0.030	0.030	0.026	0.030	0.026	0.035	0.030	0.030	0.030	0.026	0.035	0.030	0.026
	Absorptance	0.75													
	Radiant Barrier	No													
Floor / Slab	Type	Slab-on-grade floor													
	R-Value	None	R-10	None	R-10	None	R-10	None	R-10	None	R-10	None	R-10	None	R-10
Windows	WWR %	15% of conditioned floor area													
	U-Factor	0.65	0.50	0.35	0.40	0.35	0.35	0.40	0.35	0.35	0.65	0.50	0.35	0.40	0.35
	SHGC	0.30	0.40	0.40	0.25	0.40	0.25	0.40	0.25	0.40	0.30	0.40	0.40	0.25	0.40
Shading	Interior ¹	0.87	0.84	0.87	0.84	0.87	0.84	0.87	0.84	0.87	0.84	0.87	0.84	0.87	0.84
	Exterior	None													
Air Exchange Rate ²	Air Leakage	0.00036 SLA		5 ACH50 (0.00025 SLA)	3 ACH50 (0.00015 SLA)	5 ACH50 (0.00025 SLA)	3 ACH50 (0.00015 SLA)	7 ACH50 (0.00036 SLA)				5 ACH50 (0.00025 SLA)	3 ACH50 (0.00015 SLA)		
	Mech. Ventilation			60.8 CFM (0.20 ACH)		60.8 CFM (0.20 ACH)						60.8 CFM (0.20 ACH)			
Space Conditions															
Temperature Set point	72°F Heating, 75°F Cooling														
Light Heat Gains	0.547 kW		0.547 kW		0.239 kW with 75% high-efficacy lamps		0.342 kW with 50% high-efficacy lamps		0.239 kW with 75% high-efficacy lamps						
Equipment Heat Gains	0.547 kW														
Mechanical Systems															
Air Conditioner	Type/Capacity	55,800 (= 500 ft ² /ton)													
	Efficiency	13 SEER													
Electric/Gas House	Type/Capacity	Gas-fired furnace, 55,800 (= 1.0 x cooling capacity)													
	Efficiency	0.78 AFUE													
All-Electric House	Type/Capacity	Heat pump heating, 55,800 (= 1.0 x cooling capacity)													
	Efficiency	7.7 HSPF													
Duct Distribution	Leakage ³	11.2% ⁴		4.2% ⁵		4.2% ⁵		11.2% ⁴				4.2% ⁵			
	Insulation	R-6/R-6		R-6/R-6		R-6/R-6		R-8/R-6				R-8/R-6			
DHW															
DHW Daily Consumption	70 gal/day														
Type/Energy Factor	(a) Electric/Gas House (40-gallon tank type gas water heater): 0.594 (b) All-Electric House (50-gallon tank type electric water heater): 0.904														

Notes: The cells highlighted in orange represent the 2012 IRC/2012 IECC specifications that are different from the 2009 IECC.

1) To facilitate a more accurate and realistic comparison between the codes, an adjustment was applied to the interior shading values of 2009 IECC codes: 0.7 for summer and 0.85 for winter.

2) Air exchange rate = air leakage rate in addition to the mechanical ventilation rate per 2012 IECC Table R405.5.2 (1).

3) The mechanical systems of the houses were assumed to be located in the unconditioned, vented attic, which requires a duct leakage test in both 2009 IECC and 2012 IECC.

4) Calculated from a maximum duct leakage to outdoors as specified in 2009 IECC Sec. 403.2.2: 8 CFM per 100 sq.ft. of CFA .

5) Calculated from a maximum total duct leakage as specified in 2012 IECC Sec. R403.2.2: 4 CFM per 100 sq.ft. of CFA with an assumed fraction of duct areas outside the conditioned space = 0.75 .

the table¹⁰. The changes considered in this analysis include:

- 1) Increased wall insulation (CZ 3 and 4).
- 2) Increased roof insulation.
- 3) Decreased glazing U-factor (CZ 2 and 3).

4) Decreased glazing SHGC (CZ 2 and 3).

5) Reduced air leakage rate.

6) Increased air exchange rate due to added mechanical ventilation¹¹.

¹⁰ Hot water pipe R-3 insulation provision in Sec R403.4.2 of the 2012 IECC was not evaluated in this analysis.

¹¹ In order to meet the 2012 IECC, the house was assumed to be equipped with a mechanical ventilation system. The performance path analysis of the 2012 IECC requires that the mechanical ventilation rate shall be in addition to the air leakage rate to

determine an air exchange rate of a house while the 2009 IECC performance path does not have any specifications regarding the mechanical ventilation rate for its standard reference house. Thus, for an air exchange rate of a house, a value of 0.00036 SLA was used for 2009 IECC performance path, while for 2012 IRC/2012 IECC, an air exchange rate was simulated with an air leakage of 5

- 7) 75% of high-efficacy lamps for Performance Modified and Prescriptive Path.
- 8) Reduced duct leakage.

Commercial Large Office Analysis

The base-case building is a six-story office building as described in studies by Ahmad et al., (2005), Kim et al., (2009) and Mukhopadhyay et al., (2011a). The aspect ratio was kept at 1.5:1 (Leach et al., 2010). The resulting building dimensions are 149.42 ft. x 99.62 ft, which translates to a footprint area of 14,885 ft² and a total conditioned floor area of 89,311 ft². The floor-to-floor height is set at 13 ft. A plenum is modeled for each floor. The height of the

plenum is set at 4 ft. Each floor of the building is divided into four perimeter zones and a central core zone. The perimeter zones face the four orientations and have a width of 15 ft. Table 2 summarizes the base-case building characteristics used in the commercial simulation model for a performance path analysis: 2009 IECC versus 2012 IECC. Details are provided for the building envelope, lighting, HVAC systems and service water heating systems implemented in the simulation model.

Several changes were made in the 2012 IECC performance path analysis for commercial buildings. The building envelope and systems components that have different specifications from the 2009 IECC

Table 2. Base Case Building Description for Commercial Large Office Analysis

Building Component	2009 IECC			2012 IECC			
	CZ 2	CZ 3	CZ 4	CZ 2	CZ 3	CZ 4	
Envelope							
Exterior Walls	Type	Steel frame with 6" metal studs spaced at 16" on center					
	R-value (h·ft ² ·°F/Btu)	R-13	R-13+3.8 c.i.	R-13+7.5 c.i.	R-13+5.0 c.i.	R-13+7.5 c.i.	R-13+7.5 c.i.
	Absorptance	0.75					
Roof	Type	Insulation Entirely Above Deck					
	R-value (h·ft ² ·°F/Btu)	R-20 c.i.			R-20 c.i.		R-25 c.i.
	Absorptance	0.75					
	Emittance	0.9					
Floor / Slab	Type	Slab-on-Grade, Unheated					
	R-value (h·ft ² ·°F/Btu)	None			None		R-10 for 2' below
	WWR %	40%					
Windows	Framing Type	Metal framing			Fixed		
	U-factor (Btu/h·ft ² ·°F)	U-0.75	U-0.65	U-0.55	U-0.50	U-0.46	U-0.38
	SHGC	0.25		0.40	0.25		0.40
	Overhang	None					
Doors	Door Type	Swinging					
	U-factor (Btu/h·ft ² ·°F)	0.7			0.61		
	Provision of Air Barrier	None			None		Mandatory
Infiltration	Rate (ACH)	Core: 0.043, Perimeter: 0.070			Core: 0.043, Perimeter: 0.070		Core: 0.010, Perimeter: 0.015
	Space Conditions						
	Temperature Set point ¹	70°F Heating, 75°F Cooling with -10°F Setback and +5°F Setup					
	Lighting Power Density (W/ft ²)	1.0 W/ft ²			0.9 W/ft ²		
	Equipment Heat Gains (Plug Loads)	0.75 W/ft ²					
Mechanical Systems (VAV w/ reheat)							
Chiller	Type/Capacity ²	Screw chiller, ≥ 150 tons and < 300 tons					
	Efficiency ³	5.17 COP					
Boiler	Type/Capacity ²	Two gas-fired hot water boilers, ≥ 300 kBtu/hr and ≤ 2,500 kBtu/hr					
	Efficiency	75% Et			80% Et		
	Mechanical Ventilation	0.08 cfm/ft ² (5 cfm/person and 0.06 cfm/ft ²)					
	Supply Air	1.10 cfm/ft ²					
	Economizer	None			None (Trade-Off) ⁴		
SWH							
	SHW peak consumption	74 gal/hr					
	Type/Capacity	Gas storage water heater (106-gallon tank type, 100,000 Btu/hr)					
	Efficiency	80% Et (SL=1258 Btu/h)					

Notes: The cells highlighted in orange represent the 2012 IECC specifications that are different from the 2009 IECC.

1) The heating and cooling set point schedule is from Thornton et al. (2011).

ACH50 for Climate Zone 2 and 3 ACH50 for Climate Zone 3 and 4 in addition to the mechanical ventilation of 61 CFM (0.20 ACH).

- 2) Sizing runs performed using the 99.6% (winter) and 1% (summer) design temperature values from Chapter 14 of the 2009 ASHRAE Handbook-Fundamentals (ASHRAE 2009).
- 3) In this analysis, compliance of chiller performance requirements was demonstrated by meeting the minimum requirements of Path A for both full load in both 2009 IECC and 2012 IECC. Modeling of IPLV was not considered by this analysis.
- 4) The simulation model used for this analysis takes advantage of the trade-off option specified in Table C403.3.1(2) of 2012 IECC, by increasing cooling efficiency instead of modeling economizers for climate zone 2 and 3.

performance path are highlighted in light orange in the table. The changes considered in this analysis include:

- 1) Increased wall insulation (CZ 2 and 3)
- 2) Increased roof insulation (CZ 4).
- 3) Added slab insulation (CZ 4).
- 4) Decreased glazing U-factor.
- 5) Decreased door U-factor.
- 6) Reduced air leakage rate due to an installation of air-barriers¹² (CZ 4).
- 7) Decreased lighting power density.
- 8) Increased boiler efficiency.

RESULTS FOR RESIDENTIAL ANALYSIS

Figures 2 and 3 present the detailed simulation results of electric/gas and all-electric houses in three selected counties in Texas for a performance path analysis and a prescriptive path analysis, respectively. Table 3 presents the total annual source energy savings of the 2012 IRC/2012 IECC compared to the 2009 IECC for electric/gas and all-electric houses in three selected counties in Texas for both comparisons of performance path and prescriptive path analysis.

Performance Path Analysis

Across all counties, both the 2012 IRC/2012 IECC and the modified 2012 IRC/2012 IECC performance path code-compliant house reported less site energy consumption than the 2009 IECC. The total annual site energy consumption of a 2009 IECC performance path code-compliant house are: (a) electric/gas house: 99.4 MMBtu/yr (42.8 kBtu/ft²-yr) for Harris County, 108.6 MMBtu/yr (46.7 kBtu/ft²-yr) for Tarrant County, and 137.7 MMBtu/yr (59.2 kBtu/ft²-yr) for Potter County; and (b) all-electric house: 76.2 MMBtu/yr (32.8 kBtu/ft²-yr) for Harris County, 77.9 MMBtu/yr (37.9 kBtu/ft²-yr) for Tarrant County, and 88.2 MMBtu/yr (37.9 kBtu/ft²-yr) for Potter County. The modified 2012 IRC/2012 IECC performance path code-compliant house reported the following site energy totals: (a) electric/gas house: 84.6 MMBtu/yr (36.4 kBtu/ft²-yr) for Harris County, 93.2 MMBtu/yr (40.1 kBtu/ft²-yr) for Tarrant County, and 118.4 MMBtu/yr (50.9 kBtu/ft²-yr) for Potter

County; and (b) all-electric house: 62.2 MMBtu/yr (26.8 kBtu/ft²-yr) for Harris County, 61.6 MMBtu/yr (26.5 kBtu/ft²-yr) for Tarrant County, and 73.8 MMBtu/yr (31.7 kBtu/ft²-yr) for Potter County.

The annual source energy savings associated with the modified 2012 IRC/2012 IECC performance path were then calculated by comparisons to the respective, 2009 IECC performance path code-compliant houses. To calculate source energy consumption, the multipliers of 3.16 for electricity and 1.1 for natural gas were applied to site energy use per Section 405.3 of the 2009 IECC and Section R405.3 of the 2012 IECC. Across all counties, both the 2012 IRC/2012 IECC and the modified 2012 IRC/2012 IECC performance path code-compliant house reported less source energy consumption than the 2009 IECC. The annual source energy savings associated with the modified 2012 IRC/2012 IECC performance path are: (a) electric/gas house: 44.3 MMBtu/yr (19.1 kBtu/ft²-yr) for Harris County, 50.5 MMBtu/yr (21.7 kBtu/ft²-yr) for Tarrant County, and 46.2 MMBtu/yr (19.9 kBtu/ft²-yr) for Potter County; and (b) all-electric house: 44.2 MMBtu/yr (19.0 kBtu/ft²-yr) for Harris County, 51.5 MMBtu/yr (22.2 kBtu/ft²-yr) for Tarrant County, and 45.5 MMBtu/yr (19.6 kBtu/ft²-yr) for Potter County. This corresponds to: (a) electric/gas house: 19.4% for Harris County, 21.4% for Tarrant County, and 18.3% for Potter County; and (b) all-electric house: 18.4% for Harris County, 20.9% for Tarrant County, and 16.3% for Potter County. The lighting provision (i.e., 75% high efficacy lamps) was found to be the single greatest factor that contributed to the large savings with the modified 2012 IRC/2012 IECC.

Prescriptive Path Analysis

Across all counties, both the 2012 IRC/2012 IECC and the modified 2012 IRC/2012 IECC performance path code-compliant house reported less site energy consumption than the 2009 IECC. The total annual site energy consumption of a 2009 IECC prescriptive path code-compliant house are: (a) electric/gas house: 102.1 MMBtu/yr (43.9 kBtu/ft²-yr)

¹² The use of air-barriers is introduced as a mandatory requirement in the 2012 IECC for climate zone 4, which reduces the infiltration values for opaque building components to 0.04 cfm/sq.ft. The values reported in the code are at a pressure difference of 0.3 in. w.c. which is different than the pressure difference of 0.017 in. w.c. required of the values input to the DOE-2.1e. Thus in the simulations without air barriers, this

analysis used the infiltration values provided by Leach et. al., (2010), which is typical infiltration values for a large office building at a pressure difference of 0.017 in. w.c. For the simulations with air barriers, this analysis also used the infiltration values provided by Leach et al., which are reduced values as a result of installation of air-barriers.

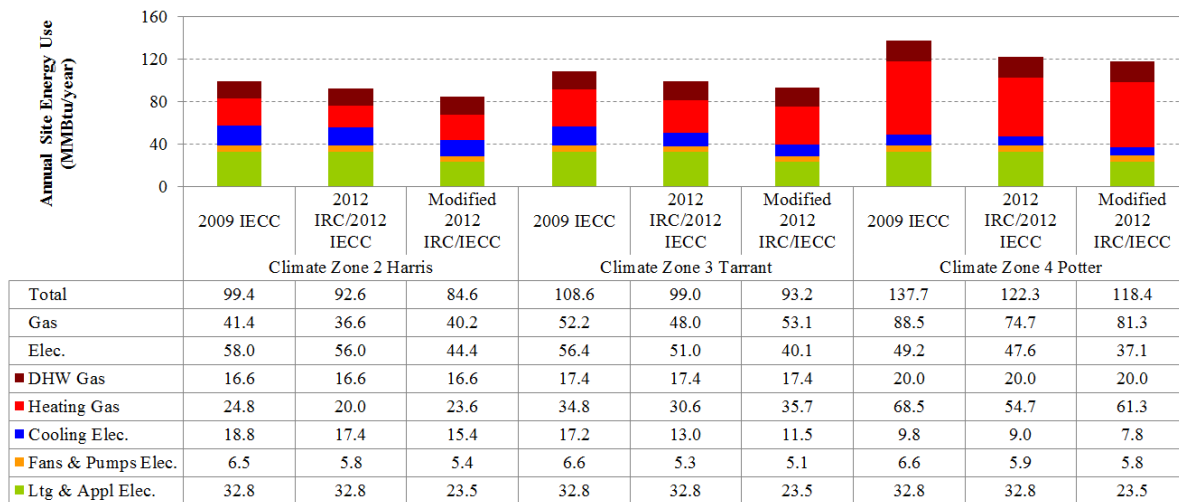
for Harris County, 114.2 MMBtu/yr (49.1 kBtu/ft²-yr) for Tarrant County, and 149.0 MMBtu/yr (64.1 kBtu/ft²-yr) for Potter County; and (b) all-electric house: 72.1 MMBtu/yr (31.0 kBtu/ft²-yr) for Harris County, 74.4 MMBtu/yr (32.0 kBtu/ft²-yr) for Tarrant County, and 87.0 MMBtu/yr (37.4 kBtu/ft²-yr) for Potter County. The modified 2012 IRC/2012 IECC prescriptive path code-compliant house reported the following site energy totals: (a) electric/gas house: 83.6 MMBtu/yr (36.0 kBtu/ft²-yr) for Harris County, 91.9 MMBtu/yr (39.5 kBtu/ft²-yr) for Tarrant County, and 115.9 MMBtu/yr (49.8 kBtu/ft²-yr) for Potter County; and (b) all-electric house: 61.8 MMBtu/yr (26.6 kBtu/ft²-yr) for Harris County, 61.1 MMBtu/yr (26.3 kBtu/ft²-yr) for Tarrant County, and 73.0 MMBtu/yr (31.4 kBtu/ft²-yr) for Potter County.

The annual source energy savings associated with the modified 2012 IRC/2012 IECC prescriptive path were then calculated by comparisons to the respective, 2009 IECC prescriptive path code-compliant houses. Across all counties, both the 2012 IRC/2012 IECC and the modified 2012 IRC/2012 IECC prescriptive path code-compliant house reported less source energy consumption than the 2009 IECC. The annual source energy savings associated with the modified 2012 IRC/2012 IECC prescriptive path are: (a) electric/gas

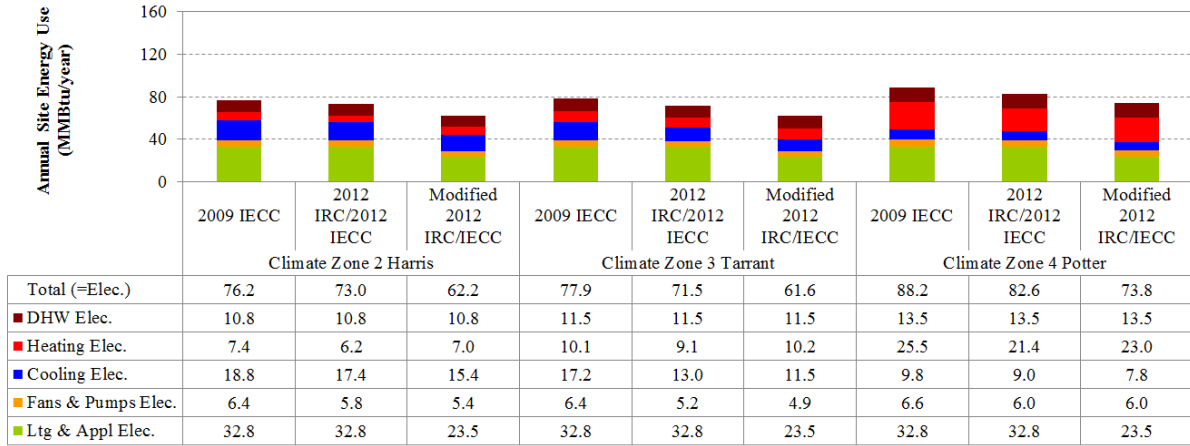
house: 36.6 MMBtu/yr (15.7 kBtu/ft²-yr) for Harris County, 46.2 MMBtu/yr (19.9 kBtu/ft²-yr) for Tarrant County, and 48.8 MMBtu/yr (21.0 kBtu/ft²-yr) for Potter County; and (b) all-electric/gas house: 32.5 MMBtu/yr (14.0 kBtu/ft²-yr) for Harris County, 42.0 MMBtu/yr (18.1 kBtu/ft²-yr) for Tarrant County, and 44.2 MMBtu/yr (19.0 kBtu/ft²-yr) for Potter County. This corresponds to: (a) electric/gas house: 16.7% for Harris County, 20.1% for Tarrant County, and 19.3% for Potter County; and (b) all-electric/gas house: 14.3% for Harris County, 17.9% for Tarrant County, and 16.1% for Potter County.

Comparison with Other Studies

Several other studies have examined the economic impacts of the 2012 IECC compared to the 2009 IECC for new residential buildings in Texas, including the DOE analysis performed by Pacific Northwest National Laboratory (PNNL) (DOE 2012); and the analysis by Building Codes Assistance Project (BCAP) (2012a-2012c). The annual energy cost savings reported in these analyses are from \$207 (16%) to \$379 (28%) in the DOE analysis and from \$248 (13%) to \$277 (14%) in the BCAP analysis across the three climate zones in Texas, which

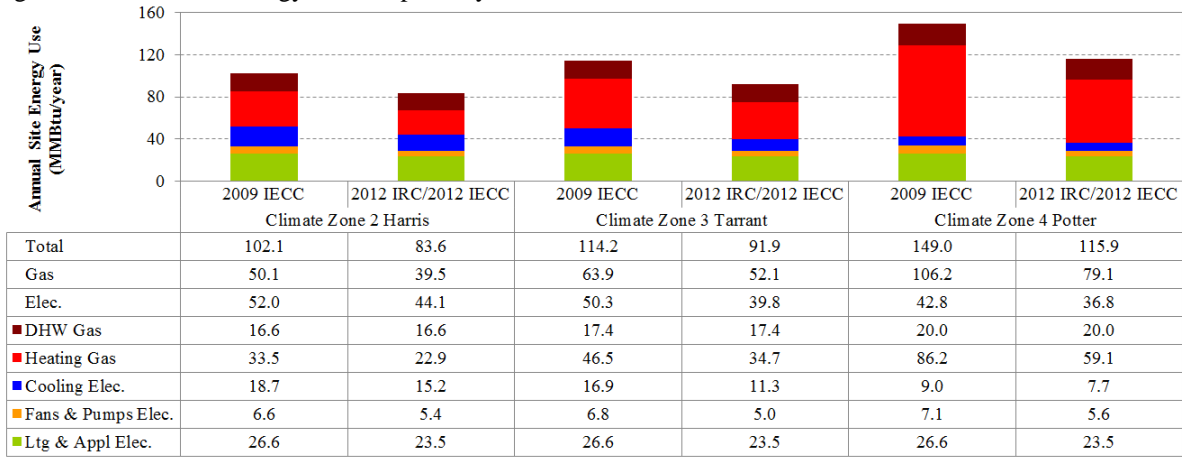


(a) Electric/Gas House

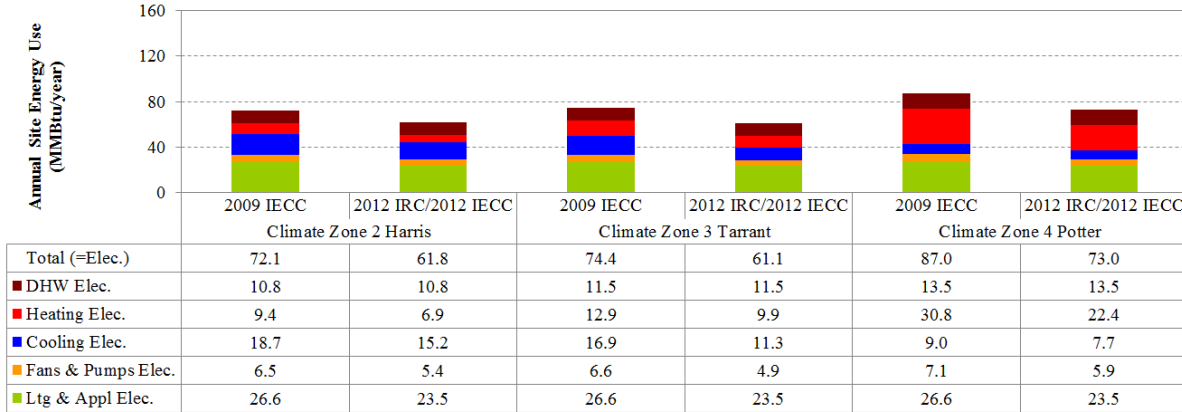


(b) All-Electric House

Figure 2. Annual Site Energy Consumption by Different End Uses for Residential Performance Path Simulations



(a) Electric/Gas House



(b) All-Electric House

Figure 3. Annual Site Energy Consumption by Different End Uses for Residential Prescriptive Path Simulations

Table 3. Total Annual Source Energy Savings (%) of the 2012 IRC/2012 IECC Compared to the 2009 IECC: Residential Single-Family Analysis

County	2012 IRC/2012 IECC Climate Zones	Performance Path Comparison		Prescriptive Path Comparison	
		Electric/Gas House	All-Electric House	Electric/Gas House	All-Electric House
Harris	2	19.4%	18.4%	16.7%	14.3%

Tarrant	3	21.4%	20.9%	20.1%	17.9%
Potter	4	18.3%	16.3%	19.3%	16.1%

generally agrees with the source energy savings reported in this study: 14% to 21%.

RESULTS FOR COMMERCIAL ANALYSIS

Figure 4 presents the detailed simulation results of large office buildings in three selected counties in Texas for a commercial performance path analysis. Table 4 presents the total annual site and source energy savings of the 2012 IECC compared to the 2009 IECC for a commercial performance path comparison.

Performance Path Analysis

Across all counties, the 2012 IECC performance path code-compliant large office building reported less site energy consumption than the 2009 IECC. The total annual site energy consumption of a 2009 IECC performance path code-compliant building are: 4,120 MMBtu/yr (46.1 kBtu/ft²-yr) for Harris County, 4,122 MMBtu/yr (46.2 kBtu/ft²-yr) for Tarrant County, and 4,523 MMBtu/yr (50.6 kBtu/ft²-yr) for Potter County. The 2012 IECC performance path code-compliant building reported the following site energy totals: 3,696 MMBtu/yr (41.4 kBtu/ft²-yr) for Harris County, 3,823 MMBtu/yr (42.8 kBtu/ft²-yr) for Tarrant County, and 3,998 MMBtu/yr (44.8 kBtu/ft²-yr) for Potter County.

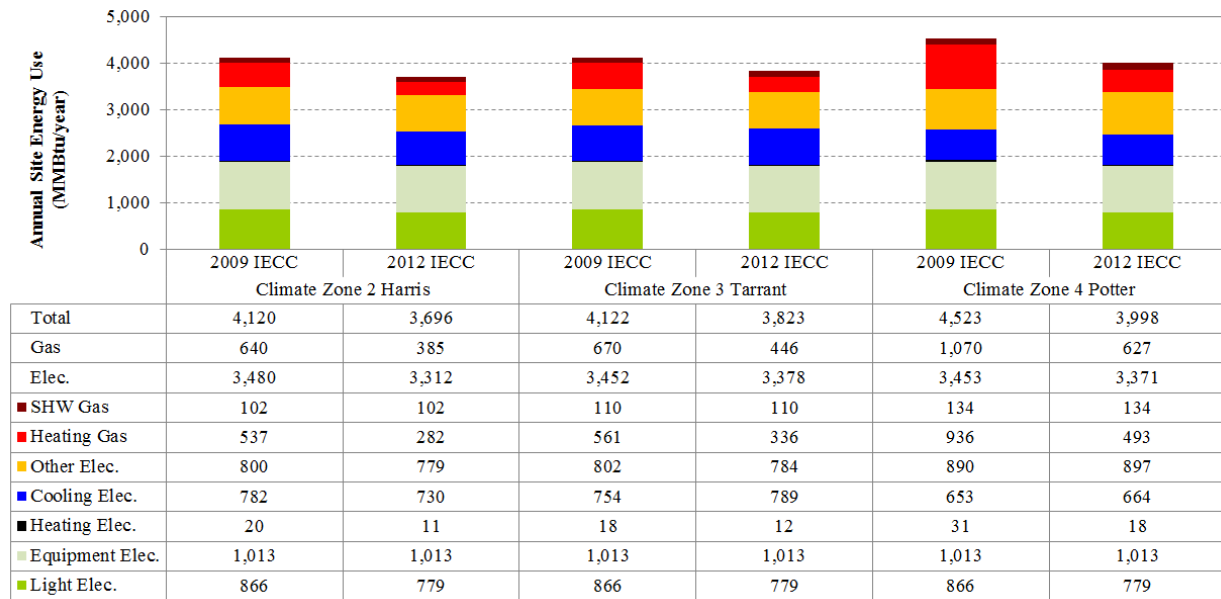


Figure 4. Annual Site Energy Consumption by Different End Uses for Commercial Performance Path Simulations

Table 4. Total Annual Source Energy Savings (%) of the 2012 IECC Compared to the 2009 IECC: Commercial Large Office Analysis

County	2012 IRC/2012 IECC Climate Zones	Performance Path Comparison	
		Site	Source
Harris	2	10.3%	7.0%
Tarrant	3	7.3%	4.1%
Potter	4	11.6%	6.2%

for Tarrant County, and 3,998 MMBtu/yr (44.8 kBtu/ft²-yr) for Potter County.

The annual source energy savings associated with the 2012 IECC performance path were then calculated by comparisons to the respective, 2009 IECC performance path code-compliant buildings. Across all counties, the 2012 IECC performance path code-compliant building reported less source energy

consumption than the 2009 IECC. The annual source energy savings associated with the 2012 IECC performance path are: 811 MMBtu/yr (9.1 kBtu/ft²-yr) for Harris County, 482 MMBtu/yr (5.4 kBtu/ft²-yr) for Tarrant County, and 745 MMBtu/yr (8.3 kBtu/ft²-yr) for Potter County. This corresponds to: 7.0% for Harris County, 4.1% for Tarrant County, and 6.2% for Potter County.

Comparison with Other Studies

Several other studies examined the commercial provisions of the 2012 IECC compared to the 2009 IECC, including the two analyses performed by PNNL (Halverson et al. 2011, Mapes and Conover 2012); and the analysis performed by Niles Bolton Associates, Inc. (2012). One of the three studies quantified savings from the ASHRAE Standard 90.1-2010 prescriptive path¹³ using 16 different building prototypes across the 15 climate zones in the U.S. (Halverson et al. (2011)).¹⁴ This study concluded that the energy use for each of the 16 building prototypes implementing the ASHRAE Standard 90.1-2010 prescriptive requirements was less than when implementing the ASHRAE Standard 90.1-2007 prescriptive requirements. When considering the national average energy savings¹⁵, the results provided 18.5% site energy savings and 18.2% source energy savings on implementing the ASHRAE Standard 90.1-2010. Specifically for large office buildings, when considering a weighted average of energy consumption across the 15 climate zones, the results provided 22.3% site energy savings and 21.5% source energy savings on implementing the ASHRAE Standard 90.1-2010. The difference in the results reported by the PNNL study and this study can be attributed to the differences in assumptions used in the simulation models of the large office building and the specifications adopted from the standards¹⁶, and because the results from the PNNL report energy consumption as a weighted average across the 15 climate zones.

SUMMARY

This paper presents a detailed technical analysis comparing the stringency of the Texas Building Energy Performance Standards (TBEPS), based on Chapter 11 of the 2009 International Residential Code (IRC) for residential construction and Chapter 5 of the 2009 International Energy Conservation Code (IECC) for commercial construction, to the recently published editions of the IRC and IECC: 2012 IRC for residential

construction and 2012 IECC for commercial construction. A series of simulations were performed using the Laboratory's single-family and large commercial office building simulation models based on the DOE-2.1e program and the appropriate TMY2 weather files for three counties representing three 2009 IECC and 2012 IECC Climate Zones across Texas: Harris County for Climate Zone 2, Tarrant County for Climate Zone 3, and Potter County for Climate Zone 4.

The analysis determined that the residential provisions of 2012 IRC¹⁷ are more stringent than the 2009 IRC that used the relevant 2009 IECC residential provisions, which is one of the two paths to comply with the 2009 IRC per Section N1101.2 of the code. The annual total source energy savings of the 2012 IRC ranges from 16.3% to 21.4% with the performance path and from 14.3% to 20.1% with the prescriptive path, depending on the climate zone and the heating system type of a house. The analysis for large office buildings also determined that the commercial provisions of 2012 IECC are more stringent than the 2009 IECC. The annual total site energy savings of the 2012 IECC ranges from 7.3% to 11.6% based on site energy use and from 4.1% to 7.0% based on source energy use, depending on the climate zone.

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¹³ To provide compliance for commercial buildings, the 2012 IECC references the ASHRAE Standard 90.1-2010 (Section C401.2, 2012 IECC), and the 2009 IECC references the ASHRAE Standard 90.1-2007 (Section 501.1, 2009 IECC).

¹⁴ Mapes and Conover (2012) provides a complete list of revisions, additions and deletions that were made to the 2009 IECC, which formed the basis of the 2012 IECC. The report also provides an objective summary of the key changes that have been made to the IECC code on going from the 2009 version to the 2012 version. The study by Niles Bolton Associates, Inc. (2012) provides a comparison of the 2009 IECC against the 2012 IECC for low-rise and high-rise multifamily buildings, which includes a discussion on the code changes and a comparison of the implementation costs. The report noted considerable differences in the compliance costs on implementing the two codes.

Although neither study directly comment on the stringency of the 2012 IECC, it is implied with the use of improved building materials, practices and increased construction costs.

¹⁵ The results were reported using floor space-weighted national energy use intensity (EUI) statistics by fuel type for each building type and standard level. In order to obtain national average estimates the results were weighted by building type and climate zone.

¹⁶ The PNNL study implements prescriptive requirements. On the other hand this study implements the performance path requirements outlined in the two standards (Chapter 11: Energy Cost Budget Method).

¹⁷ The residential provisions in Chapter 11 of the 2012 IRC are identical to the 2012 IECC.

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