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A COMPARISON OF BUILDING ENERGY CODE STRINGENCY: 2009 IRC VERSUS 2012 IRC FOR SINGLE-FAMILY RESIDENCES IN TEXAS

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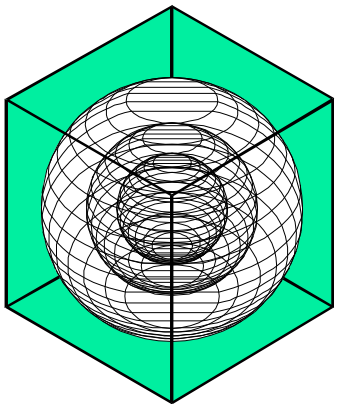

ENERGY SYSTEMS LABORATORY

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PREFACE

The original version of this report was published in December 2011. In July 2012, significant revisions were made in this report to include: 1) the impact of new EIR calculation models[1] that were recently incorporated into the Laboratory's single-family simulation model (BDL version 4.01.09 of International Code Compliance Calculator (IC3)) on the results; 2) the impact of high-efficacy lighting provision (Sec. R404.1 of the 2012 IECC) on the results; and 3) the results of prescriptive path analysis. The remainder of this report, including the base-case house used in the analysis and overall approaches, remains unchanged.

[1] Details on a new cooling EIR calculation model are available in Kim et al (2012).
[2] Details on a new cooling EIR calculation model are available in Kim et al (2012).
[3] Details on a new cooling EIR calculation model are available in Kim et al (2012).
[4] In the 2012 IRC and 2012 IECC, a mechanical ventilation system is required to be installed for the houses that have an air

EXECUTIVE SUMMARY

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, 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 Texas Building Energy Performance Standards (TBEPS).

This report, focusing on single-family residence provisions, is in support of the letter of recommendation sent to the State Energy Conservation office (SECO) on December 8, 2011. The report provides 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 (2009 IRC) for single-family residential construction, to the recently published 2012 International Residential Code (2012 IRC), Chapter 11.

In this analysis:

- **The prescriptive and performance methods from the 2009 IECC residential provisions (Chapters 1-4) were used to represent the TBEPS / Chapter 11 of the 2009 IRC.** Chapter 11 of the 2009 IRC, Section N1101.2, requires compliance to be demonstrated by either meeting the requirements in this chapter or of the 2009 IECC. The IRC contains requirements for a prescriptive method of compliance, while the IECC contains both prescriptive and performance methods of compliance.
- **The prescriptive and performance methods from the 2012 IECC residential provisions (Chapters 1-4) were used to represent the recently published code 2012 IRC, Chapter 11**. Chapter 11 of the 2012 IRC is identical to the 2012 IECC residential provisions (Chapters 1-4).

A series of simulations were performed using an ESL single-family simulation model (BDL version 4.01.09 of International Code Compliance Calculator (IC3) that includes new EIR calculation models[2]) based on the DOE-2.1e program and the appropriate TMY2 weather files for three counties representing three 2009 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 and 2012 IECC are more stringent than the 2009 IRC (using the prescriptive and performance methods from the 2009 IECC residential provisions, as explained above). Tables 1 and 2 present 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: Table 1 for a performance path comparison and Table 2 for a prescriptive path comparison.

[2] Details on a new cooling EIR calculation model are available in Kim et al (2012).

Table 1. 2009 IECC Performance Path vs. 2012 IRC and 2012 IECC Performance Path

County	2012 IRC and 2012 IECC Climate Zones	Total Annual Source Energy Savings of the 2012 IRC/2012 IECC Performance Path compared to the 2009 IECC (%)[1,2]	
		Gas Heating, DHW	Heat Pump Heating, Electric DHW
Houston (HAR)	2	19.4%	18.4%
Dallas (TAR)	3	21.4%	20.9%
Amarillo (POT)	4	18.3%	16.3%

[1]***Base-Case Simulation Assumptions:*** Analysis used a single-family house, 2,325 ft2, single-story, four bedrooms, slab-on-grade, ducts in the unconditioned vented attic, window-to-floor ratio: 15%, windows equally distributed (N, E, S, W), and no exterior shading. Air exchange rate: 0.00036 SLA for 2009 IECC; for 2012 IRC/2012 IECC, air leakage simulated using 5 ACH50 (i.e., 0.00025 SLA) for Climate Zones 2 and 3 ACH50 (i.e., 0.00015 SLA) for Climate Zones 3 and 4 in addition to the mechanical ventilation of 61 CFM. Annual mechanical ventilation fan energy use: 239 kWh/yr for both 2009 IECC and 2012 IRC/2012 IECC. HVAC distribution efficiency simulated using R6 insulation for supply and return ducts and total duct leakage of 11% to outdoor for 2009 IECC; for 2012 IRC/2012 IECC, simulated using R6 insulation for supply and return ducts and total duct leakage of 4% to outdoor. Internal heat gains adjusted to include 75% of high-efficacy lamps for 2012 IRC/2012 IECC. All other building envelope and system parameters set as per 2009 IECC and 2012 IRC/2012 IECC for county shown (IC3 ver. 4.01.09).
[2]***Source Energy Consumption:*** A factor of 3.16 was used to calculate the source electricity consumption. A factor of 1.1 was used to calculate source gas energy consumption.

Table 2. 2009 IECC Prescriptive Path vs. 2012 IRC and 2012 IECC Prescriptive Path

County	2012 IRC and 2012 IECC Climate Zones	Total Annual Source Energy Savings of the 2012 IRC/2012 IECC Prescriptive Path compared to the 2009 IECC (%)[1,2]	
		Gas Heating, DHW	Heat Pump Heating, Electric DHW
Houston (HAR)	2	16.7%	14.3%
Dallas (TAR)	3	20.1%	17.9%
Amarillo (POT)	4	19.3%	16.1%

[1]***Base-Case Simulation Assumptions:*** Analysis used a single-family house, 2,325 ft2, single-story, four bedrooms, slab-on-grade, ducts in the unconditioned vented attic, window-to-floor ratio: 15%, windows equally distributed (N, E, S, W), and no exterior shading. Air exchange rate: 7 ACH50 (i.e., 0.00036 SLA) in addition to the mechanical ventilation of 61 CFM for 2009 IECC; for 2012 IRC/2012 IECC, air leakage simulated using 5 ACH50 (i.e., 0.00025 SLA) for Climate Zone 2 and 3 ACH50 (i.e., 0.00015 SLA) for Climate Zone 3 and 4 in addition to the mechanical ventilation of 61 CFM. Annual mechanical ventilation fan energy use: 239 kWh/yr for both 2009 IECC and 2012 IRC/2012 IECC. HVAC distribution efficiency simulated using R8 insulation for supply, R6 for return ducts and total duct leakage of 11% to outdoor for 2009 IECC; for 2012 IRC/2012 IECC, simulated using R8 insulation for supply, R6 for return ducts and total duct leakage of 4% to outdoor. Internal heat gains adjusted to include 50% of high-efficacy lamps for 2009 IECC; and 75% of high-efficacy lamps for 2012 IRC/2012 IECC. Hot water pipe R-3 insulation provision unevaluated. All other building envelope and system parameters set as per 2009 IECC and 2012 IRC/2012 IECC for county shown (IC3 ver. 4.01.09).
[2]***Source Energy Consumption:*** A factor of 3.16 was used to calculate the source electricity consumption. A factor of 1.1 was used to calculate source gas energy consumption.

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1 INTRODUCTION

This report presents the results of 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 (2009 IRC) for single-family residential construction to the 2012 International Residential Code (2012 IRC). The residential provisions in Chapter 11 of the 2012 IRC are identical to the 2012 IECC. The analysis used the relevant 2009 IECC residential (Chapters 1-4) provisions, which is one of the two paths to comply with the 2009 IRC per Section N1101.2 of the code.

A series of simulations were performed using an ESL single-family simulation model (BDL version 4.01.09 of International Code Compliance Calculator (IC3) that includes new EIR calculation models[3]) based on the DOE-2.1e program and the appropriate TMY2 weather files for three counties representing three 2009 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 base-case building was assumed to be a 2,325 sq. ft., square-shape, one story, single-family, detached house The base-case building envelope and system characteristics were determined from the general characteristics and the climate-specific characteristics as determined in the 2009 and 2012 IECC prescriptive and performance path analysis. Two options based on the choice of heating fuel type were considered: (a) an electric/gas house (gas-fired furnace for space heating, and gas water heater for domestic water heating), and (b) an all-electric house (heat pump for space heating, and electric water heater for domestic water heating).

1.1 Organization of the Report

The report is organized in the following order; Section 1 presents the introduction and purpose of the report. Section 2 presents the methodology, including overview and the base-case model used for simulation. Section 3 provides the results of simulation and the annual energy savings associated with the 2012 IECC for a performance path comparison. The results for a prescriptive comparison are presented in Section 4 while Section 5 gives a summary.

[3] Details on a new cooling EIR calculation model are available in Kim et al (2012).

2 METHODOLOGY

This section describes the methodology and assumptions used in this analysis to determine the stringency of the 2012 IRC/2012 IECC versus 2009 IECC. Section 2.1 presents an overall approach used in this analysis. Section 2.2 describes the base-case building characteristics.

2.1 Overview

The analysis was performed using an ESL single-family simulation model (BDL version 4.01.09 of IC3 that includes new EIR calculation models) based on the DOE-2.1e program of the 2009 IECC and the 2012 IRC/2012 IECC code-compliant residences and the appropriate TMY2 weather files. Three counties in Texas representing three 2009 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). For each representative county, a series of simulations that comply with the corresponding requirements of the 2009 IECC and the 2012 IRC/2012 IECC were executed: for (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).

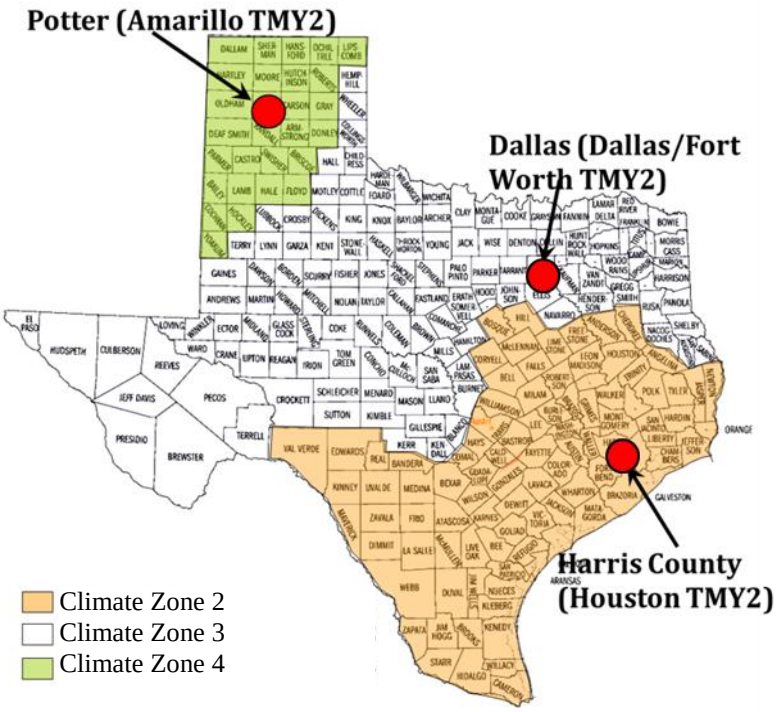


Figure 1. 2009 and 2012 IECC Climate Zone Classification and Three Selected Counties in Texas.

2.2 **Base-Case Building Description**

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 system[4]. 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).

The base-case building envelope and system characteristics were determined from the general characteristics and the climate-specific characteristics as specified in the 2009 IECC and 2012 IRC/2012 IECC: per Section 405 of the 2009 IECC and Section R405 of the 2012 IECC (or Section N1105 of the 2012 IRC) for a performance path comparison; and per Section 401 to 404 of the 2009 IECC and Section R401 to R404 of the 2012 IECC (or Section N1101 to N1104 of the 2012 IRC) for a prescriptive path comparison.

2.2.1 Performance Path Analysis

Table 3 summarizes the base-case building characteristics for each climate zone that were used for a performance path analysis with information sources. 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 '2009 IRC and 2012 IECC Performance Modified' in Table 3. 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 IECC[5].

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

1) Increased roof/ceiling insulation
    - Climate Zone 2: From U-0.035 (R-28.9) to U-0.030 (R-33.7)
    - Climate Zone 3: From U-0.035 (R-28.9) to U-0.030 (R-33.7)
    - Climate Zone 4: From U-0.030 (R-33.7) to U-0.026 (R-38.8)

[4] In the 2012 IRC and 2012 IECC, a mechanical ventilation system is required to be installed for the houses that have an air infiltration rate less than 5 ACH when tested with a blower door at a pressure of 0.2 inch w.c (50 Pa) 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 ACH in Climate Zones 1 and 2, and 3 ACH in Climate Zones 3 through 8 to comply with the 2012 IECC, the houses need to be provided with appropriate ventilation rate based on the Table M1507.3.3(1) of the 2012 IRC. However, the code does not have any provisions for the operation of the installed mechanical ventilation systems, including how it is to be modeled.

[5] 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 in permanently installed lighting fixtures to be high-efficacy lamps. To take account of this provision in the simulations, 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.

2) Increased wall insulation
    - Climate Zone 2: U-0.082 (R-11.8) for both codes (no changes)
    - Climate Zone 3: From U-0.082 (R-11.8) to U-0.057 (R-18.9)
    - Climate Zone 4: From U-0.082 (R-11.8) to U-0.057 (R-18.9)

3) Decreased glazing U-factor
    - Climate Zone 2: From U-0.65 to U-0.40
    - Climate Zone 3: From U-0.50 to U-0.35
    - Climate Zone 4: U-0.35 for both codes (no changes)

4) Decreased glazing SHGC
    - Climate Zone 2: From 0.30 to 0.25
    - Climate Zone 3: From 0.30 to 0.25
    - Climate Zone 4: 0.40 for both codes (no changes)

5) Interior shading fraction (assumptive input for performance path analysis)[6]
    - Climate Zone 2: From 0.7 for summer and 0.85 for winter to 0.87 for both seasons
    - Climate Zone 3: From 0.7 for summer and 0.85 for winter to 0.87 for both seasons
    - Climate Zone 4: From 0.7 for summer and 0.85 for winter to 0.84 for both seasons

6) Reduced air leakage[7]
    - Climate Zone 2: From 0.00036 SLA (7 ACH50) to 5 ACH50
    - Climate Zone 3: From 0.00036 SLA (7 ACH50) to 3 ACH50
    - Climate Zone 4: From 0.00036 SLA (7 ACH50) to 3 ACH50

7) Added mechanical ventilation rate (standard reference house input for performance path analysis)[8]
    - Climate Zones 2, 3, and 4: From 0 to 60.75 cfm (0.20 ACH)[9]

8) Reduced duct leakage
    - Climate Zones 2, 3, and 4: From 8 cfm per 100 sq.ft. of conditioned floor are (CFA) of duct leakage to outdoors (11.2 %) to 4 cfm per 100 sq.ft. of CFA of total duct leakage (4.2%)[10]

[6] The fractions for the 2012 IECC were calculated using: 0.92 − (0.21 × SHGC of the standard reference design).
[7] Testing is optional in the 2009 IECC, while it is mandatory in the 2012 IECC.
[8] The house was assumed to be equipped with a mechanical ventilation system. The performance path analysis of the 2012 IECC (Section R405) 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, 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 ACH50 (i.e., 0.00025 SLA) for Climate Zone 2 and 3 ACH50 (i.e., 0.00015 SLA) for Climate Zone 3 and 4 in addition to the mechanical ventilation of 61 CFM (0.20 ACH). In addition, the annual mechanical ventilation fan energy use of 239 kWh/yr was added for both 2009 IECC and 2012 IRC/2012 IECC. 239 kWh/yr was calculated using: 0.03942 × Conditioned Floor Area + 29.565 × (Number of bedrooms +1) from Table 405.5.2(1) of the 2009 IECC and Table R405.5.2(1) of the 2012 IECC.
[9] 60.75 cfm (0.20 ACH) was calculated using: 0.01 × Conditioned Floor Area + 7.5 × (Number of bedrooms + 1) from Table 405.5.2(1) of the 2009 IECC and Table R405.5.2(1) of the 2012 IECC.
[10] The 2012 IECC includes only 'total duct leakage' option, which is 4 cfm per 100 sq.ft. of conditioned floor area (CFA) per Section R403.2.2. To create an input to the International Code Compliance Calculator (IC3), 3 cfm per 100 sq.ft. of CFA was assumed for 'duct leakage to outdoors,' which results in 4.2% duct leakage.

9) 75% of high-efficacy lamps (for 2012 IRC and 2012 IECC Performance Modified)
    - Climate Zones 2, 3, and 4: From 0.547 kW to 0.239 kW for internal heat gains from lighting

2.2.2 Prescriptive Path Analysis

Table 4 summarizes the base-case building characteristics for each climate zone that were used for a prescriptive path analysis with information sources. 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, and they are noted in the table under the column labeled 'comments.'

Several changes were made in the 2012 IRC and 2012 IECC prescriptive path. The building envelope and systems components that have different specifications from the 2009 IECC prescriptive path are highlighted in light orange in the table[11]. These changes include:

1) Increased roof/ceiling insulation
    - Climate Zone 2: From U-0.035 (R-28.9) to U-0.030 (R-33.7)
    - Climate Zone 3: From U-0.035 (R-28.9) to U-0.030 (R-33.7)
    - Climate Zone 4: From U-0.030 (R-33.7) to U-0.026 (R-38.8)

2) Increased wall insulation
    - Climate Zone 2: U-0.082 (R-11.8) for both codes (no changes)
    - Climate Zone 3: From U-0.082 (R-11.8) to U-0.057 (R-18.9)
    - Climate Zone 4: From U-0.082 (R-11.8) to U-0.057 (R-18.9)

3) Decreased glazing U-factor
    - Climate Zone 2: From U-0.65 to U-0.40
    - Climate Zone 3: From U-0.50 to U-0.35
    - Climate Zone 4: U-0.35 for both codes (no changes)

4) Decreased glazing SHGC
    - Climate Zone 2: From 0.30 to 0.25
    - Climate Zone 3: From 0.30 to 0.25
    - Climate Zone 4: 0.40 for both codes (no changes)

5) 75% of high-efficacy lamps[12]
    - Climate Zones 2, 3, and 4: From 0.342 kW (50% high-efficacy lamps) to 0.239 kW (75% high-efficacy lamps) for internal heat gains from lighting

[11] Hot water pipe R-3 insulation provision in Sec R403.4.2 of the 2012 IECC was not evaluated in this analysis.
[12] 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.

6) Reduced air leakage[13]
    - Climate Zone 2: From 7 ACH50 to 5 ACH50
    - Climate Zone 3: From 7 ACH50 to 3 ACH50
    - Climate Zone 4: From 7 ACH50 to 3 ACH50

7) Reduced duct leakage
    - Climate Zones 2, 3, and 4: From 8 cfm per 100 sq.ft. of conditioned floor are (CFA) of duct leakage to outdoors (11.2 %) to 4 cfm per 100 sq.ft. of CFA of total duct leakage (4.2%)[14]

[13] A testing is optional in 2009 IECC, while it is mandatory in the 2012 IECC.
[14] The 2012 IECC includes only 'total duct leakage' option, which is 4 cfm per 100 sq.ft. of conditioned floor area (CFA) per Section R403.2.2. For an input to the International Code Compliance Calculator (IC3), 3 cfm per 100 sq.ft. of CFA was assumed for 'duct leakage to outdoors,' which results in 4.2% duct leakage.

Table 3. Base Case Building Description: Performance Path Analysis

Characteristics	2009 IECC Performance			2012 IRC and 2012 IECC Performance			2012 IRC and 2012 IECC Performance Modified[1]			Information Source			
	CZ 2	CZ 3	CZ 4	CZ 2	CZ 3	CZ 4	CZ 2	CZ 3	CZ 4	2009 IECC	2012 IRC	2012 IECC	Others
	HAR	TAR	POT	HAR	TAR	POT	HAR	TAR	POT				
Building													
Building Type	Single family, detached house												
Gross Area	2,325 sq. ft. (48.21 ft. x 48.21 ft.)												NAHB (2003)
Number of Floors	1												NAHB (2003)
Floor to Floor Height (ft.)	8												NAHB (2003)
Orientation	South facing												
Construction													
Construction	Light-weight wood frame with 2x4 studs spaced at 16" on center												NAHB (2003)
Floor	Slab-on-grade floor												NAHB (2003)
Roof Configuration	Unconditioned, vented attic												NAHB (2003)
Roof Absorptance	0.75									Table 405.5.2(1)	Table N1105.5.2(1)	Table R405.5.2(1)	
Ceiling U-Factor	0.035		0.030	0.030		0.026	0.030		0.026	Table 402.1.3	Table N1102.1.3	Table R402.1.3	
Wall Absorptance	0.75									Table 405.5.2(1)	Table N1105.5.2(1)	Table R405.5.2(1)	
Wall U-Factor	0.082			0.082	0.057		0.082	0.057		Table 402.1.3	Table N1102.1.3	Table R402.1.3	
Slab Perimeter Insulation	None		R-10	None		R-10	None		R-10	Table 402.1.1	Table N1102.1.1	Table R402.1.1	
U-Factor of Glazing (Btu/hr-sq.ft.-°F)	0.65	0.50	0.35	0.40	0.35	0.35	0.40	0.35	0.35	Table 402.1.3	Table N1102.1.3	Table R402.1.3	
Solar Heat Gain Coefficient (SHGC)	0.30		0.40	0.25		0.40	0.25		0.40	Table 402.1.1	Table N1102.1.1	Table R402.1.1	
Window Area	15% of conditioned floor area									Table 405.5.2(1)	Table N1105.5.2(1)	Table R405.5.2(1)	
Interior Shading	Summer 0.7, Winter 0.85 (Simulation adjustment[2]: 0.87 for HAR and TAR; and 0.84 for POT)			0.87		0.84	0.87		0.84	Table 405.5.2(1)	Table N1105.5.2(1)	Table R405.5.2(1)	
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									Table 405.5.2(1)	Table N1105.5.2(1)	Table R405.5.2(1)	
Internal Heat Gains	1.095 kW (0.547 kW for lighting and 0.547 kW for equipment)			1.095 kW (0.547 kW for lighting and 0.547 kW for equipment)			0.786 kW (0.239 kW for lighting with 75% high-efficacy lamps; and 0.547 kW for equipment)			Table 405.5.2(1)	Table N1105.5.2(1) and Sec. N1104.1	Table R405.5.2(1) and Sec. R404.1	
Air Leakage (SG)	0.00036 SLA			5 ACH50 (0.00025 SLA)	3 ACH50 (0.00015 SLA)		5 ACH50 (0.00025 SLA)	3 ACH50 (0.00015 SLA)		Table 405.5.2(1)	Sec. N1102.4.1.2	Sec. R402.4.1.2	
Mechanical Ventilation[3]	None			60.8 CFM (0.20 ACH)			60.8 CFM (0.20 ACH)			Table 405.5.2(1)	Table N1105.5.2(1) and Sec. N1103.5	Table R405.5.2(1) and Sec. R403.5	
Mechanical Systems													
HVAC System Efficiency	(a) Electric/Gas House (gas fired furnace): SEER 13 AC, 0.78 AFUE furnace												Federal minimum efficiency
	(b) All-Electric House (heat pump heating): SEER 13 AC, 7.7 HSPF												
Cooling Capacity (Btu/hr)	55,800 (= 500 sq. ft./ton)												
Heating Capacity (Btu/hr)	55,800 (= 1.0 x cooling capacity)												
DHW daily consumption	70 gal/day									Table 405.5.2(1)	Table N1105.5.2(1)	Table R405.5.2(1)	
DHW Heater Energy Factor[4]	(a) Electric/Gas House (40-gallon tank type gas water heater): 0.594												Federal minimum efficiency
	(b) All-Electric House (50-gallon tank type electric water heater): 0.904												
Duct Distribution System Efficiency[5]	11.2% duct leakage[6], R-6/R-6 duct insulation			4.2% duct leakage[7], R-6/R-6 duct insulation			4.2% duct leakage[7], R-6/R-6 duct insulation			Sec. 403.2.2 and 405.2	Sec. N1103.2.2 and N1105.2	Sec. R403.2.2 and R405.2	

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

1) 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 in permanently installed lighting fixtures to be high-efficacy lamps. To take account of this provision in the simulations, a modification was applied to the 2012 IECC Performance Path.

2) To facilitate a more accurate and realistic comparison between the codes, an adjustment was applied to the 2009 IECC codes.

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

4) DHW tank size was determined from the ASHRAE Handbook - HVAC Systems and Equipment.

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

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

7) Calculated from a maximum total duct leakage specified in 2012 IECC Sec. R403.2.2: 4 CFM per 100 sq.ft. of CFA .

Table 4. Base Case Building Description: Prescriptive Path Analysis

Characteristics	2009 IECC Prescriptive			2012 IRC and 2012 IECC Prescriptive			Comments	Information Source				
	CZ 2	CZ 3	CZ 4	CZ 2	CZ 3	CZ 4		2009 IRC	2009 IECC	2012 IRC	2012 IECC	Others
	HAR	TAR	POT	HAR	TAR	POT						
Building												
Building Type	Single family, detached house											
Gross Area	2,325 sq. ft. (48.21 ft. x 48.21 ft.)											NAHB (2003)
Number of Floors	1											NAHB (2003)
Floor to Floor Height (ft.)	8											NAHB (2003)
Orientation	South facing											
Construction												
Construction	Light-weight wood frame with 2x4 studs spaced at 16" on center											NAHB (2003)
Floor	Slab-on-grade floor											NAHB (2003)
Roof Configuration	Unconditioned, vented attic											NAHB (2003)
Roof Absorptance	0.75						Same as performance		Table 405.5.2(1)	Table N1105.5.2(1)	Table R405.5.2(1)	
Ceiling U-Factor	0.035		0.030	0.030		0.026		Table N1102.1.2	Table 402.1.3	Table N1102.1.3	Table R402.1.3	
Wall Absorptance	0.75						Same as performance		Table 405.5.2(1)	Table N1105.5.2(1)	Table R405.5.2(1)	
Wall U-Factor	0.082			0.082	0.057			Table N1102.1.2	Table 402.1.3	Table N1102.1.3	Table R402.1.3	
Slab Perimeter Insulation	None		R-10	None		R-10		Table N1102.1	Table 402.1.1	Table N1102.1.1	Table R402.1.1	
U-Factor of Glazing (Btu/hr-sq.ft.-°F)	0.65	0.50	0.35	0.40	0.35	0.35		Table N1102.1.2	Table 402.1.3	Table N1102.1.3	Table R402.1.3	
Solar Heat Gain Coefficient (SHGC)	0.30		0.40	0.25		0.40		Table N1102.1	Table 402.1.1	Table N1102.1.1	Table R402.1.1	
Window Area	15% of conditioned floor area						Same as performance		Table 405.5.2(1)	Table N1105.5.2(1)	Table R405.5.2(1)	
Interior Shading	0.86		0.84	0.87		0.84	Same as performance		Table 405.5.2(1)	Table N1105.5.2(1)	Table R405.5.2(1)	
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						Same as performance		Table 405.5.2(1)	Table N1105.5.2(1)	Table R405.5.2(1)	
Internal Heat Gains[1]	0.889 kW (0.342 kW for lighting with 50% high-efficacy lamps; and 0.547 kW for equipment)			0.786 kW (0.239 kW for lighting with 75% high-efficacy lamps; and 0.547 kW for equipment)				Sec. N1104.1	Sec. 404.1	Sec. N1104.1	Sec. R404.1	
Air Leakage (SG)	7 ACH50 (0.00036 SLA)			5 ACH50 (0.00025 SLA)	3 ACH50 (0.00015 SLA)			Sec. N1102.4.2.1	Sec. 402.4.2.1	Sec. N1102.4.1.2	Sec. R402.4.1.2	
Mechanical Ventilation[2]	60.8 CFM (0.20 ACH)			60.8 CFM (0.20 ACH)			Same as performance			Sec. N1103.5	Sec. R403.5	
Mechanical Systems												
HVAC System Efficiency	(a) Electric/Gas House (gas fired furnace): SEER 13 AC, 0.78 AFUE furnace						Same as performance					Federal minimum efficiency
	(b) All-Electric House (heat pump heating): SEER 13 AC, 7.7 HSPF											
Cooling Capacity (Btu/hr)	55,800 (= 500 sq. ft./ton)						Same as performance					
Heating Capacity (Btu/hr)	55,800 (= 1.0 x cooling capacity)											
DHW daily consumption	70 gal/day						Same as performance		Table 405.5.2(1)	Table N1105.5.2(1)	Table R405.5.2(1)	
DHW Heater Energy Factor[3]	(a) Electric/Gas House (40-gallon tank type gas water heater): 0.594						Same as performance					Federal minimum efficiency
	(b) All-Electric House (50-gallon tank type electric water heater): 0.904											
Duct Distribution System Efficiency[4]	11.2% duct leakage[5], R-8/R-6 duct insulation			4.2% duct leakage[6], R-8/R-6 duct insulation				Sec. N1103.2.1 and N1103.2.2	Sec. 403.2.1 and 403.2.2	Sec. N1103.2.1 and N1103.2.2	Sec. R403.2.1 and R403.2.2	

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

1) The assumption on internal heat gains for 0% high-efficacy lamps was made based on the performance path (Table 405.5.2(1) of 2009 IECC and Table R405.5.2(1) of 2012 IECC), which corresponds to 0.547 kW for lighting.

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

3) DHW tank size was determined from the ASHRAE Handbook - HVAC Systems and Equipment.

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

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

6) Calculated from a maximum total duct leakage specified in 2012 IECC Sec. R403.2.2: 4 CFM per 100 sq.ft. of CFA .

3 RESULTS: PERFORMANCE PATH ANALYSIS

This section presents the results of performance path simulations and examines the annual source energy savings associated with the 2012 IRC/2012 IECC step-by-step for: (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)[15]. Tables 5-7 show the input step-by-step for the simulations for Harris, Tarrant, and Potter counties. Tables 8-10 summarize the results of simulations for each county, including: the annual site energy consumption (by different end-uses, fuel types, and the total); the annual source energy consumption by fuel types and the total, and the calculated source energy percentage savings associated with the 2012 IRC/2012 IECC above the 2009 IECC code-compliant base cases. The results are also presented graphically in Figures 2-12: the annual site energy consumption by end-uses is shown in Figures 2-4; the monthly site energy consumption by fuel types is shown in Figures 5 and 6; the peak summer and winter day hourly electricity use and demand savings is shown in Figures 7-9; and the annual source energy consumption by fuel types is shown in Figures 10-12.

3.1 Annual Total Site Energy Consumption

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 modified 2012 IRC/ 2012 IECC performance path code-compliant house reported the following site energy totals:

(a) For an electric/gas house:
- 84.6 MMBtu/yr (36.4 kBtu/ft^2·yr) for Harris County,
- 93.2 MMBtu/yr (40.1 kBtu/ft^2·yr) for Tarrant County, and
- 118.4 MMBtu/yr (50.9 kBtu/ft^2·yr) for Potter County.

(b) For an all-electric house:
- 62.2 MMBtu/yr (26.8 kBtu/ft^2·yr) for Harris County,
- 61.6 MMBtu/yr (26.5 kBtu/ft^2·yr) for Tarrant County, and
- 73.8 MMBtu/yr (31.7 kBtu/ft^2·yr) for Potter County.

The 2009 IECC code-compliant house reported the following site energy totals:

(a) For an electric/gas house:
- 99.4 MMBtu/yr (42.8 kBtu/ft^2·yr) for Harris County,
- 108.6 MMBtu/yr (46.7 kBtu/ft^2·yr) for Tarrant County, and
- 137.7 MMBtu/yr (59.2 kBtu/ft^2·yr) for Potter County.

(b) For an all-electric house:
- 76.2 MMBtu/yr (32.8 kBtu/ft^2·yr) for Harris County,
- 77.9 MMBtu/yr (33.5 kBtu/ft^2·yr) for Tarrant County, and
- 88.2 MMBtu/yr (37.9 kBtu/ft^2·yr) for Potter County.

3.2 Peak Summertime and Wintertime Demands

The modified 2012 IRC/ 2012 IECC code-compliant houses reported lower peak summertime demands:

(a) For an electric/gas house:
- 4.2 kW for Harris County,
- 3.9 kW for Tarrant County, and

[15] More detailed analysis was performed for the performance path, and the results of the performance path analysis are presented step-by-step to examine the impact of the different changes in the 2012 IECC on the results. On the other hand, detailed analysis was not performed for the prescriptive path analysis.

- 3.9 kW for Potter County.

(b) For an all-electric house:

- 4.5 kW for Harris County,
- 4.2 kW for Tarrant County, and
- 4.3 kW for Potter County.

Not surprisingly, the 2009 IECC houses reported higher peak summertime demands:

(a) For an electric/gas house:

- 5.2 kW for Harris County,
- 5.5 kW for Tarrant County, and
- 4.8 kW for Potter County.

(b) For an all-electric house:

- 5.5 kW for Harris County,
- 5.8 kW for Tarrant County, and
- 5.2 kW for Potter County.

In the analysis, the same peak day was used regardless of the house type: August 20 for Harris County, July 29 for Tarrant County, and June 29 for Potter County.

In the winter, the peak electric demands were estimated for an all-electric house only. For the modified 2012 IRC/2012 IECC performance path code-compliant houses where lower wintertime demands are:

(b) For an all-electric house:

- 6.6 kW for Harris County,
- 6.6 kW for Tarrant County, and
- 12.3 kW for Potter County.

For the 2009 IECC code-compliant houses where higher peak wintertime demands were found:

(b) For an all-electric house:

- 8.2 kW for Harris County,
- 8.6 kW for Tarrant County, and
- 15.0 kW for Potter County.

The peak days used in the analysis were: January 11 for Harris County, January 15 for Tarrant County, and January 7 for Potter County.

3.3 **Annual Total Source Energy Consumption**

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 modified 2012 IRC/2012 IECC performance path code-compliant house reported the following source energy totals:

(a) For an electric/gas house:

- 184.6 MMBtu/yr (79.4 kBtu/ft^2·yr) for Harris County,
- 185.2 MMBtu/yr (79.6 kBtu/ft^2·yr) for Tarrant County, and
- 206.7 MMBtu/yr (88.9 kBtu/ft^2·yr) for Potter County.

(b) For an all-electric house:

- 196.6 MMBtu/yr (84.6 kBtu/ft^2·yr) for Harris County,
- 194.7 MMBtu/yr (83.7 kBtu/ft^2·yr) for Tarrant County, and
- 233.3 MMBtu/yr (100.3 kBtu/ft^2·yr) for Potter County.

The 2009 IECC code-compliant house reported the following source energy totals:

(a) For an electric/gas house:
- 228.9 MMBtu/yr (98.4 kBtu/ft^2·yr) for Harris County,
- 235.7 MMBtu/yr (101.4 kBtu/ft^2·yr) for Tarrant County, and
- 252.9 MMBtu/yr (108.8 kBtu/ft^2·yr) for Potter County.

(b) For an all-electric house:
- 240.8 MMBtu/yr (103.6 kBtu/ft^2·yr) for Harris County,
- 246.2 MMBtu/yr (105.9 kBtu/ft^2·yr) for Tarrant County, and
- 278.8 MMBtu/yr (119.9 kBtu/ft^2·yr) for Potter County.

3.4 **Peak Demand Savings from the 2012 IRC/2012 IECC**

The peak electric demand reductions associated with the modified 2012 IRC/ 2012 IECC performance path were calculated for both summer and winter periods. For summer, the reductions in peak summertime electric demands are expected to happen in the afternoon between 3 to 5 p.m.:

(a, b) For both electric/gas and an all-electric house:
- 1.0 kW for Harris County,
- 1.6 kW for Tarrant County, and
- 0.9 kW for Potter County.

For winter, the electric demand reductions were estimated for an all-electric house only:

(b) For an all-electric house:
- 1.6 kW for Harris County,
- 2.0 kW for Tarrant County, and
- 2.6 kW for Potter County.

The corresponding percentage summer electric demand savings over the 2009 IECC code-compliant houses are:

(a) For an electric/gas house:
- 19% for Harris County,
- 29% for Tarrant County, and
- 18% for Potter County.

(b) For an all-electric house:
- 18% for Harris County,
- 28% for Tarrant County, and
- 17% for Potter County.

In the winter, the percent savings are:

(b) For an all-electric house:
- 20% for Harris County,
- 23% for Tarrant County, and
- 18% for Potter County.

3.5 **Annual Source Energy Savings from the 2012 IRC/2012 IECC**

The annual source energy savings associated with the modified 2012 IRC/2012 IECC performance path were calculated by comparisons to the respective, 2009 IECC code-compliant houses:

(a) For an electric/gas house:
- 44.3 MMBtu/yr (19.1 kBtu/ft^2·yr) for Harris County,
- 50.5 MMBtu/yr (21.7 kBtu/ft^2·yr) for Tarrant County, and

- 46.2 MMBtu/yr (19.9 kBtu/ft^2·yr) for Potter County.

(b) For a heat pump house:

- 44.2 MMBtu/yr (19.0 kBtu/ft^2·yr) for Harris County,
- 51.5 MMBtu/yr (22.2 kBtu/ft^2·yr) for Tarrant County, and
- 45.5 MMBtu/yr (19.6 kBtu/ft^2·yr) for Potter County.

The corresponding percentage savings based on annual total source energy consumption of the 2009 IECC code-compliant house are:

(a) For an electric/gas house:

- 19.4% for Harris County,
- 21.4% for Tarrant County, and
- 18.3% Potter County.

(b) For a heat pump house:

- 18.4% for Harris County,
- 20.9% for Tarrant County, and
- 16.3% for Potter County.

Table 5. Input Parameters for Step-by-Step Performance Path Simulations of Changes in the 2012 IRC/2012 IECC: Harris County for Climate Zone 2.

Run No.	Test Cases	Roof R-Value	Wall R-Value	Glazing U-Factor	Glazing SHGC	SLA for House	Supply Duct Leakage	Return Duct Leakage	Lighting (kW)
	2009 IECC NG House for Harris (CZ 2)	28.9	11.8	0.65	0.30	0.00036	0.056	0.056	0.547
1	Increased Roof Insulation	**33.7**	11.8	0.65	0.30	0.00036	0.056	0.056	0.547
2	Decreased Window U-Value	28.9	11.8	**0.40**	0.30	0.00036	0.056	0.056	0.547
3	Decreased Window SHGC	28.9	11.8	0.65	**0.25**	0.00036	0.056	0.056	0.547
4	Decreased Infiltration	28.9	11.8	0.65	0.30	**0.00049**	0.056	0.056	0.547
5	Decreased Duct Leakage	28.9	11.8	0.65	0.30	0.00036	**0.021**	**0.021**	0.547
	2012 IRC/2012 IECC Performance	**33.7**	**11.8**	**0.40**	**0.25**	**0.00049**	**0.021**	**0.021**	0.547
	2012 IRC/2012 IECC Performance Modified	**33.7**	**11.8**	**0.40**	**0.25**	**0.00049**	**0.021**	**0.021**	**0.239**
	2009 IECC HP House for Harris (CZ 2)	28.9	11.8	0.65	0.30	0.00036	0.056	0.056	0.547
1	Increased Roof Insulation	**33.7**	11.8	0.65	0.30	0.00036	0.056	0.056	0.547
2	Decreased Window U-Value	28.9	11.8	**0.40**	0.30	0.00036	0.056	0.056	0.547
3	Decreased Window SHGC	28.9	11.8	0.65	**0.25**	0.00036	0.056	0.056	0.547
4	Decreased Infiltration	28.9	11.8	0.65	0.30	**0.00049**	0.056	0.056	0.547
5	Decreased Duct Leakage	28.9	11.8	0.65	0.30	0.00036	**0.021**	**0.021**	0.547
	2012 IRC/2012 IECC Performance	**33.7**	**11.8**	**0.40**	**0.25**	**0.00049**	**0.021**	**0.021**	0.547
	2012 IRC/2012 IECC Performance Modified	**33.7**	**11.8**	**0.40**	**0.25**	**0.00049**	**0.021**	**0.021**	**0.239**

Table 6. Input Parameters for Step-by-Step Performance Path Simulations of Changes in the 2012 IRC/2012 IECC: Tarrant County for Climate Zone 3.

Run No.	Test Cases	Roof R-Value	Wall R-Value	Glazing U-Factor	Glazing SHGC	SLA for House	Supply Duct Leakage	Return Duct Leakage	Lighting (kW)
	2009 IECC NG House for Tarrant (CZ 3)	28.9	11.8	0.50	0.30	0.00036	0.056	0.056	0.547
1	Increased Roof Insulation	**33.7**	11.8	0.50	0.30	0.00036	0.056	0.056	0.547
2	Increased Wall Insulation	28.9	**18.9**	0.50	0.30	0.00036	0.056	0.056	0.547
3	Decreased Window U-Value	28.9	11.8	**0.35**	0.30	0.00036	0.056	0.056	0.547
4	Decreased Window SHGC	28.9	11.8	0.50	**0.25**	0.00036	0.056	0.056	0.547
5	Decreased Infiltration	28.9	11.8	0.50	0.30	**0.00037**	0.056	0.056	0.547
6	Decreased Duct Leakage	28.9	11.8	0.50	0.30	0.00036	**0.021**	**0.021**	0.547
	2012 IRC/2012 IECC Performance	**33.7**	**18.9**	**0.35**	**0.25**	**0.00037**	**0.021**	**0.021**	0.547
	2012 IRC/2012 IECC Performance Modified	**33.7**	**18.9**	**0.35**	**0.25**	**0.00037**	**0.021**	**0.021**	**0.239**
	2009 IECC HP House for Tarrant (CZ 3)	28.9	11.8	0.50	0.30	0.00036	0.056	0.056	0.547
1	Increased Roof Insulation	**33.7**	11.8	0.50	0.30	0.00036	0.056	0.056	0.547
2	Increased Wall Insulation	28.9	**18.9**	0.50	0.30	0.00036	0.056	0.056	0.547
3	Decreased Window U-Value	28.9	11.8	**0.35**	0.30	0.00036	0.056	0.056	0.547
4	Decreased Window SHGC	28.9	11.8	0.50	**0.25**	0.00036	0.056	0.056	0.547
5	Decreased Infiltration	28.9	11.8	0.50	0.30	**0.00037**	0.056	0.056	0.547
6	Decreased Duct Leakage	28.9	11.8	0.50	0.30	0.00036	**0.021**	**0.021**	0.547
	2012 IRC/2012 IECC Performance	**33.7**	**18.9**	**0.35**	**0.25**	**0.00037**	**0.021**	**0.021**	0.547
	2012 IRC/2012 IECC Performance Modified	**33.7**	**18.9**	**0.35**	**0.25**	**0.00037**	**0.021**	**0.021**	**0.239**

Table 7. Input Parameters for Step-by-Step Performance Path Simulations of Changes in the 2012 IRC/2012 IECC: Potter County in Climate Zone 4.

Run No.	Test Cases	Roof R-Value	Wall R-Value	Glazing U-Factor	Glazing SHGC	SLA for House	Supply Duct Leakage	Return Duct Leakage	Lighting (kW)
	2009 IECC NG House for Potter (CZ 4)	33.7	11.8	0.35	0.40	0.00036	0.056	0.056	0.547
1	Increased Roof Insulation	**38.8**	11.8	0.35	0.40	0.00036	0.056	0.056	0.547
2	Increased Wall Insulation	33.7	**18.9**	0.35	0.40	0.00036	0.056	0.056	0.547
3	Decreased Infiltration	33.7	11.8	0.35	0.40	**0.00032**	0.056	0.056	0.547
4	Decreased Duct Leakage	33.7	11.8	0.35	0.40	0.00036	**0.021**	**0.021**	0.547
	2012 IRC/2012 IECC Performance	**38.8**	**18.9**	**0.35**	**0.40**	**0.00032**	**0.021**	**0.021**	0.547
	2012 IRC/2012 IECC Performance Modified	**38.8**	**18.9**	**0.35**	**0.40**	**0.00032**	**0.021**	**0.021**	**0.239**
	2009 IECC HP House for Potter (CZ 4)	33.7	11.8	0.35	0.40	0.00036	0.056	0.056	0.547
1	Increased Roof Insulation	**38.8**	11.8	0.35	0.40	0.00036	0.056	0.056	0.547
2	Increased Wall Insulation	33.7	**18.9**	0.35	0.40	0.00036	0.056	0.056	0.547
3	Decreased Infiltration	33.7	11.8	0.35	0.40	**0.00032**	0.056	0.056	0.547
4	Decreased Duct Leakage	33.7	11.8	0.35	0.40	0.00036	**0.021**	**0.021**	0.547
	2012 IRC/2012 IECC Performance	**38.8**	**18.9**	**0.35**	**0.40**	**0.00032**	**0.021**	**0.021**	0.547
	2012 IRC/2012 IECC Performance Modified	**38.8**	**18.9**	**0.35**	**0.40**	**0.00032**	**0.021**	**0.021**	**0.239**

Table 8. Results of Step-by-Step Performance Path Simulations of Changes in the 2012 IRC/2012 IECC: Harris County for Climate Zone 2.

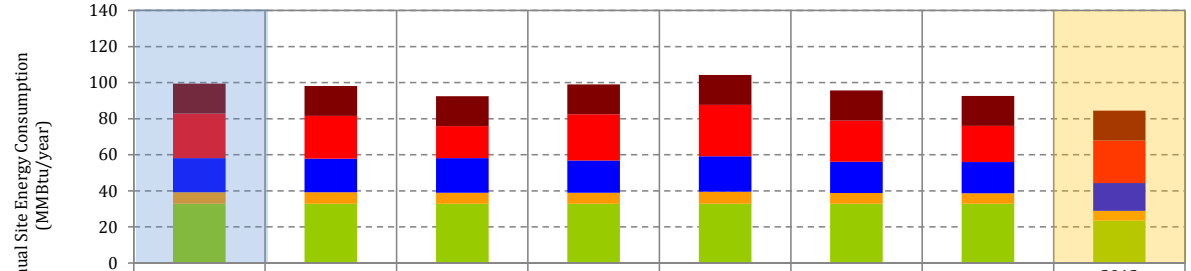
Run No.	Test Cases	Annual Site Energy Consumption by End Use (MMBtu/yr)					Annual Site Energy Consumption by Fuel Type (MMBtu/yr)			Annaul Source Energy Consumption by Fuel Type (MMBtu/yr)			Savings Above 2009 IECC (Source %)		
		Cooling	Heating	Lgt & Appl	Fans & Pumps	DHW	Elec.	Gas	Total	Elec.	Gas	Total	Elec.	Gas	Total
	2009 IECC NG House for Harris (CZ 2)	18.8	24.8	32.8	6.5	16.6	58.0	41.4	99.4	183.3	45.5	228.9			
1	Increased Roof Insulation	18.6	23.8	32.8	6.4	16.6	57.7	40.4	98.1	182.4	44.4	226.8	0.5%	2.4%	**0.9%**
2	Decreased Window U-Value	19.1	17.8	32.8	6.2	16.6	58.1	34.4	92.5	183.7	37.8	221.5	-0.2%	16.9%	**3.2%**
3	Decreased Window SHGC	17.9	25.5	32.8	6.2	16.6	56.8	42.1	98.9	179.5	46.3	225.9	2.1%	-1.7%	**1.3%**
4	Decreased Infiltration	19.7	28.5	32.8	6.7	16.6	59.2	45.1	104.3	187.1	49.6	236.7	-2.1%	-8.9%	**-3.4%**
5	Decreased Duct Leakage	17.3	22.9	32.8	6.0	16.6	56.0	39.5	95.5	177.0	43.5	220.5	3.4%	4.6%	**3.7%**
	2012 IRC/2012 IECC Performance	17.4	20.0	32.8	5.8	16.6	56.0	36.6	92.6	177.0	40.3	217.3	3.4%	11.6%	**5.1%**
	2012 IRC/2012 IECC Performance Modified	15.4	23.6	23.5	5.4	16.6	44.4	40.2	84.6	140.4	44.2	184.6	23.4%	2.9%	**19.4%**
	2009 IECC HP House for Harris (CZ 2)	18.8	7.4	32.8	6.4	10.8	76.2	-	76.2	240.8	-	240.8			
1	Increased Roof Insulation	18.6	7.2	32.8	6.3	10.8	75.6	-	75.6	239.0	-	239.0	0.8%	-	**0.8%**
2	Decreased Window U-Value	19.1	5.8	32.8	6.2	10.8	74.6	-	74.6	235.8	-	235.8	2.1%	-	**2.1%**
3	Decreased Window SHGC	17.9	7.5	32.8	6.2	10.8	75.1	-	75.1	237.4	-	237.4	1.4%	-	**1.4%**
4	Decreased Infiltration	19.7	8.3	32.8	6.6	10.8	78.1	-	78.1	246.9	-	246.9	-2.5%	-	**-2.5%**
5	Decreased Duct Leakage	17.3	6.9	32.8	6.0	10.8	73.7	-	73.7	232.9	-	232.9	3.3%	-	**3.3%**
	2012 IRC/2012 IECC Performance	17.4	6.2	32.8	5.8	10.8	73.0	_	73.0	230.7	_	230.7	4.2%	_	**4.2%**
	2012 IRC/2012 IECC Performance Modified	15.4	7.0	23.5	5.4	10.8	62.2	_	62.2	196.6	_	196.6	18.4%	_	**18.4%**

Table 9. Results of Step-by-Step Performance Path Simulations of Changes Made in the 2012 IRC/2012 IECC: Tarrant County for Climate Zone 3.

Run No.	Test Cases	Annual Site Energy Consumption by End Use (MMBtu/yr)					Annual Site Energy Consumption by Fuel Type (MMBtu/yr)			Annaul Source Energy Consumption by Fuel Type (MMBtu/yr)			Savings Above 2009 IECC (Source %)		
		Cooling	Heating	Lgt & Appl	Fans & Pumps	DHW	Elec.	Gas	Total	Elec.	Gas	Total	Elec.	Gas	Total
	2009 IECC NG House for Tarrant (CZ 3)	17.2	34.8	32.8	6.6	17.4	56.4	52.2	108.6	178.3	57.4	235.7			
1	Increased Roof Insulation	17.0	33.3	32.8	6.5	17.4	56.2	50.7	106.9	177.6	55.8	233.4	0.4%	2.9%	**1.0%**
2	Increased Wall Insulation	16.8	32.8	32.8	6.4	17.4	55.9	50.2	106.1	176.7	55.2	231.9	0.9%	3.8%	**1.6%**
3	Decreased Window U-Value	15.4	33.6	32.8	6.1	17.4	54.2	51.0	105.2	171.3	56.1	227.4	3.9%	2.3%	**3.5%**
4	Decreased Window SHGC	16.2	35.9	32.8	6.4	17.4	55.2	53.3	108.5	174.5	58.6	233.1	2.1%	-2.1%	**1.1%**
5	Decreased Infiltration	17.2	34.9	32.8	6.6	17.4	56.5	52.3	108.8	178.6	57.5	236.1	-0.2%	-0.2%	**-0.2%**
6	Decreased Duct Leakage	15.8	32.2	32.8	6.1	17.4	54.6	49.6	104.2	172.6	54.6	227.2	3.2%	5.0%	**3.6%**
	2012 IRC/2012 IECC Performance	13.0	30.6	32.8	5.3	17.4	51.0	48.0	99.0	161.2	52.8	214.0	9.6%	8.0%	**9.2%**
	2012 IRC/2012 IECC Performance Modified	11.5	35.7	23.5	5.1	17.4	40.1	53.1	93.2	126.8	58.4	185.2	28.9%	-1.7%	**21.4%**
	2009 IECC HP House for Tarrant (CZ 3)	17.2	10.1	32.8	6.4	11.5	77.9	-	77.9	246.2	-	246.2			
1	Increased Roof Insulation	17.0	9.8	32.8	6.3	11.5	77.2	-	77.2	244.0	-	244.0	0.9%	-	**0.9%**
2	Increased Wall Insulation	16.8	9.7	32.8	6.2	11.5	76.9	-	76.9	243.1	-	243.1	1.3%	-	**1.3%**
3	Decreased Window U-Value	15.4	9.8	32.8	5.9	11.5	75.3	-	75.3	238.0	-	238.0	3.3%	-	**3.3%**
4	Decreased Window SHGC	16.2	10.4	32.8	6.2	11.5	76.9	-	76.9	243.1	-	243.1	1.3%	-	**1.3%**
5	Decreased Infiltration	17.2	10.2	32.8	6.4	11.5	77.9	-	77.9	246.2	-	246.2	0.0%	-	**0.0%**
6	Decreased Duct Leakage	15.8	9.5	32.8	6.0	11.5	75.5	-	75.5	238.6	-	238.6	3.1%	-	**3.1%**
	2012 IRC/2012 IECC Performance	13.0	9.1	32.8	5.2	11.5	71.5	_	71.5	226.0	_	226.0	8.2%	_	**8.2%**
	2012 IRC/2012 IECC Performance Modified	11.5	10.2	23.5	4.9	11.5	61.6	_	61.6	194.7	_	194.7	20.9%	_	**20.9%**

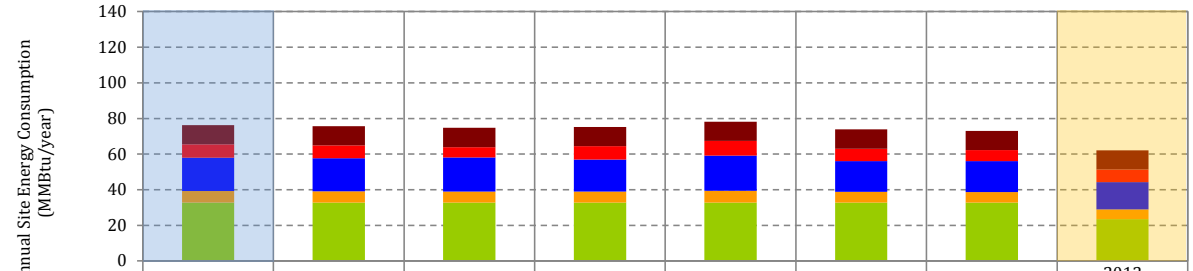
Table 10. Results of Step-by-Step Performance Path Simulations of Changes Made in the 2012 IRC/2012 IECC: Potter County for Climate Zone 4.

Run No.	Test Cases	Annual Site Energy Consumption by End Use (MMBtu/yr)					Annual Site Energy Consumption by Fuel Type (MMBtu/yr)			Annaul Source Energy Consumption by Fuel Type (MMBtu/yr)			Savings Above 2009 IECC (Source %)		
		Cooling	Heating	Lgt & Appl	Fans & Pumps	DHW	Elec.	Gas	Total	Elec.	Gas	Total	Elec.	Gas	Total
	2009 IECC NG House for Potter (CZ 4)	9.8	68.5	32.8	6.6	20.0	49.2	88.5	137.7	155.5	97.4	252.9			
1	Increased Roof Insulation	9.7	66.3	32.8	6.5	20.0	49.0	86.3	135.3	154.9	94.9	249.8	0.4%	2.5%	**1.2%**
2	Increased Wall Insulation	9.7	64.5	32.8	6.4	20.0	48.9	84.5	133.4	154.6	93.0	247.5	0.6%	4.5%	**2.1%**
3	Decreased Infiltration	9.8	64.3	32.8	6.5	20.0	49.0	84.3	133.3	154.9	92.7	247.6	0.4%	4.7%	**2.1%**
4	Decreased Duct Leakage	9.2	62.9	32.8	6.2	20.0	48.2	82.9	131.1	152.4	91.2	243.6	2.0%	6.3%	**3.7%**
	2012 IRC/2012 IECC Performance	9.0	54.7	32.8	5.9	20.0	47.6	74.7	122.3	150.5	82.2	232.6	3.3%	15.6%	**8.0%**
	2012 IRC/2012 IECC Performance Modified	7.8	61.3	23.5	5.8	20.0	37.1	81.3	118.4	117.3	89.4	206.7	24.6%	8.1%	**18.3%**
	2009 IECC HP House for Potter (CZ 4)	9.8	25.5	32.8	6.6	13.5	88.2	-	88.2	278.8	-	278.8			
1	Increased Roof Insulation	9.7	24.9	32.8	6.5	13.5	87.3	-	87.3	275.9	-	275.9	1.0%	-	**1.0%**
2	Increased Wall Insulation	9.7	24.3	32.8	6.4	13.5	86.6	-	86.6	273.7	-	273.7	1.8%	-	**1.8%**
3	Decreased Infiltration	9.8	24.3	32.8	6.5	13.5	86.7	-	86.7	274.0	-	274.0	1.7%	-	**1.7%**
4	Decreased Duct Leakage	9.2	23.7	32.8	6.4	13.5	85.6	-	85.6	270.6	-	270.6	2.9%	-	**2.9%**
	2012 IRC/2012 IECC Performance	9.0	21.4	32.8	6.0	13.5	82.6	_	82.6	261.1	_	261.1	6.3%	_	**6.3%**
	2012 IRC/2012 IECC Performance Modified	7.8	23.0	23.5	6.0	13.5	73.8	_	73.8	233.3	_	233.3	16.3%	_	**16.3%**



	2009 IECC NG House for Harris (CZ 2)	Increased Roof Insulation	Decreased Window U-Value	Decreased Window SHGC	Decreased Infiltration	Decreased Duct Leakage	2012 IRC/2012 IECC Performance	2012 IRC/2012 IECC Performance Modified
Total	99.4	98.1	92.5	98.9	104.3	95.5	92.6	84.6
DHW	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6
Heating	24.8	23.8	17.8	25.5	28.5	22.9	20.0	23.6
Cooling	18.8	18.6	19.1	17.9	19.7	17.3	17.4	15.4
Fans & Pumps	6.5	6.4	6.2	6.2	6.7	6.0	5.8	5.4
Lgt & Appl	32.8	32.8	32.8	32.8	32.8	32.8	32.8	23.5

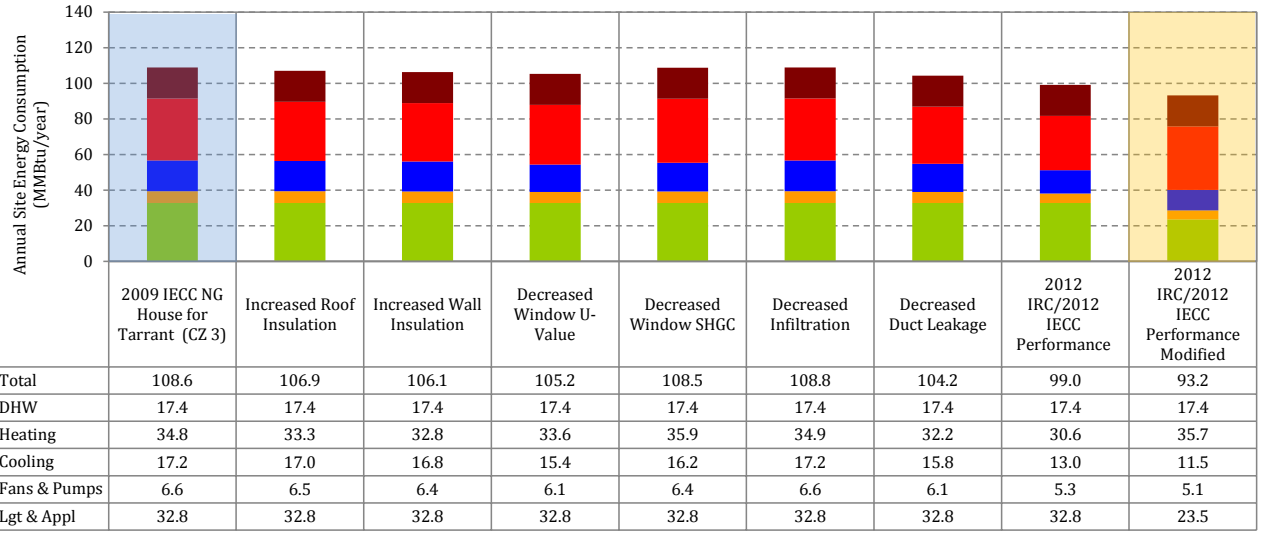
(a) Electric/Gas House



	2009 IECC HP House for Harris (CZ 2)	Increased Roof Insulation	Decreased Window U-Value	Decreased Window SHGC	Decreased Infiltration	Decreased Duct Leakage	2012 IRC/2012 IECC Performance	2012 IRC/2012 IECC Performance Modified
Total	76.2	75.6	74.6	75.1	78.1	73.7	73.0	62.2
DHW	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8
Heating	7.4	7.2	5.8	7.5	8.3	6.9	6.2	7.0
Cooling	18.8	18.6	19.1	17.9	19.7	17.3	17.4	15.4
Fans & Pumps	6.4	6.3	6.2	6.2	6.6	6.0	5.8	5.4
Lgt & Appl	32.8	32.8	32.8	32.8	32.8	32.8	32.8	23.5

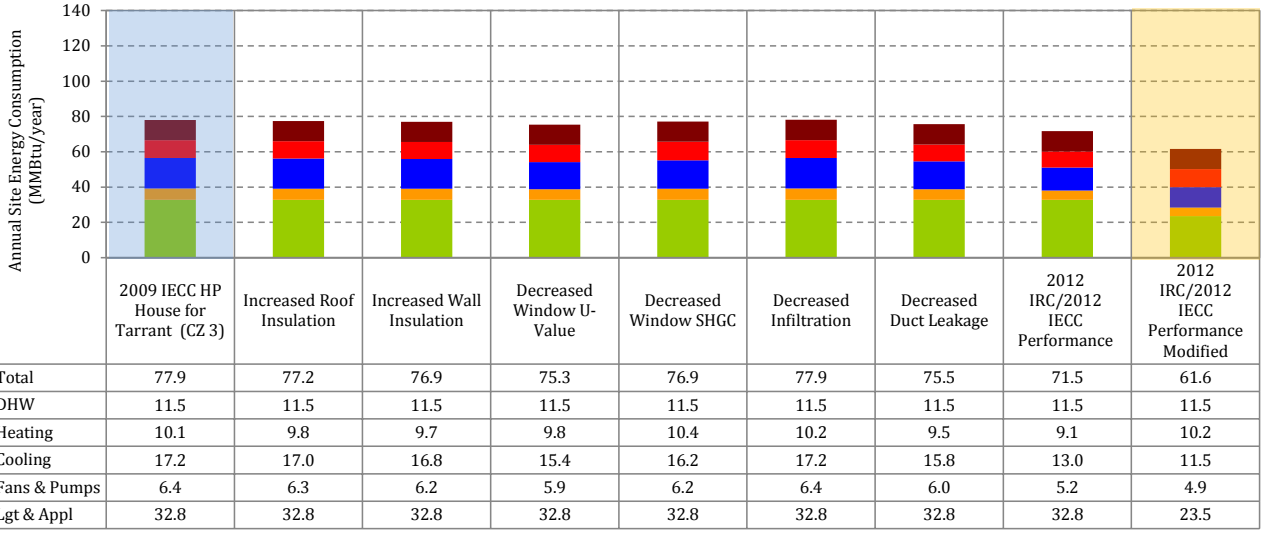
(b) All-Electric House

Figure 2. Annual Site Energy Consumption by Different End Uses for Step-by-Step Performance Path Simulations: Harris County for Climate Zone 2.



	2009 IECC NG House for Tarrant (CZ 3)	Increased Roof Insulation	Increased Wall Insulation	Decreased Window U-Value	Decreased Window SHGC	Decreased Infiltration	Decreased Duct Leakage	2012 IRC/2012 IECC Performance	2012 IRC/2012 IECC Performance Modified
Total	108.6	106.9	106.1	105.2	108.5	108.8	104.2	99.0	93.2
DHW	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4
Heating	34.8	33.3	32.8	33.6	35.9	34.9	32.2	30.6	35.7
Cooling	17.2	17.0	16.8	15.4	16.2	17.2	15.8	13.0	11.5
Fans & Pumps	6.6	6.5	6.4	6.1	6.4	6.6	6.1	5.3	5.1
Lgt & Appl	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	23.5

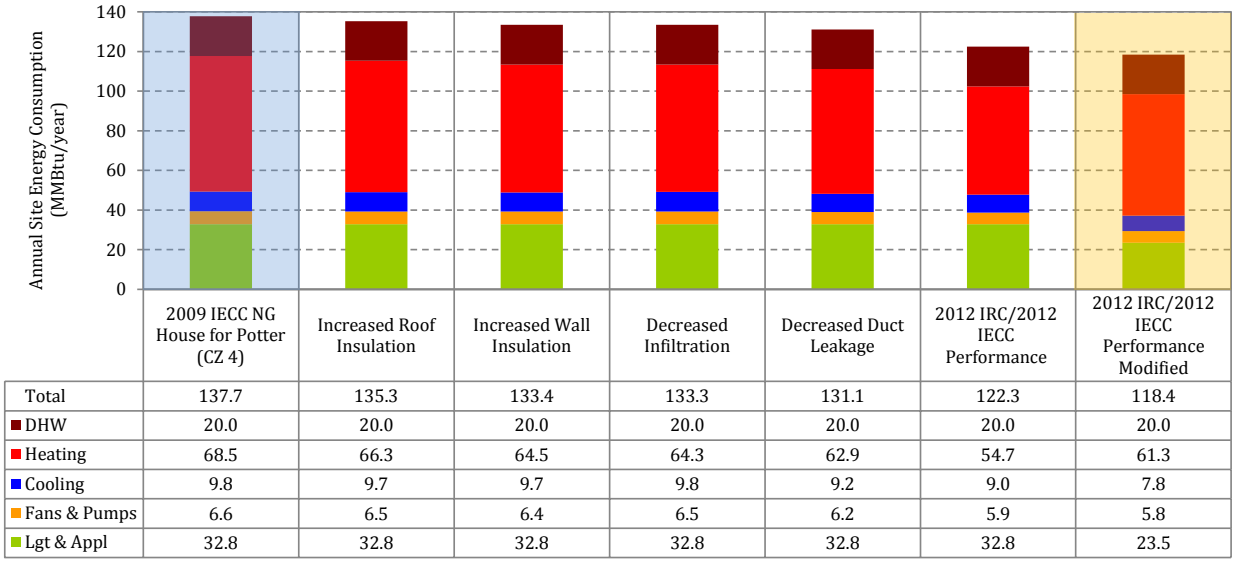
(a) Electric/Gas House



	2009 IECC HP House for Tarrant (CZ 3)	Increased Roof Insulation	Increased Wall Insulation	Decreased Window U-Value	Decreased Window SHGC	Decreased Infiltration	Decreased Duct Leakage	2012 IRC/2012 IECC Performance	2012 IRC/2012 IECC Performance Modified
Total	77.9	77.2	76.9	75.3	76.9	77.9	75.5	71.5	61.6
DHW	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5
Heating	10.1	9.8	9.7	9.8	10.4	10.2	9.5	9.1	10.2
Cooling	17.2	17.0	16.8	15.4	16.2	17.2	15.8	13.0	11.5
Fans & Pumps	6.4	6.3	6.2	5.9	6.2	6.4	6.0	5.2	4.9
Lgt & Appl	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	23.5

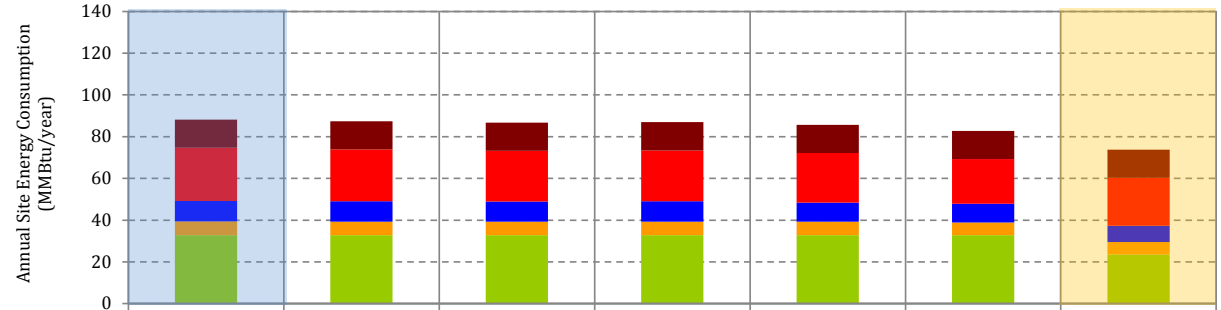
(b) All-Electric House

Figure 3. Annual Site Energy Consumption by Different End Uses for Step-by-Step Performance Path Simulations: Tarrant County for Climate Zone 3.



	2009 IECC NG House for Potter (CZ 4)	Increased Roof Insulation	Increased Wall Insulation	Decreased Infiltration	Decreased Duct Leakage	2012 IRC/2012 IECC Performance	2012 IRC/2012 IECC Performance Modified
Total	137.7	135.3	133.4	133.3	131.1	122.3	118.4
DHW	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Heating	68.5	66.3	64.5	64.3	62.9	54.7	61.3
Cooling	9.8	9.7	9.7	9.8	9.2	9.0	7.8
Fans & Pumps	6.6	6.5	6.4	6.5	6.2	5.9	5.8
Lgt & Appl	32.8	32.8	32.8	32.8	32.8	32.8	23.5

(a) Electric/Gas House



	2009 IECC HP House for Potter (CZ 4)	Increased Roof Insulation	Increased Wall Insulation	Decreased Infiltration	Decreased Duct Leakage	2012 IRC/2012 IECC Performance	2012 IRC/2012 IECC Performance Modified
Total	88.2	87.3	86.6	86.7	85.6	82.6	73.8
DHW	13.5	13.5	13.5	13.5	13.5	13.5	13.5
Heating	25.5	24.9	24.3	24.3	23.7	21.4	23.0
Cooling	9.8	9.7	9.7	9.8	9.2	9.0	7.8
Fans & Pumps	6.6	6.5	6.4	6.5	6.4	6.0	6.0
Lgt & Appl	32.8	32.8	32.8	32.8	32.8	32.8	23.5

(b) All-Electric House

Figure 4. Annual Site Energy Consumption by Different End Uses for Step-by-Step Performance Path Simulations: Potter County for Climate Zone 4.

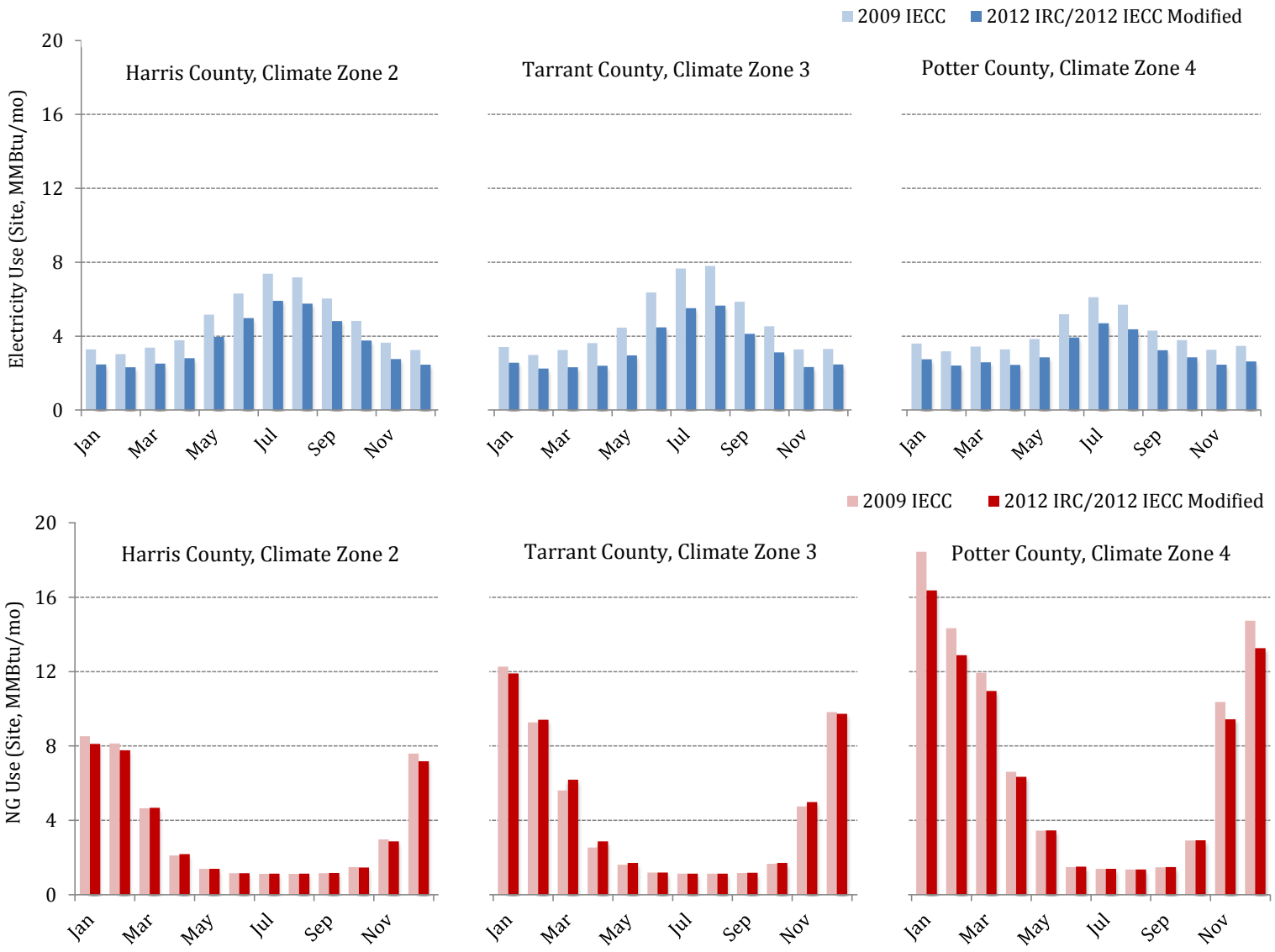


Figure 5. Monthly Electricity and Natural Gas Use for the 2009 IECC and the Modified 2012 IRC/2012 IECC Performance Path Code-Compliant, Electric/Gas House.

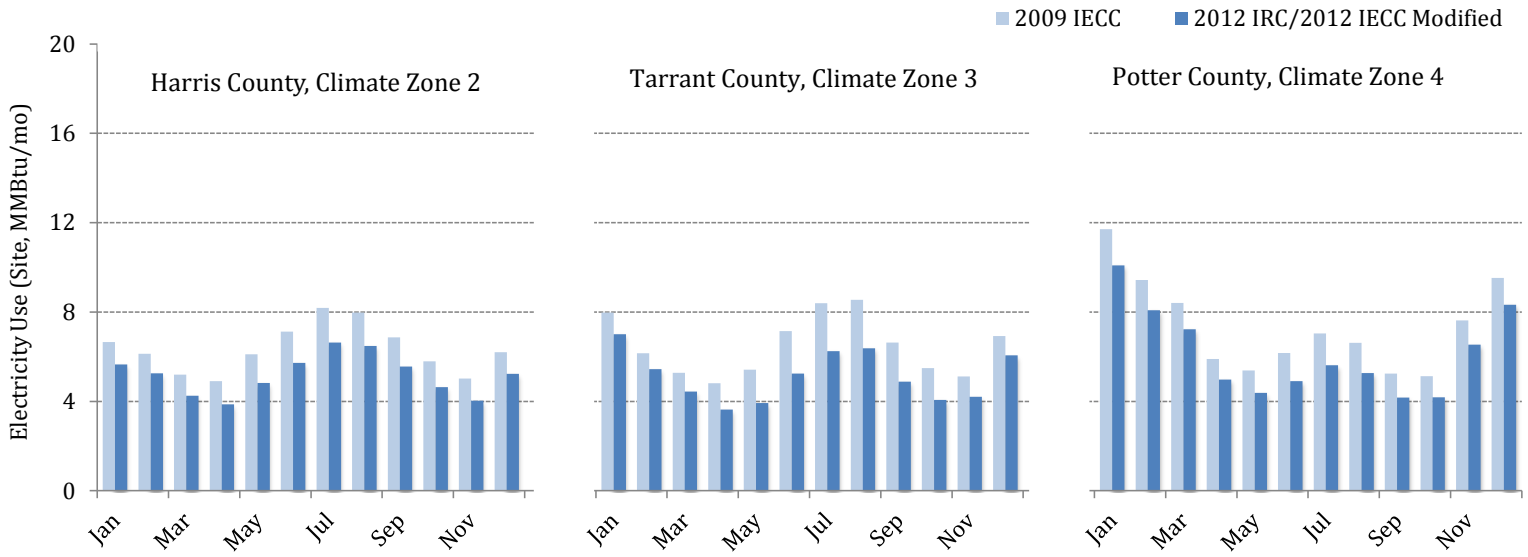


Figure 6. Monthly Electricity Use for the 2009 IECC and the Modified 2012 IRC/2012 IECC Performance Path Code-Compliant, All-Electric House.

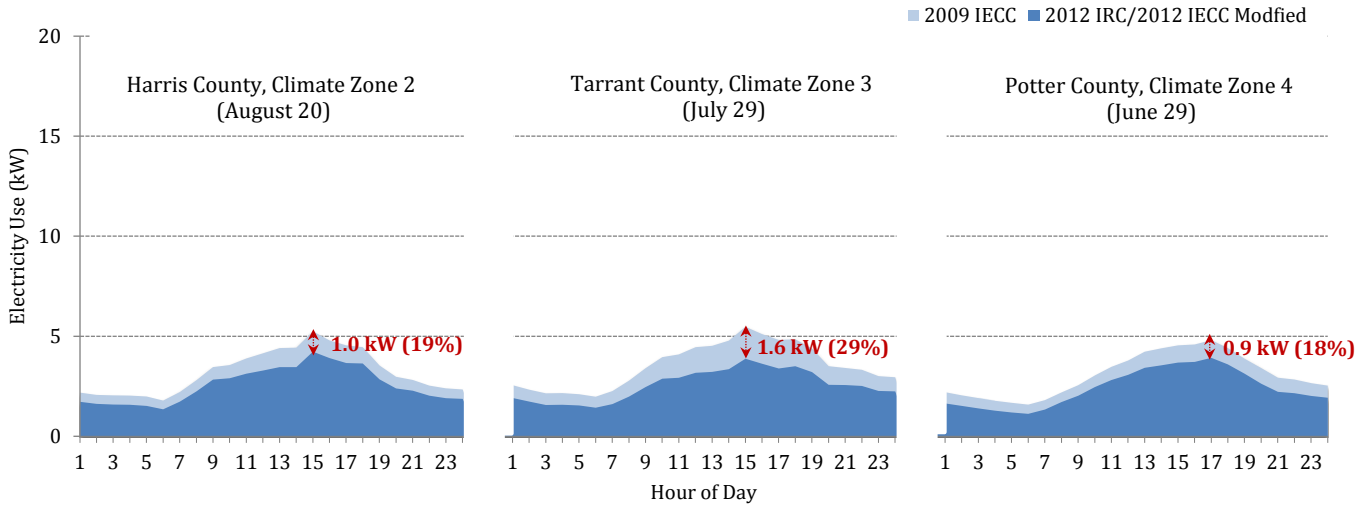


Figure 7. Peak Summer Day Hourly Electricity Use and Demand Savings for the 2009 IECC and the Modified 2012 IRC/2012 IECC Performance Path Code-Compliant, Electric/Gas House.

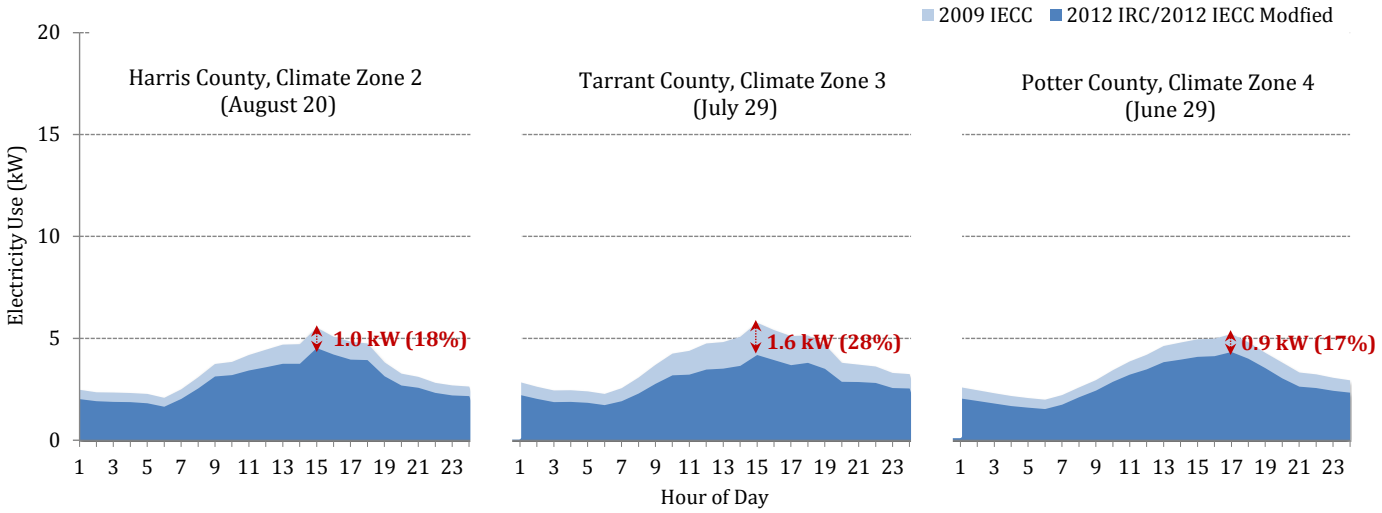


Figure 8. Peak Summer Day Hourly Electricity Use and Demand Savings for the 2009 IECC and the Modified 2012 IRC/2012 IECC Performance Path Code-Compliant, All-Electric House.

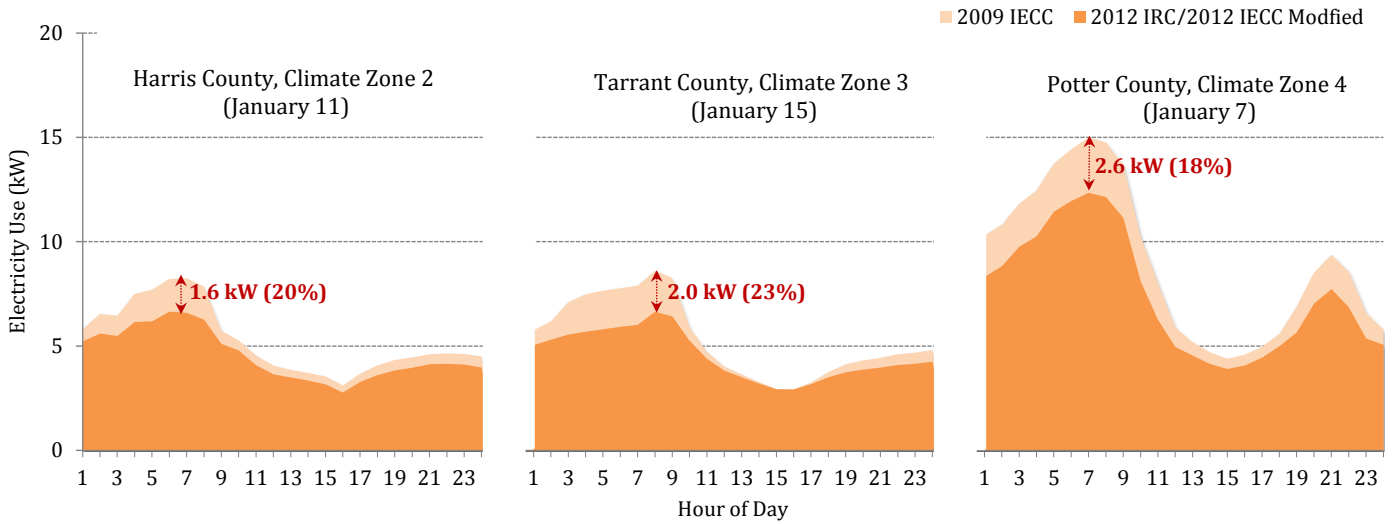
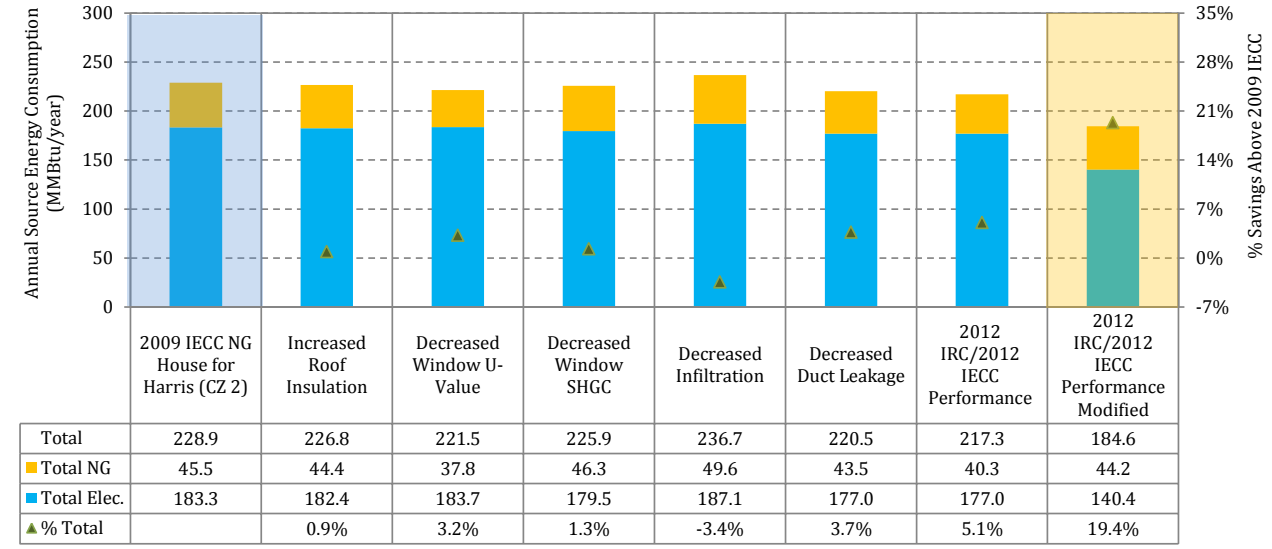
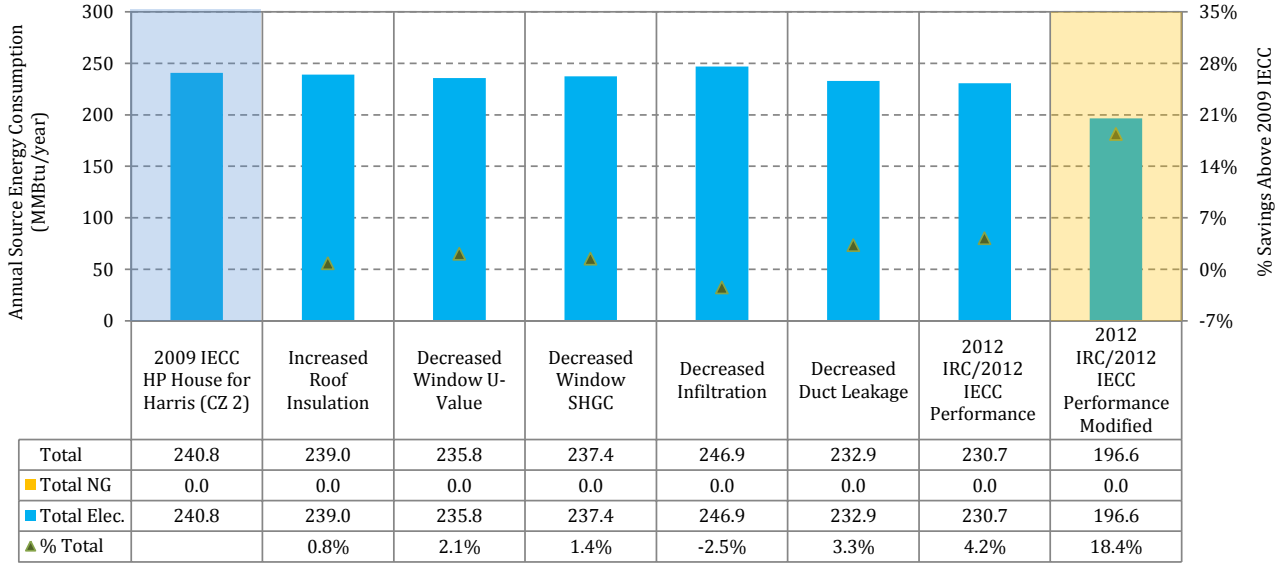


Figure 9. Peak Winter Day Hourly Electricity Use and Demand Savings for the 2009 IECC and the Modified 2012 IRC/2012 IECC Performance Path Code-Compliant, All-Electric House.



	2009 IECC NG House for Harris (CZ 2)	Increased Roof Insulation	Decreased Window U-Value	Decreased Window SHGC	Decreased Infiltration	Decreased Duct Leakage	2012 IRC/2012 IECC Performance	2012 IRC/2012 IECC Performance Modified
Total	228.9	226.8	221.5	225.9	236.7	220.5	217.3	184.6
Total NG	45.5	44.4	37.8	46.3	49.6	43.5	40.3	44.2
Total Elec.	183.3	182.4	183.7	179.5	187.1	177.0	177.0	140.4
% Total		0.9%	3.2%	1.3%	-3.4%	3.7%	5.1%	19.4%

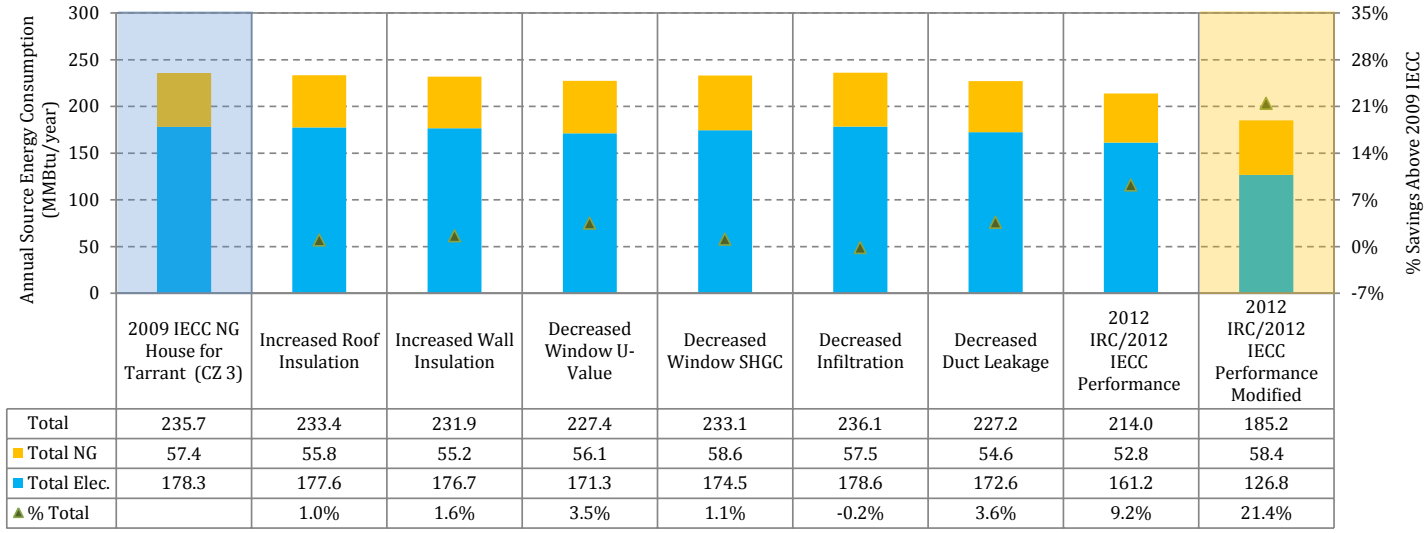
(a) Electric/Gas House



	2009 IECC HP House for Harris (CZ 2)	Increased Roof Insulation	Decreased Window U-Value	Decreased Window SHGC	Decreased Infiltration	Decreased Duct Leakage	2012 IRC/2012 IECC Performance	2012 IRC/2012 IECC Performance Modified
Total	240.8	239.0	235.8	237.4	246.9	232.9	230.7	196.6
Total NG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Elec.	240.8	239.0	235.8	237.4	246.9	232.9	230.7	196.6
% Total		0.8%	2.1%	1.4%	-2.5%	3.3%	4.2%	18.4%

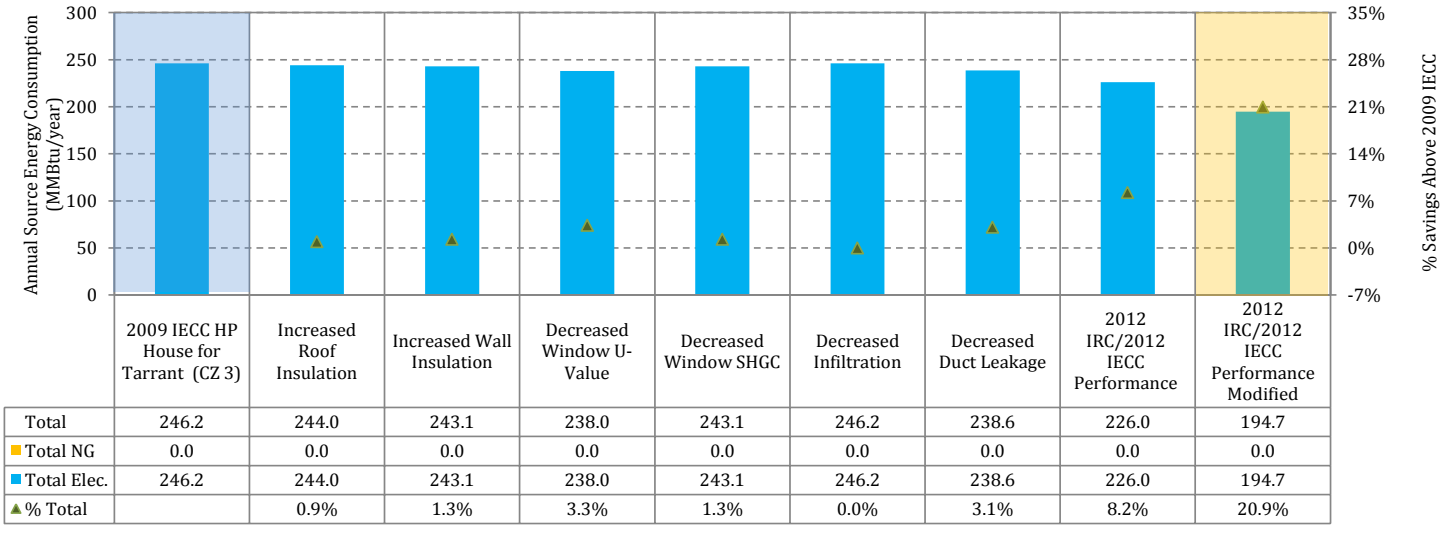
(b) All-Electric House

Figure 10. Annual Source Energy Consumption by Fuel Type and Percent Savings Above 2009 IECC Performance Path Code-Compliant House for Step-by-Step Simulations: Harris County for Climate Zone 2.



	2009 IECC NG House for Tarrant (CZ 3)	Increased Roof Insulation	Increased Wall Insulation	Decreased Window U-Value	Decreased Window SHGC	Decreased Infiltration	Decreased Duct Leakage	2012 IRC/2012 IECC Performance	2012 IRC/2012 IECC Performance Modified
Total	235.7	233.4	231.9	227.4	233.1	236.1	227.2	214.0	185.2
Total NG	57.4	55.8	55.2	56.1	58.6	57.5	54.6	52.8	58.4
Total Elec.	178.3	177.6	176.7	171.3	174.5	178.6	172.6	161.2	126.8
% Total		1.0%	1.6%	3.5%	1.1%	-0.2%	3.6%	9.2%	21.4%

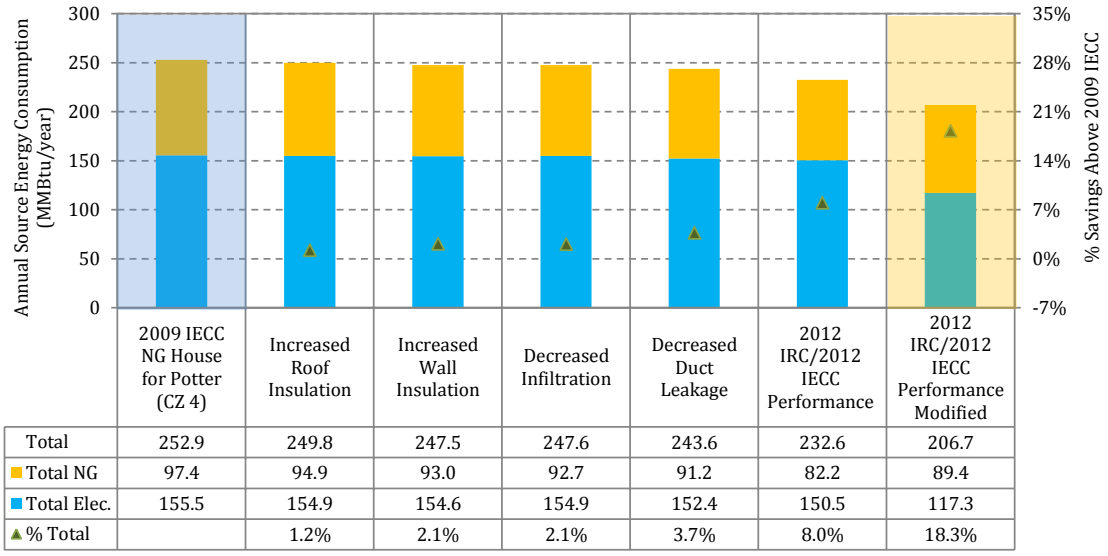
(a) Electric/Gas House



	2009 IECC HP House for Tarrant (CZ 3)	Increased Roof Insulation	Increased Wall Insulation	Decreased Window U-Value	Decreased Window SHGC	Decreased Infiltration	Decreased Duct Leakage	2012 IRC/2012 IECC Performance	2012 IRC/2012 IECC Performance Modified
Total	246.2	244.0	243.1	238.0	243.1	246.2	238.6	226.0	194.7
Total NG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Elec.	246.2	244.0	243.1	238.0	243.1	246.2	238.6	226.0	194.7
% Total		0.9%	1.3%	3.3%	1.3%	0.0%	3.1%	8.2%	20.9%

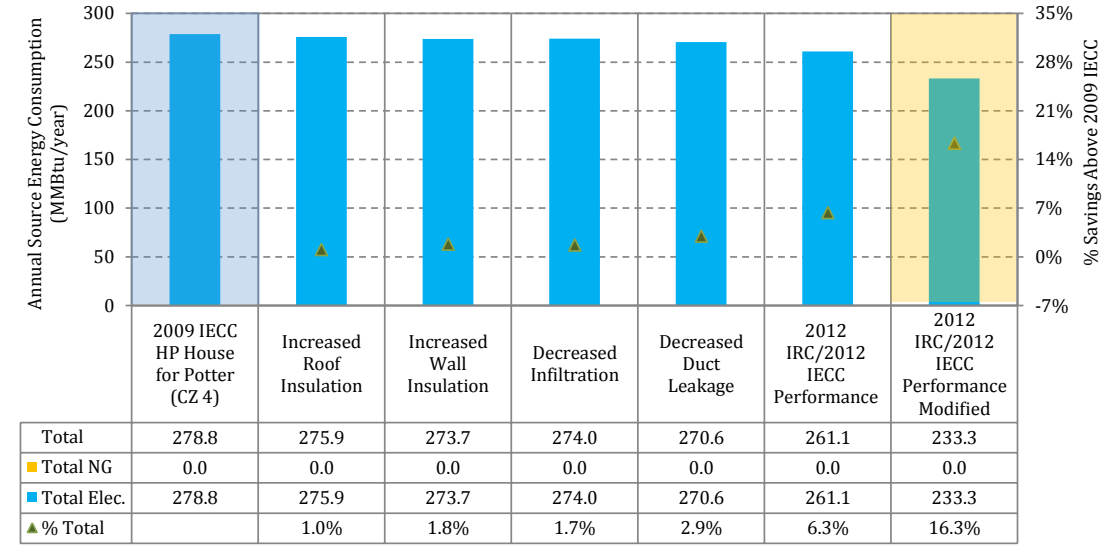
(b) All-Electric House

Figure 11. Annual Source Energy Consumption by Fuel Type and Percent Savings Above 2009 IECC Performance Path Code-Compliant House for Step-by-Step Simulations: Tarrant County for Climate Zone 3.



	2009 IECC NG House for Potter (CZ 4)	Increased Roof Insulation	Increased Wall Insulation	Decreased Infiltration	Decreased Duct Leakage	2012 IRC/2012 IECC Performance	2012 IRC/2012 IECC Performance Modified
Total	252.9	249.8	247.5	247.6	243.6	232.6	206.7
Total NG	97.4	94.9	93.0	92.7	91.2	82.2	89.4
Total Elec.	155.5	154.9	154.6	154.9	152.4	150.5	117.3
% Total		1.2%	2.1%	2.1%	3.7%	8.0%	18.3%

(a) Electric/Gas House



	2009 IECC HP House for Potter (CZ 4)	Increased Roof Insulation	Increased Wall Insulation	Decreased Infiltration	Decreased Duct Leakage	2012 IRC/2012 IECC Performance	2012 IRC/2012 IECC Performance Modified
Total	278.8	275.9	273.7	274.0	270.6	261.1	233.3
Total NG	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Elec.	278.8	275.9	273.7	274.0	270.6	261.1	233.3
% Total		1.0%	1.8%	1.7%	2.9%	6.3%	16.3%

(b) All-Electric House

Figure 12. Annual Source Energy Consumption by Fuel Type and Percent Savings Above 2009 IECC Performance Path Code-Compliant House for Step-by-Step Simulations: Potter County for Climate Zone 4.

4 RESULTS: PRESCRIPTIVE PATH ANALYSIS

This section presents the results of prescriptive path simulations and examines the annual source energy savings associated with the 2012 IRC/2012 IECC for (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)[16]. Table 11 shows the input of prescriptive path simulations for Harris, Tarrant, and Potter Counties. Table 12 summarizes the results of simulations for each county, including: the annual site energy consumption (by different end-uses, fuel types, and the total); the annual source energy consumption by fuel types and the total, and the calculated source energy percentage savings associated with the 2012 IRC/2012 IECC above the 2009 IECC code-compliant base cases. The results are also graphically represented in Figures 13 and 14: the annual site energy consumption by end-uses in Figure 13; and the annual source energy consumption by fuel types in Figure 14.

4.1 Annual Total Site Energy Consumption

Across all counties, the 2012 IRC/2012 IECC prescriptive path code-compliant house reported less site energy consumption than the 2009 IECC with the following site energy totals:

(a) For an electric/gas house:
- 83.6 MMBtu/yr (36.0 kBtu/ft^2·yr) for Harris County,
- 91.9 MMBtu/yr (39.5 kBtu/ft^2·yr) for Tarrant County, and
- 115.9 MMBtu/yr (49.9 kBtu/ft^2·yr) for Potter County.

(b) For an all-electric house:
- 61.8 MMBtu/yr (26.6 kBtu/ft^2·yr) for Harris County,
- 61.1 MMBtu/yr (26.3 kBtu/ft^2·yr) for Tarrant County, and
- 73.0 MMBtu/yr (31.4 kBtu/ft^2·yr) for Potter County.

The 2009 IECC code-compliant house reported the following site energy totals:

(a) For an electric/gas house:
- 102.1 MMBtu/yr (43.9 kBtu/ft^2·yr) for Harris County,
- 114.2 MMBtu/yr (49.1 kBtu/ft^2·yr) for Tarrant County, and
- 149.0 MMBtu/yr (64.1 kBtu/ft^2·yr) for Potter County.

(b) For an all-electric house:
- 72.1 MMBtu/yr (31.0 kBtu/ft^2·yr) for Harris County,
- 74.4 MMBtu/yr (32.0 kBtu/ft^2·yr) for Tarrant County, and
- 87.0 MMBtu/yr (37.4 kBtu/ft^2·yr) for Potter County.

4.2 Annual Total Source Energy Consumption

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, the 2012 IRC/2012 IECC prescriptive path code-compliant house reported less source energy consumption than the 2009 IECC with the following source energy totals:

(a) For an electric/gas house:
- 182.9 MMBtu/yr (78.6 kBtu/ft^2·yr) for Harris County,
- 183.1 MMBtu/yr (78.8 kBtu/ft^2·yr) for Tarrant County, and

[16] More detailed analysis was performed for the performance path, and the results of the performance path analysis are presented step-by-step to examine the impact of the different changes in the 2012 IECC on the results. On the other hand, detailed analysis was not performed for the prescriptive path analysis.

- 203.4 MMBtu/yr (87.5 kBtu/ft^2·yr) for Potter County.

(b) For an all-electric house:

- 195.3 MMBtu/yr (84.0 kBtu/ft^2·yr) for Harris County,
- 193.1 MMBtu/yr (83.1 kBtu/ft^2·yr) for Tarrant County, and
- 230.7 MMBtu/yr (99.2 kBtu/ft^2·yr) for Potter County.

The 2009 IECC code-compliant house reported the following source energy totals:

(a) For an electric/gas house:

- 219.5 MMBtu/yr (94.4 kBtu/ft^2·yr) for Harris County,
- 229.3 MMBtu/yr (98.6 kBtu/ft^2·yr) for Tarrant County, and
- 252.1 MMBtu/yr (108.4 kBtu/ft^2·yr) for Potter County.

(b) For an all-electric house:

- 227.9 MMBtu/yr (98.0 kBtu/ft^2·yr) for Harris County,
- 235.2 MMBtu/yr (101.1 kBtu/ft^2·yr) for Tarrant County, and
- 275.0 MMBtu/yr (118.3 kBtu/ft^2·yr) for Potter County.

4.3 **Annual Source Energy Savings from the 2012 IRC/2012 IECC**

The annual source energy savings associated with the 2012 IRC/2012 IECC were calculated by comparisons to the respective, 2009 IECC code-compliant houses:

(a) For an electric/gas house:

- 36.6 MMBtu/yr (15.8 kBtu/ft^2·yr) for Harris County,
- 46.2 MMBtu/yr (19.9 kBtu/ft^2·yr) for Tarrant County, and
- 48.8 MMBtu/yr (21.0 kBtu/ft^2·yr) for Potter County.

(b) For a heat pump house:

- 32.5 MMBtu/yr (14.0 kBtu/ft^2·yr) for Harris County,
- 42.0 MMBtu/yr (18.1 kBtu/ft^2·yr) for Tarrant County, and
- 44.2 MMBtu/yr (19.0 kBtu/ft^2·yr) for Potter County.

The corresponding percentage savings based on annual total source energy consumption of the 2009 IECC code-compliant house are:

(a) For an electric/gas house:

- 16.7% for Harris County,
- 20.1% for Tarrant County, and
- 19.3% Potter County.

(b) For a heat pump house:

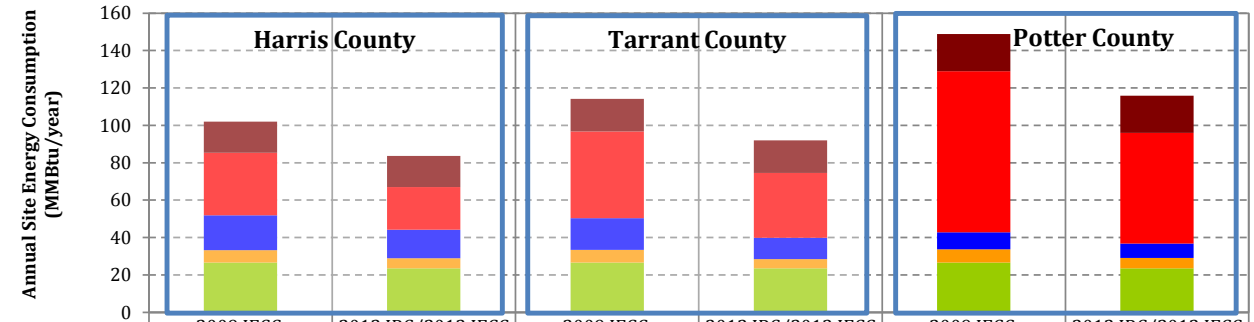
- 14.3% for Harris County,
- 17.9% for Tarrant County, and
- 16.1% for Potter County.

Table 11. Input Parameters for Prescriptive Path Simulations of the 2009 IECC and the 2012 IRC/2012 IECC.

Test Cases		SLA for House	Roof R-Value	Wall R-Value	Glazing U-Factor	Glazing SHGC	Lighting (kW)	Supply Duct Leakage	Return Duct Leakage
Harris (CZ 2)	2009 IECC Prescriptive NG House	0.00060	28.9	11.8	0.65	0.30	0.342	0.056	0.056
	2012 IRC/2012 IECC Prescriptive NG	**0.00049**	**33.7**	11.8	**0.40**	**0.25**	**0.239**	**0.021**	**0.021**
	2009 IECC Prescriptive HP House	0.00060	28.9	11.8	0.65	0.30	0.342	0.056	0.056
	2012 IRC/2012 IECC Prescriptive HP	**0.00049**	**33.7**	11.8	**0.40**	**0.25**	**0.239**	**0.021**	**0.021**
Tarrant (CZ 3)	2009 IECC Prescriptive NG House	0.00058	28.9	11.8	0.50	0.30	0.342	0.056	0.056
	2012 IRC/2012 IECC Prescriptive NG	**0.00037**	**33.7**	**18.9**	**0.35**	**0.25**	**0.239**	**0.021**	**0.021**
	2009 IECC Prescriptive HP House	0.00058	28.9	11.8	0.50	0.30	0.342	0.056	0.056
	2012 IRC/2012 IECC Prescriptive HP	**0.00037**	**33.7**	**18.9**	**0.35**	**0.25**	**0.239**	**0.021**	**0.021**
Potter (CZ 4)	2009 IECC Prescriptive NG House	0.00053	33.7	11.8	0.35	0.40	0.342	0.056	0.056
	2012 IRC/2012 IECC Prescriptive NG	**0.00032**	**38.8**	**18.9**	0.35	0.40	**0.239**	**0.021**	**0.021**
	2009 IECC Prescriptive HP House	0.00053	33.7	11.8	0.35	0.40	0.342	0.056	0.056
	2012 IRC/2012 IECC Prescriptive HP	**0.00032**	**38.8**	**18.9**	0.35	0.40	**0.239**	**0.021**	**0.021**

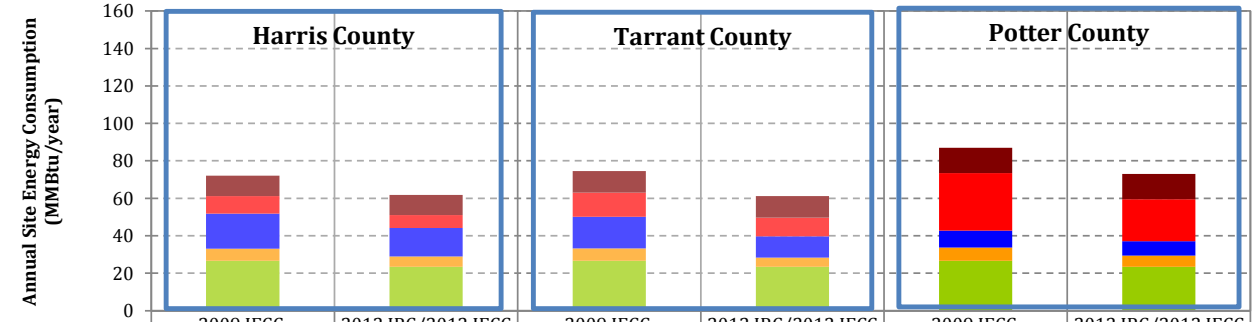
Table 12. Results of Prescriptive Path Simulations of the 2009 IECC and the 2012 IRC/2012 IECC.

Test Cases		Annual Site Energy Consumption by End Use (MMBtu/yr)					Annual Site Energy Consumption by Fuel Type (MMBtu/yr)			Annaul Source Energy Consumption by Fuel Type (MMBtu/yr)			Savings Above 2009 IECC (Source %)		
		Cooling	Heating	Lgt & Appl	Fans & Pumps	DHW	Elec.	Gas	Total	Elec.	Gas	Total	Elec.	Gas	Total
Harris (CZ 2)	2009 IECC Prescriptive NG House	18.7	33.5	26.6	6.6	16.6	52.0	50.1	102.1	164.4	55.1	219.5			
	2012 IRC/2012 IECC Prescriptive NG	15.2	22.9	23.5	5.4	16.6	44.1	39.5	83.6	139.4	43.5	182.9	15.2%	21.2%	**16.7%**
	2009 IECC Prescriptive HP House	18.7	9.4	26.6	6.5	10.8	72.1	-	72.1	227.9	-	227.9			
	2012 IRC/2012 IECC Prescriptive HP	15.2	6.9	23.5	5.4	10.8	61.8	-	61.8	195.3	-	195.3	14.3%	-	**14.3%**
Tarrant (CZ 3)	2009 IECC Prescriptive NG House	16.9	46.5	26.6	6.8	17.4	50.3	63.9	114.2	159.0	70.3	229.3			
	2012 IRC/2012 IECC Prescriptive NG	11.3	34.7	23.5	5.0	17.4	39.8	52.1	91.9	125.8	57.3	183.1	20.9%	18.5%	**20.1%**
	2009 IECC Prescriptive HP House	16.9	12.9	26.6	6.6	11.5	74.4	-	74.4	235.2	-	235.2			
	2012 IRC/2012 IECC Prescriptive HP	11.3	9.9	23.5	4.9	11.5	61.1	-	61.1	193.1	-	193.1	17.9%	-	**17.9%**
Potter (CZ 4)	2009 IECC Prescriptive NG House	9.0	86.2	26.6	7.1	20.0	42.8	106.2	149.0	135.3	116.8	252.1			
	2012 IRC/2012 IECC Prescriptive NG	7.7	59.1	23.5	5.6	20.0	36.8	79.1	115.9	116.3	87.0	203.4	14.0%	25.5%	**19.3%**
	2009 IECC Prescriptive HP House	9.0	30.8	26.6	7.1	13.5	87.0	-	87.0	275.0	-	275.0			
	2012 IRC/2012 IECC Prescriptive HP	7.7	22.4	23.5	5.9	13.5	73.0	-	73.0	230.7	-	230.7	16.1%	-	**16.1%**



	Harris County		Tarrant County		Potter County	
	2009 IECC Prescriptive	2012 IRC/2012 IECC Prescriptive	2009 IECC Prescriptive	2012 IRC/2012 IECC Prescriptive	2009 IECC Prescriptive	2012 IRC/2012 IECC Prescriptive
Total	102.1	83.6	114.2	91.9	149.0	115.9
DHW	16.6	16.6	17.4	17.4	20.0	20.0
Heating	33.5	22.9	46.5	34.7	86.2	59.1
Cooling	18.7	15.2	16.9	11.3	9.0	7.7
Fans & Pumps	6.6	5.4	6.8	5.0	7.1	5.6
Lgt & Appl	26.6	23.5	26.6	23.5	26.6	23.5

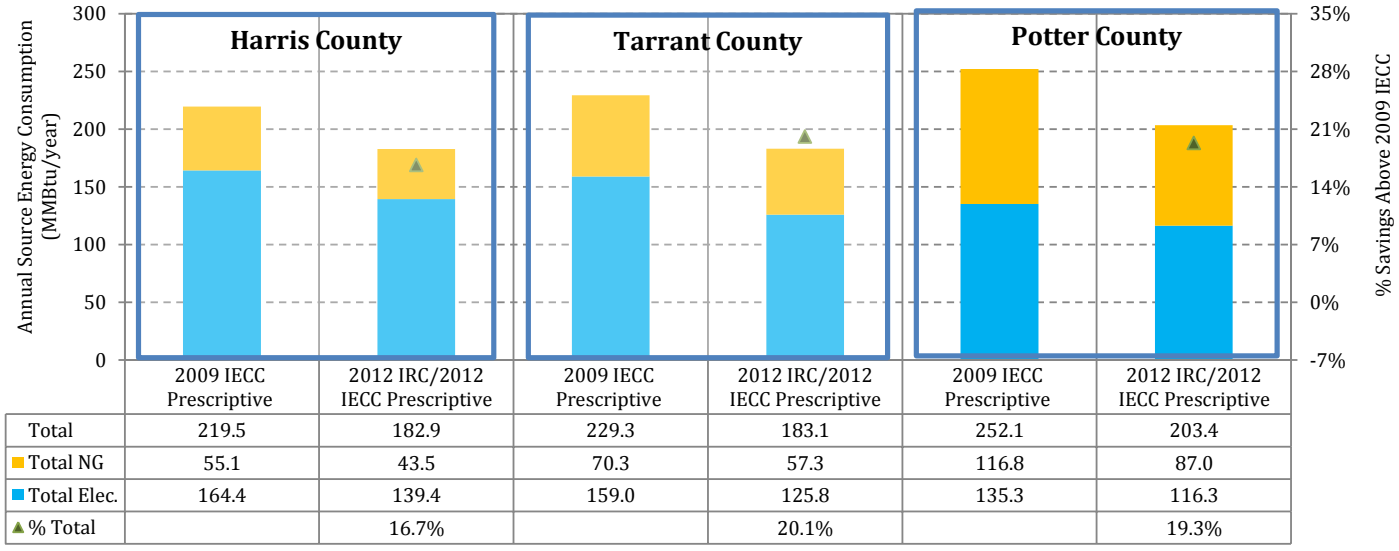
(a) Electric/Gas House



	Harris County		Tarrant County		Potter County	
	2009 IECC Prescriptive	2012 IRC/2012 IECC Prescriptive	2009 IECC Prescriptive	2012 IRC/2012 IECC Prescriptive	2009 IECC Prescriptive	2012 IRC/2012 IECC Prescriptive
Total	72.1	61.8	74.4	61.1	87.0	73.0
DHW	10.8	10.8	11.5	11.5	13.5	13.5
Heating	9.4	6.9	12.9	9.9	30.8	22.4
Cooling	18.7	15.2	16.9	11.3	9.0	7.7
Fans & Pumps	6.5	5.4	6.6	4.9	7.1	5.9
Lgt & Appl	26.6	23.5	26.6	23.5	26.6	23.5

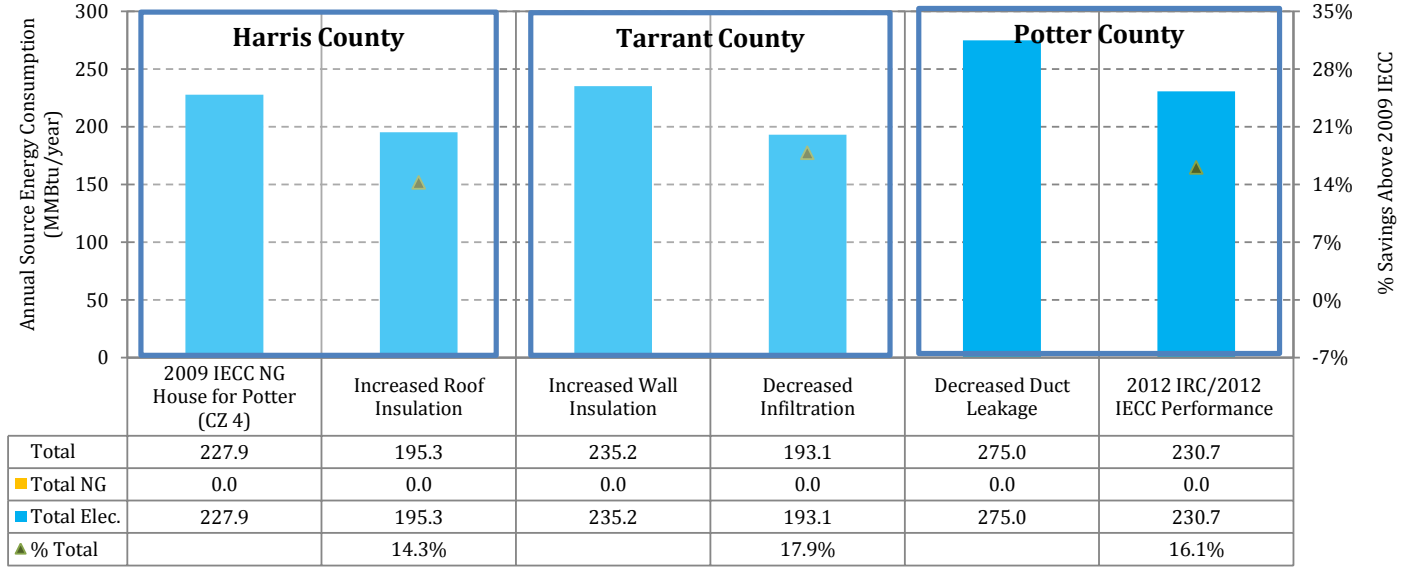
(b) All-Electric House

Figure 13. Annual Site Energy Consumption by Different End Uses for Prescriptive Path Simulations.



	2009 IECC Prescriptive	2012 IRC/2012 IECC Prescriptive	2009 IECC Prescriptive	2012 IRC/2012 IECC Prescriptive	2009 IECC Prescriptive	2012 IRC/2012 IECC Prescriptive
Total	219.5	182.9	229.3	183.1	252.1	203.4
Total NG	55.1	43.5	70.3	57.3	116.8	87.0
Total Elec.	164.4	139.4	159.0	125.8	135.3	116.3
% Total		16.7%		20.1%		19.3%

(a) Electric/Gas House



	2009 IECC NG House for Potter (CZ 4)	Increased Roof Insulation	Increased Wall Insulation	Decreased Infiltration	Decreased Duct Leakage	2012 IRC/2012 IECC Performance
Total	227.9	195.3	235.2	193.1	275.0	230.7
Total NG	0.0	0.0	0.0	0.0	0.0	0.0
Total Elec.	227.9	195.3	235.2	193.1	275.0	230.7
% Total		14.3%		17.9%		16.1%

(b) All-Electric House

Figure 14. Annual Source Energy Consumption by Fuel Type and Percent Savings Above 2009 IECC Prescriptive Path Code-Compliant House.

5 SUMMARY

A technical analysis was performed to compare the stringency of the Texas Building Energy Performance Standards (TBEPS) for single-family residential construction, based on the 2009 International Residential Code (2009 IRC), to the 2012 International Residential Code (2012 IRC). The analysis used the relevant 2009 IECC residential (Chapters 1-4) provisions, which is one of the two paths to comply with the 2009 IRC per Section N1101.2 of the code, and the 2012 IECC provisions which are identical to the 2012 IRC. A series of simulations were performed using an ESL single-family simulation model (BDL version 4.01.09 of International Code Compliance Calculator (IC3) that includes new EIR calculation models) based on the DOE-2.1e program and the appropriate TMY2 weather files for three counties representing three 2009 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. The estimated annual source energy savings associated with the 2012 IRC and 2012 IECC performance path compared to the 2009 IECC performance path are:

(a) For an electric/gas house:
- 19.4% for Harris County,
- 21.4% for Tarrant County, and
- 18.3% Potter County.

(b) For a heat pump house:
- 18.4% for Harris County,
- 20.9% for Tarrant County, and
- 16.3% for Potter County.

The estimated annual source energy savings associated with the 2012 IRC and 2012 IECC prescriptive path compared to the 2009 IECC prescriptive path are:

(a) For an electric/gas house:
- 16.7% for Harris County,
- 20.1% for Tarrant County, and
- 19.3% Potter County.

(b) For a heat pump house:
- 14.3% for Harris County,
- 17.9% for Tarrant County, and
- 16.1% for Potter County.

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