A COMPARATIVE ANALYSIS OF RESIDENTIAL ENERGY USE FOR 2009 IECC CODE COMPLIANCE AND 2001 IECC COMPLIANCE WITH 2006 NAECA APPLIANCE STANDARDS FOR SELECTED CLIMATE ZONES IN TEXAS

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ABSTRACT

This paper presents results of a comparative analysis of the electricity and natural gas savings from the implementation of 2009 International Energy Conservation Code (IECC) when compared with the 2001 IECC[1] specifications with 2006 NAECA for a new single-family residential construction. The analysis uses a DOE-2 simulation for five locations in Texas (Houston, Brownsville, Dallas/Fort Worth, El Paso and Amarillo).

The analysis shows that a code – compliant house built to the specifications of the 2009 IECC uses 10% – 16% less site energy annually than a house meeting the specifications of the 2001 IECC, for an air-conditioned house with a natural gas furnace. The results also show that an air conditioned 2009 code - compliant house with a heat pump uses 10% - 14% less site energy annually.

BACKGROUND

In this study a 2009 code-compliant house with updated specifications was compared to a 2001 code-compliant house that had characteristics from a 2001 code compliant house. The analysis was performed using a ResNet-certified DOE-2 simulation for five locations in Texas: Houston, Brownsville, Dallas/Fort Worth, El Paso and Amarillo, which covers all climate zones in Texas.

METHODOLOGY

Overview

In order to quantify the energy savings from the implementation of the 2009 IECC code three sets of simulation models were prepared – a 2001 code-compliant house, a 2001 code-compliant house with modifications and a 2009 code-compliant house. The 2001 code-compliant house was modified to facilitate a fair comparison with the 2009 code-compliant house. The models were prepared for a house with electric heat-pump heating and domestic hot water (DHW) and a house with natural gas heating and DHW. Table 1 provides a list of input parameters for the base-case simulation models and for the corresponding code-compliant simulation models. TMY2 weather files for Houston, Brownsville, Dallas / Fort Worth, El Paso and Amarillo were used in all the simulations. Figure 1 shows the single-family house configuration.

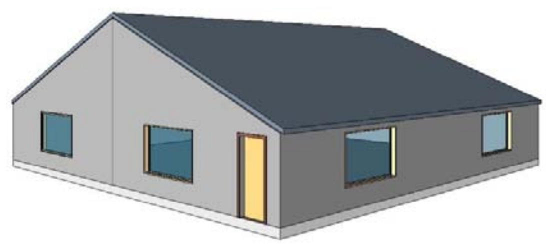

Figure 1: Typical Single-Family House

Simulation

The simulation used a single story, 2500 sqft house with four bedrooms, no exterior shading a slab-on-grade floor, ducts in the unconditioned space, vented attic, and no slab perimeter insulation except in climate zones 9B in 2001 IECC and 4B in 2009 IECC. Simulations were run using the 2001 IECC, 2001 IECC modified and 2009 IECC performance path for the selected counties (climate zones) with two heating options (gas/electric and all electric). The results are tabulated in Table 2. Percent savings of 2009 IECC over the 2001 IECC are presented for both site and source energy. A factor of 3.16 was used to calculate the source electricity consumption. A factor of 1.1 is used to calculate source gas energy consumption (Exception to Section 405.3, IECC 2009).

[1] 2001 IECC refers to 2000 IECC with IECC 2001 Amendments

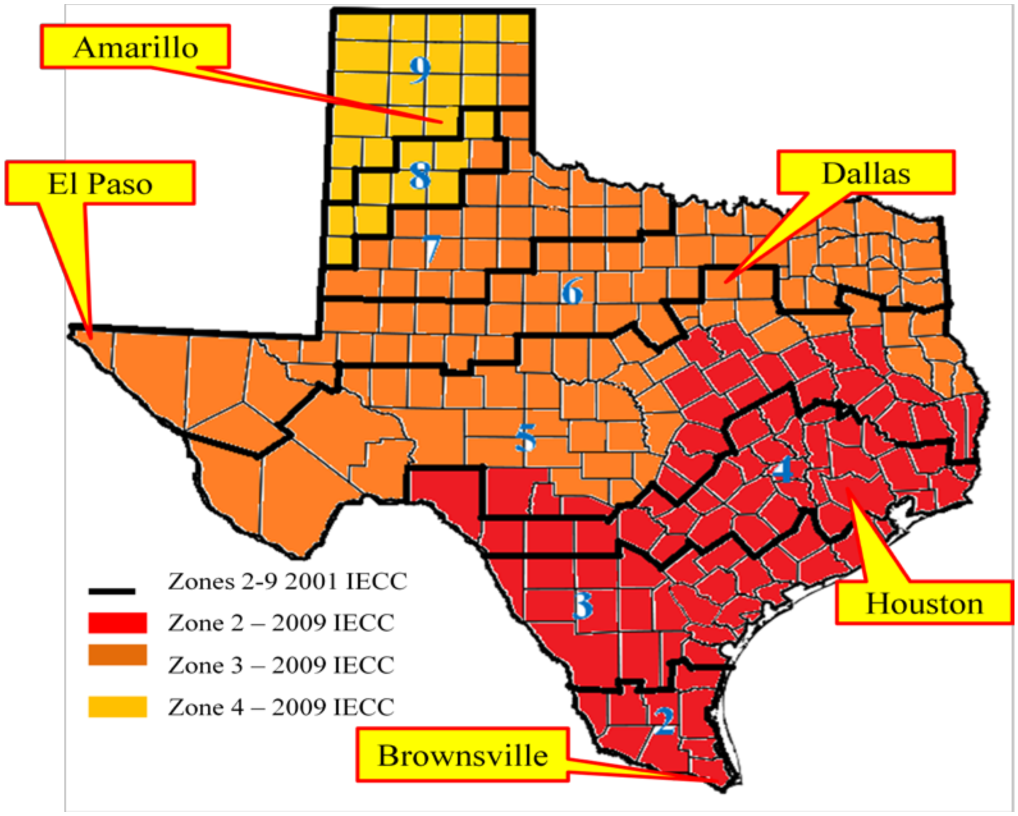

Figure 2: Map of Texas showing climate zones and the counties simulated.

Climate Zones

In this analysis the state of Texas has been divided into climate zones for the 2001 IECC and the 2009 IECC, with each code having different climate zones. The 2001 IECC divides the State of Texas into 8 Zones 2B, 3B, 3C, 4B, 5A, 5B, 6B, 7B, 8 and 9B. For this analysis five zones 2B, 4B, 5B, 6B and 9B were selected as representative counties (Cameron 2B, Harris 4B, Tarrant 5B, El Paso 6B, and Armstrong 9B, respectively). Likewise, the 2009 IECC divides the state of Texas in three Zones, Zone 2, 3 and 4 (classifications A and B are for Dry and Wet Regions). For this analysis, the representative counties used were Harris and Cameron for zone 2A/2B, Tarrant for zone 3A , El Paso for zone 3B and Armstrong for zone 4B.

Building Envelope Characteristics

Several components of the building envelope have different specifications for the two codes. To analyze this, a comparison was made between the two codes for each component in order to assess the stringency of the code. The comparison includes glazing area, building envelope, doors, attic and air exchange rate. Table 1 presents selected parameters that were used to generate the input for the 2001 code as well as the 2009 code simulation models.

Glazing Area: The glazing area in both the 2000 and 2009 IECC codes was specified in terms of window-to-floor area ratio (WFAR). For the 2001 IECC, the WFAR is a fixed value and is dependent on the area of conditioned space and is independent of the wall area for a code house. Therefore, the WFAR was fixed at 18% for the 2001 IECC. For 2009 IECC, the WFAR is equal to the proposed building if the window area is less than 15% of the floor area. In case the WFAR of the proposed building exceeds 15% of the floor area, the WFAR of the standard house was fixed at 15%.

Building Envelope Specifications: The specifications for the various components of the building envelope for the 2001 IECC for the performance path are stated in several different sections of the code. The wall R-value was obtained from Table 402.1.1(1) and the U-value for the fenestration was obtained from Table 402.1.1(2). Specifications of all other envelope components such as the R-value for the roof/ceiling, floor and crawl space wall (in case the house has a crawlspace), slab perimeter R-value (when the foundation type is slab on grade) and basement wall R-value (for house with basement) were found in the prescriptive tables (Table 502.2.4). These prescriptive tables for building envelope components are subdivided based on window-to-wall area ratio (WWAR) for the house.

In the 2009 IECC, the performance path references the specifications laid out in the prescriptive tables of the code. In the 2009 tables the building envelope no longer uses the WWAR as a basis of specifying the envelope characteristics. The specifications for the ceiling R-value, the roof R-value, the wall R-value and the U-factor for the glazing for the standard house were defined in Table 402.1.3. Specifications for the fenestration SHGC were provided in Table 402.1.1. In addition, in Section 402.5 of the code the area-weighted average maximum fenestration U-factor permitted using trade-offs from Section 402, was 0.48 in zones 4 and 5 and 0.40 in zones 6 through 8 for vertical fenestration. The area weighted average maximum fenestration SHGC permitted using trade-offs from Section 405 in zones 1 through 3 was 0.50.

*Door*s: For the 2001 IECC prescriptive and performance paths the U-value of the doors was set to be at 0.2 Btu/hr–sq–ft–F. (Sec. 402.1.3.4.3). Since the code is silent about information for locating the doors in the model, two doors were assumed, one each on the front and the back of the house. In contrast, the 2009 IECC specifications has two doors assigned to the north orientation (Table 402.1.3). However, for the purpose of this analysis, two doors were assumed - one each on the front and back orientation. The specification for the U-Value of the door was the same as the specifications for the fenestration U-values.

Attic Infiltration: The 2001 IECC is silent about guidance for attic infiltration for the performance and prescriptive path. Therefore, the simulation model assumes a fractional leakage of 0.0033 when using the Sherman-Grimsrud model (Winkelmann, 1993) and 1.5 air changes per hour (ACH) when using the air change per hour method to calculate impact of attic infiltration. These values were adopted from the 2009 IECC.

Air Exchange Rate: Standard Air Leakage area is dependent on the number of stories in the house for 2001 IECC. As per Sec 402.1.3.10 of the 2001 IECC the values are set at 0.00057 for a one-story house. The value was obtained by converting the normalized leakage of 0.57 as proposed in the code and is calculated using the Sherman-Grimsrud infiltration method. For the 2009 IECC performance path, the value of the air exchange rate was set at 0.00036 as per specifications from Table 405.5.2(1).

Space Conditions

Internal Heat Gains: In Section 402.1.3.6 of the 2001 IECC the internal gains were fixed at 3,000 Btu/hr regardless of the house size. To perform the analysis, the values were modified to 3,909 Btu/hr in order to match the 2009 IECC simulation which is based on the house size of 2500sqft. In the 2009 IECC, the internal heat gains are a function of conditioned area square footage and the number of bedrooms in the house. The internal heat gains were calculated by the equation provided in Table 405.5.2 (1) of the code.

Interior Shading: In Section 402.1.3.5 of 2001 IECC the values used for interior shading for summer and winter were 0.7 and 0.9 respectively. In Table 405.5.2 (1) of the 2009 IECC performance path and prescriptive path the interior shading for summer and winter has values of 0.7 and 0.85, respectively.

Systems

Thermostat Settings: The 2001 IECC recommends a thermostat setting of 78 ^{o}F for cooling and 68^{o}F for heating (Table 402.1.3.5), and a setback of 5^{o}F. However, the modified 2001 IECC did not have any setback, and the thermostat settings were modified to 75^{o}F for cooling and 72^{o}F for heating to match the specifications in the 2009 IECC (Table 405.5.2 (1)).

Heating and Cooling System Efficiency: The same efficiencies for cooling (SEER 13) and heating (HSPF 7.7, AFUE 0.78) are assumed in both 2001 IECC and 2009 IECC. Heating and cooling system efficiency trade-offs are allowed for the 2001 IECC. However, in the 2009 IECC (Table 503.2.3 (1), (2), (3)) no trade-offs are allowed.

Service Water Heating Efficiency: In the 2001 IECC the minimum domestic water heating efficiency is specified in Table 504.2, which is a function of the water heater capacity. In the 2009 IECC the service water efficiency of the base-case house is the same as that of the proposed design house which removes the benefits the user would obtain if installing a higher efficiency water heater than the one prescribed by the 2006 NAECA.

Building Component	Performance Path 2000/2001 IECC										Performance Path 2000/2001 IECC Modified										Comments	2009 IECC Performance			
	2B	3B	3C	4B	5A	5B	6B	7B	8	9B	2B	3B	3C	4B	5A	5B	6B	7B	8	9B		2A/2B	3A	3B	4B
	CAM			HAR		TAR	ELP			ARM	CAM			HAR		TAR	ELP			ARM		HAR / CAM	TAR	ELP	ARM
Above-grade walls - U Factor/R Value	0.085	0.09	0.09	0.085	0.09	0.085	0.08	0.1	0.06	0.064	0.085	0.09	0.1	0.085	0.09	0.085	0.1	0.1	0.06	0.064		0.082	0.082	0.082	0.082
Above-grade floors - U Factor/R Value	R-11	R-11	R-11	R-13	R-19	R-19	R-19	R-19	R-19	R-19	R-11	R-11	R-11	R-13	R-19	R-19	R-19	R-19	R-19	R-19		0.064	0.047	0.047	0.047
Ceilings - U Factor/ R Value	R 30	R 30	R 30	R 30	R38	R38	R38	R38	R38	R38	R 30	R 30	R 30	R 30	R38	R38	R38	R38	R38	R38		0.035	0.035	0.035	0.03
Slab R-value & Depth	R-0	R-0	R-0	R-0	R-0	R-0	R-0	R-0	R-0	R-6	R-0	R-0	R-0	R-0	R-0	R-0	R-0	R-0	R-0	R-6		0	0	0	10, 2ft
Attic - Infiltration	0.0033 Frac-Leak-Area										0.0033 Frac-Leak-Area										Note A	0.0033 Frac-Leak-Area			
Doors - Location and area	1- South, 1-North										1- South, 1-North										Note A	1-South, 1-North			
Doors - U Factor	0.2										0.2											0.65	0.5	0.5	0.35
Glazing - Area	18% WFR										18% WFR											15% WFR			
Glazing - U Factor	0.47	0.47	0.47	0.47	0.47	0.47	0.44	0.4	0.41	0.41	0.47	0.47	0.5	0.47	0.47	0.47	0.4	0.4	0.41	0.41		0.65	0.5	0.5	0.35
Glazing - SHGC	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.68	0.68	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.68	0.68		0.3	0.3	0.3	0.4
Glazing - Interior shading	Sum: 0.7 Win: 0.9										Sum: 0.7 Win: 0.9											Sum: 0.7 Win: 0.85			
Air exchange rate	SLA=0.00057										SLA=0.00057											SLA= 0.00036			
Internal gains	3000 Btu/hr										Simulation:3909 Btu/hr										Note B	3909 Btu/hr			
Structural mass	80% carpet, 20% tile										80% carpet, 20% tile										Note A	80% carpet, 20% tile			
Heating and cooling system - Size	500 ft^2/ton										500 ft^2/ton										Note A	500 ft^2/ton			
Heating and cooling system - Efficiency	AC: 13 SEER; Gas Furnace: 78% AFUE; Heat Pump: 7.7 HSPF										AC: 13 SEER; Gas Furnace: 78% AFUE; Heat Pump: 7.7 HSPF											AC: 13 SEER; Gas Furnace: 78% AFUE; Heat Pump: 7.7 HSPF			
Service water heating	70 gal/day										70 gal/day											70 gal/day			
Service water heating - Efficiency	Gas: 0.544 Electric: 0.864										Gas: 0.544 Electric: 0.864											Gas: 0.594 Electric: 0.904			
Thermal distribution system - Efficiency	1 story: 0.8										1 story: 0.8											Thermal Distribution Efficiency 0.88			
Thermal distribution system - Duct insulation	Supply: R8 Return: R4										Supply: R8 Return: R4											N.A			
Thermal distribution system - Duct leakage	20%										20%										Note A	N.A			
Thermostat	Heating 68F, Cooling 78F, 5F setback										Heating 72F, Cooling 75F, No Setback										Note B	Heating 72F, Cooling 75F, No Setback			

Notes:

Base Case: Single family house, 2500 sq. ft., 1 story, 4 bedrooms, Slab-on-grade floor, solar absorptance of 0.75 and remittance of 0.9 for wall and roof, ducts in the unconditioned and vented attic, no exterior shading, no slab perimeter insulation.

Note A: No guidance in the 2001 IECC code. Hence a value similar to the 2009 IECC- Performance Path is assumed.
Note B: Recalculated to match the values obtained from the 2009 IECC.

Table 1: Single-family Input Parameters for 2001 and 2009 Code-Compliant Simulation Models

Duct Leakage: No provisions were given in the 2001 IECC about duct leakage (Parker et al., 1993). Hence, a duct leakage value of 20% was assumed. For the 2009 IECC, an option for using specified thermal distribution efficiency is provided (Table 405.5.2(2)). However, when the thermal distribution efficiency is not used the duct leakage in Section. 403.2.2 of the code is used. Therefore, a duct leakage of 8 CFM/100ft2 to outdoor was used, which gives a value for the duct leakage equal to 11.1%.

Duct Insulation: The 2001 IECC prescribes the supply duct and return duct to be insulated with insulation of R-values of R-8 and R-4 respectively. The 2009 IECC recommends that both the supply and return ducts be insulated with insulation of R-8 and R-6 respectively (Section 403.2.1).

RESULTS

Figure 3 to 6 present the results of the comparison for both site and source energy consumption. The percentage savings above code is presented in Table 2.

For all the sites simulated, the total energy use increases for the modified 2001 IECC house (Base-Case) as compared to the 2001 IECC house. This is due to the reduced settings of internal energy gains and thermostat settings on switching from the 2001 code to the 2001 modified code. This increase in annual energy use comes from an increase in energy use from lights and miscellaneous equipment as well as from space heating and cooling. It should be noted that the corresponding 2001 IECC simulations consume much less energy than the 2009 IECC simulations.

On switching from the modified 2001 code to the 2009 code resulted in the reduction in annual energy consumption. This reduction in energy consumption is primarily due to change in space heating and cooling energy consumption as well as change in domestic water heating energy consumption.

Results of the comparison of the 2001 IECC with the values obtained from implementing the 2009 IECC performance path, when considering gas heating, the site energy savings are in the range of 10.9% to 16.4%. The source energy savings are in the range of 11.9% to 16.7%. When considering the heat pump option both the site and source energy savings are in the range of 10.9% to 14.6%.

Houses in Amarillo saved the most energy on going from modified 2001 IECC to 2009 IECC by saving over 16% in site and source energy for houses with gas heating and 14% in site and source energy for houses with heat pump heating. While houses in El Paso saved the least energy on going from modified 2001 IECC to 2009 IECC by saving 10% - 11% in site and source energy respectively for houses with gas heating and 10% in both site and source energy for houses with heat pump heating.

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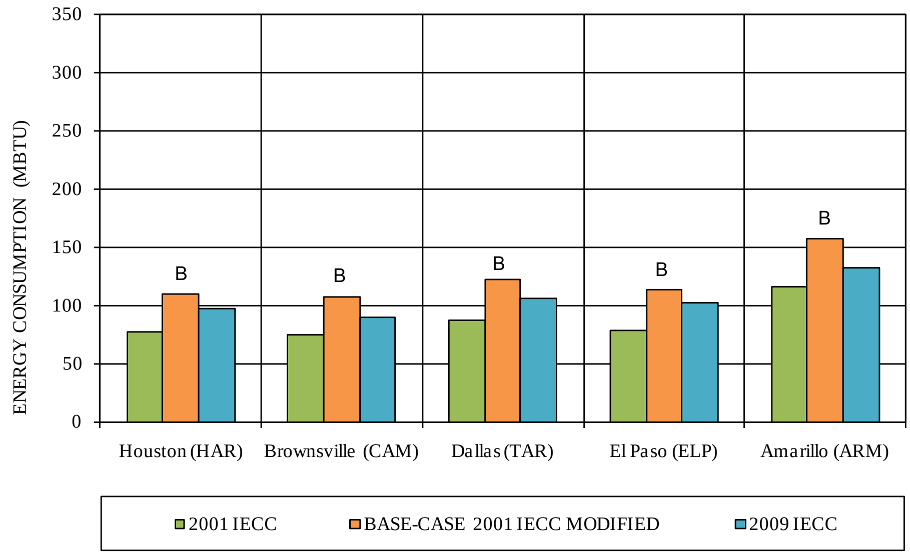

Figure 3: A Comparison of the Annual Site Energy Consumption for Five Counties for a Code-Compliant House with Natural Gas Heating and DHW

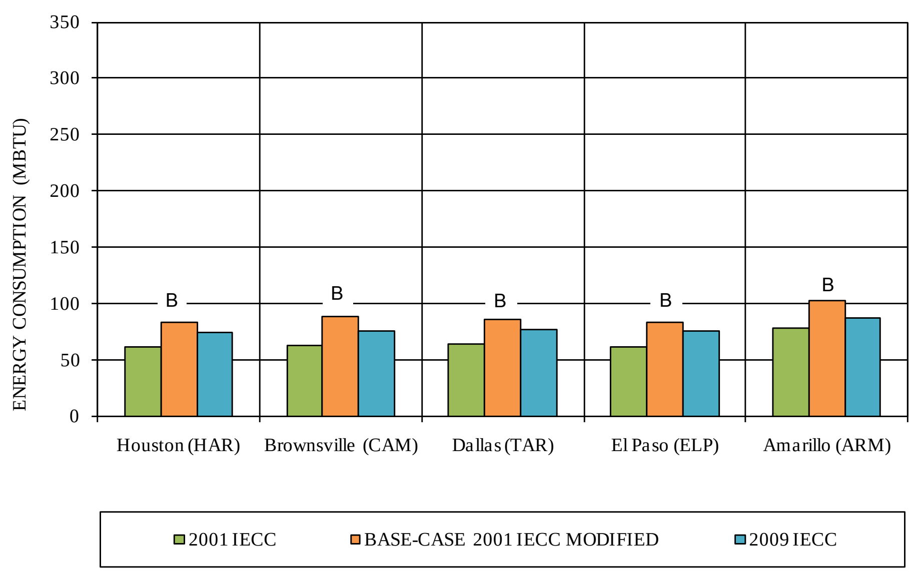

Figure 4: A Comparison of the Annual Site Energy Consumption for Five Counties for a Code-Compliant House with Heat Pump Heating and Electric DHW

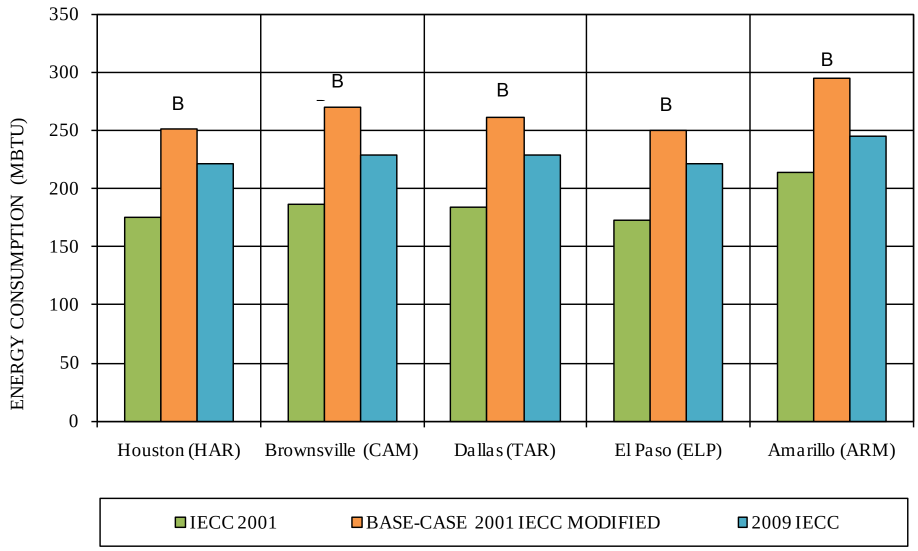

Figure 5 A Comparison of the Annual Source Energy Consumption for Five Counties for a Code-Compliant House with Natural Gas Heating and DHW

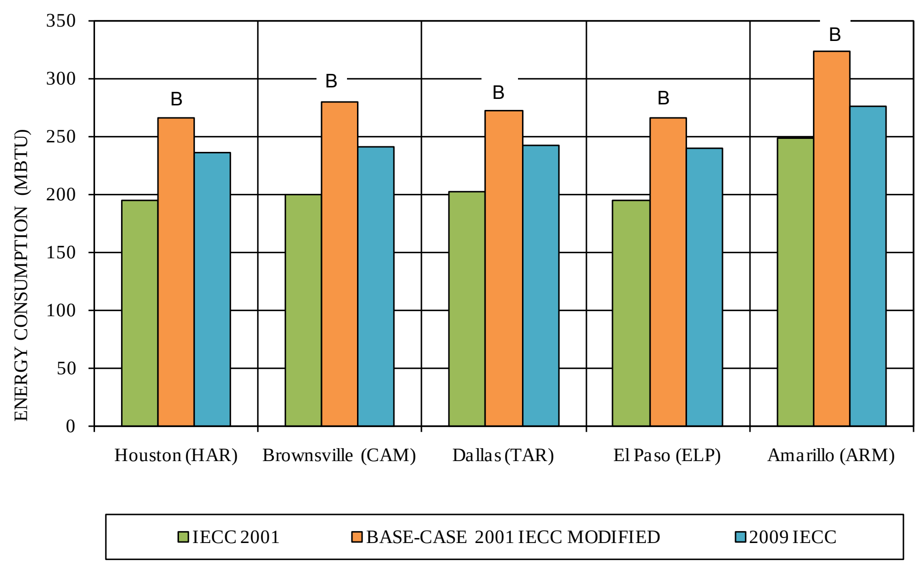

Figure 6: A Comparison of the Annual Source Energy Consumption for Five Counties for a Code-Compliant House with Heat Pump Heating and Electric DHW

County	IECC 2009 Weather Zones	Energy Type	Total Annual Savings of the IECC 2009 Performance Path compared to the IECC 2000/2001 (%)	
			Gas Heating, DHW	Heat Pump Heating, Electric DHW
Houston (HAR)	2A	Site	10.9 %	10.9 %
		Source	11.9 %	10.9 %
Brownsville (CAM)	2B	Site	16.4 %	13.6 %
		Source	15.1 %	13.6 %
Dallas (TAR)	3A	Site	12.8 %	10.8 %
		Source	12.3 %	10.8 %
El Paso (ELP)	3B	Site	10.2 %	10.0 %
		Source	11.2 %	10.0 %
Amarillo (ARM)	4B	Site	16.0 %	14.6 %
		Source	16.7 %	14.6 %

Table 2: Summary of the Comparison between 2001 IECC Performance Path vs. 2009 IECC Performance Path