AN ANALYSIS OF THE RESIDENTIAL ENERGY SAVINGS FROM THE IMPLEMENTATION OF THE 2001 IECC AND 2006 NAECA APPLIANCE STANDARDS IN THE STATE OF TEXAS

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ABSTRACT

This paper presents results of an analysis of the annual electricity and natural gas savings from implementation of the 2001 International Energy Conservation Code (IECC) specifications with updated 2006 specifications for mechanical systems to new single-family residential construction, using a code-traceable DOE-2 simulation for two locations in Texas. In this analysis a sensitivity analysis was performed which included the impact of changing the Seasonal Energy Efficiency Ratio (SEER) and Heating Seasonal Performance Factor (HSPF) values in code-compliant construction (i.e., SEER 13, HSPF 7.7) as required by National Appliance Energy Conservation Act (NAECA, 2006).

The results show that the annual energy consumption for a typical single-family residence decreased by 18.8% when comparing a pre-code house with natural gas heating, where the SEER for the air-conditioner was increased from 10 to 13, to a code-compliant house incorporating the 2006 NAECA standards in Houston , and by 16.0% for a similar house in Dallas/Fort Worth area. In a house employing a heat pump as a source of heating, where the SEER for the air-conditioner was increased from 10 to 13 and the HSPF was increased from 6.6 to 7.7, the annual energy consumption decreased by 18.2% for a house in Houston and by 16.6% for a similar house in Dallas/Fort Worth.

BACKGROUND

The 77th Texas Legislature in 2001 established Senate Bill 5(SB-5), which addressed NOx emission reductions in non-attainment and new non-attainment areas by establishing programs to reduce vehicle emissions and reductions due to energy efficiency and the use of renewable energy resources. This paper presents results that show the annual energy savings from implementing the energy efficiency measures in the 2001 IECC[1] and the efficiency updates required by National Appliance Energy Conservation Act (NAECA, 2006). In this study a code-compliant house with updated specifications was compared to a pre-code house that had characteristics from a pre-2001 survey conducted by the National Association of Home Builders (NAHB 2006). The analysis also includes the impact of changing the SEER and HSPF values in code-compliant construction (i.e., from SEER 10 to SEER 13, and HSPF 6.6 from to HSPF 7.7).The analysis was performed using a code-traceable DOE-2 simulation for two weather locations in Texas: Houston and Dallas/FortWorth.

METHODOLOGY

Overview

In order to quantify the energy savings from the original efficiency measures in the 2001 IECC three sets of simulation models were prepared – a pre-code house, a code-compliant house and a code-compliant house plus the 2006 updates. These models were prepared for a house with electric heating and domestic hot water (DHW) and a house with natural gas heating and DHW.

The first pre-code simulation model includes a house with SEER 10 air-conditioner and natural gas furnace with an Annual Fuel Utilization Efficiency (AFUE) of 0.78. The second pre-code simulation model assumes a house a SEER 10 air-conditioner and an HSPF 6.6 heat pump for heating. The remaining assumptions in the pre-code models were based on a survey of pre-code construction obtained from the survey data obtained from the National Association of Home Builders (NAHB 2006) and other sources as indicated in Table 1.

The second set of simulations was based on the specifications for a code-compliant single-family building that met all aspects of the 2001 IECC. One house assumes HVAC equipment with a SEER 10 air-conditioner and natural gas furnace with an AFUE 0.78. The second house assumes HVAC equipment with a SEER 10 air conditioner and a HSPF 6.6 heat pump for heating. The third set of simulations includes the updated specifications of the HVAC equipment as required by the 2006 NAECA (i.e., electric cooling - SEER 13 and heat pump heating -

[1] The 2001 IECC notation indicates the 2000 IECC (ICC 1999) as modified by the 2001 supplement (ICC 2001)

HSPF 7.7). TMY2 weather files for Houston and Dallas/Fort Worth were used in all the simulations. Figure 1 shows the single-family simulation model. Table 1 provides a selected list of input parameters for the base-case simulation models and for the corresponding code-compliant simulation models.

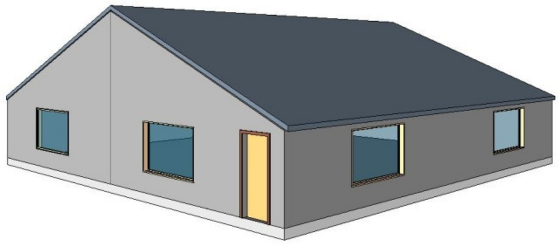

Figure 1: Typical Single-Family House.

Simulation Execution

A total of twelve simulations were performed. In order to facilitate the analysis, a batch simulation tool, the Desktop DOE-2 Processor (DDP) was developed (Liu 2008). This tool requires a reduced set of input parameters to run DOE-2 input files. The parameters are input in an Excel spreadsheet. Information in each row of the spreadsheet is used to generate a single include file which is then used to run the DOE-2 input file. Figure 2 shows an excerpt of the Excel spreadsheet which was used to generate the parametric inputs. The parameters were divided into two major categories; LOADS and SYSTEMS, which correspond to the simulation process followed in the DOE-2 input file. The LOADS were then further divided into building, construction, space conditions and shading parameters.

Single-Family Input File Characteristics

Table 1 presents selected parameters which are used to generate the input for the pre-code as well as the code-compliant simulation models. The pre-code house was modeled based on information obtained from the survey conducted by NAHB (2003) for pre-code residential buildings in Texas. In the absence of any guidance in the NAHB survey, the same conditions were used for the pre-code and code-compliant house. For example, internal heat gains were set at 3000 Btu/hour for both the pre-code as well as the code-compliant houses. In cases where the characteristics of the pre-code simulation model were less stringent than the code-compliant simulation model, these characteristics were considered in the pre-code simulation model. In cases where the characteristics of the pre-code simulation model were more stringent than those in the code-compliant simulation model, the code-compliant characteristics were used in the pre-code simulation model.

Building Envelope Characteristics

The house was a 2,325 sq. ft., square shaped, one story, single-family, detached house facing south, with a floor-to-ceiling height of 8 ft. The house had an attic with a roof pitched at 23 degrees, which contained the HVAC systems and ductwork, and had a light-weight wood frame construction with 2x4 studs spaced at 16" on center, a slab-on-grade floor and an unconditioned, vented attic. The house had a fascia brick exterior and asphalt shingle roofing. The window area is equal to 18% of the floor area distributed equally on all four sides with no exterior shading as required by the 2001 IECC. This is equivalent to 27% window-to-wall area ratio. Two 20 sq. ft. doors with a U-value of 0.2 Btu/h-sq. ft.-°F were placed on the north and south walls. Information regarding the framing factors for the walls, floor and ceiling was obtained from ASHRAE Report RP-904 (ASHRAE 2001). The house was simulated as a single-zone building using a delayed construction mode (i.e., DOE-2's Custom Weighting Factors) to take into account the thermal mass of the construction materials and the slab on grade floor.

For the pre-code simulation model the values of several building envelope characteristics were obtained from the NAHB survey. The wall insulation was set at R-13. The ceiling insulation was set at R-26.75 for Dallas and R-27 for Houston. For Dallas the glazing U-factor was set to 0.87 and the Solar Heat Gain Coefficient (SHGC) was set at 0.66. For Houston the glazing U-factor was set at 1.11 and the SHGC was set at 0.71.

Tables 402.1.1(1) and 402.1.1(2) of the 2001 IECC provide the values for wall insulation and glazing U-factor for the code-compliant simulation model sets. Based on the climate-specific characteristics for the standard design, the code-compliant house was modeled with an assembly U-value of 0.085 Btu/h-sq. ft.-°F, a fenestration U-value of 0.47 Btu/h-sq. ft.-°F, and a 0.40 solar heat gain coefficient (SHGC). Table 502.2.4(6) of the 2001 IECC was used provide the prescriptive values for ceiling and slab insulation. For Houston R-30 was required for ceiling insulation and for Dallas R-38 was required for ceiling insulation. No perimeter slab insulation was modeled for either location, due to the potential presence of termites.

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

CHARACTERISTIC	PRE-CODE ASSUMPTIONS		SOURCES	CODE-COMPLIANT ASSUMPTIONS		SOURCES	COMMENTS
Building							
Building type	Single family, detached house			Single family, detached house			
Gross area	2,325 sq. ft. (48.22 ft. x 48.22 ft.)		NAHB (2003)	2,325 sq. ft. (48.22 ft. x 48.22 ft.)		NAHB (2003)	
Number of floors	1		NAHB (2003)	1		NAHB (2003)	
Floor to floor height (ft.)	8		NAHB (2003)	8		NAHB (2003)	
Orientation	South facing			South facing			
Construction							
Construction	Light-weight wood frame with 2x4 studs spaced at 16" on center		NAHB (2003)	Light-weight wood frame with 2x4 studs spaced at 16" on center		NAHB (2003)	
Roof outside emissivity	0.9			0.9			
Floor	Slab-on-grade floor		NAHB (2003)	Slab-on-grade floor		NAHB (2003)	
Roof configuration	Unconditioned, vented attic		NAHB (2003)	Unconditioned, vented attic		NAHB (2003)	
Roof absorptance	0.75			0.75			Assuming asphalt shingle roofing
Ceiling insulation (hr-sq.ft.-°F/Btu)	DALLAS: R-26.75 HOUSTON: R-27		NAHB (2003)	DAL: R-38 HOU: R-30		2001 IECC, Table 502.2.4(6), (p.83)	Based on HDD65 and 27% window-to-wall area ratio
Wall absorptance	0.55			0.55			Assuming brick facia exterior
Wall insulation (hr-sq.ft.-°F/Btu)	R-13[1]		NAHB (2003)	R-13		2001 IECC, Table	Based on HDD65
Slab Perimeter Insulation	None		2001 IECC, Table 502.2.4(6), (p.83)	None		2001 IECC, Table 502.2.4(6), (p.83)	Based on HDD65 and 27% window-to-wall area ratio
Ground reflectance	0.24		DOE2.1e User Manual	0.24		DOE2.1e User	Assuming grass
U-Factor of glazing (Btu/hr-sq.ft.°F)	DALLAS: 0.87 HOUSTON: 1.11		NAHB (2003)	0.47		2001 IECC, Table 402.1.1(2), (p.63)	Based on HDD65
Solar Heat Gain Coefficient (SHGC)	DALLAS: 0.66 HOUSTON: 0.71		NAHB (2003)	0.4		2001 IECC, Section 402.1.3.1.4, (p.64)	0.4 for HDD < 3500, and 0.68 for HDD ≥ 3500
Window area	18% of conditioned floor area		2001 IECC, Section 402.1.1, (p.63)	18% of conditioned floor area		2001 IECC, Section 402.1.1, (p.63)	This amounts to 418.5 sq. ft. window area and 27% window-to-wall area ratio for the assumed base case building configuration
Exterior shading	None		2001 IECC, Section	None		2001 IECC, Section	
Space Conditions							
Space temperature setpoint	68°F Heating, 78°F Cooling, 5°F set-back/ set-up for winter and summer, respectively, for 6 hours per day		2001 IECC, Table 402.1.3.5, (p.64)	68°F Heating, 78°F Cooling, 5°F set-back/ set-up for winter and summer, respectively, for 6 hours per day		2001 IECC, Table 402.1.3.5, (p.64)	
Internal heat gains	0.88 W (modeled as 0.44 W for lighting and 0.44 W for equipment)		2001 IECC, Section 402.1.3.6, (p.65)	0.88 W (modeled as 0.44 W for lighting and 0.44 W for equipment)		2001 IECC, Section 402.1.3.6, (p.65)	This assumes heat gains from lighting, equipment and occupants.
Number of occupants	None		2001 IECC, Section 402.1.3.6, (p.65)	None		2001 IECC, Section 402.1.3.6, (p.65)	Assuming internal gains include heat gain from occupants
Mechanical Systems	ELECTRIC/GAS	ALL-ELECTRIC		Electric/Gas	All-electric		
HVAC system type	Electric cooling (air conditioner) and natural gas heating (gas fired furmace)	Electric cooling and heating (air conditioner with heat pump)		Electric cooling (air conditioner) and natural gas heating (gas fired furmace)	Electric cooling and heating (air conditioner with heat pump)		
HVAC system efficiency	SEER 10 AC,[2] 0.78AFUE furnace[3]	SEER 10 AC, 6.6 HSPF heat pump	NAECA (2006)	SEER 10 AC, 0.78 AFUE furnace	SEER 10 AC, 6.6 HSPF heat pump	NAECA (2006)	
Cooling capacity (Btu/hr)	55,800			55,800			500 sq. ft./ton
Heating capacity (Btu/hr)	55,800			55,800			Same as cooling capacity
DHW system type	40-gallon tanktype gas water heater with a standing pilot light	50-gallon tanktype electric water heater (without a pilot light)	Tank size from ASHRAE HVAC Systems and Equipment Handbook	40-gallon tanktype gas water heater with a standing pilot light	50-gallon tanktype electric water heater (without a pilot light)	Tank size from ASHRAE HVAC Systems and Equipment Handbook	
DHW heater energy factor	0.54	0.86	2001 IECC, Table 504.2, (p.91)	0.54	0.86	2001 IECC, Table 504.2, (p.91)	(a) 0.62-0.0019V, (b) 0.93-0.00132V, Where V=storage volume (gal.)
Duct location	Unconditioned, vented attic		NAHB (2003)	Unconditioned, vented attic		NAHB (2003)	
Duct leakage (%)	20%		Parker et al. (1993)	20%		Parker et al. (1993)	
Duct insulation (hr-sq.ft.-°F/Btu)	R-8 (supply) and R-4 (return)		2001 IECC	R-8 (supply) and R-4 (return)		2001 IECC	
Supply Static Pressure	1			1			
CFM/ton for system and duct model	360			360			

[1]Wall insulation for pre-code house was found to be R-14.25 for Dallas and R-14 for Houston. However, the values were set to R-13 in the simulation model.

[2] SEER values for the pre-code house was found to be SEER11. However, the values were set to SEER 10 in the simulation model to match the code.

[3] AFUE values for the pre-code house was found to be at 80%. However the values were set to 78% in the simulation model to match the code.

Space Conditions

As per Section 402.1.3.6 of the 2001 IECC, internal heat gains were fixed at 3000 Btu/hr for a single-family unit. In addition the house was modeled without occupants and four bedrooms. The infiltration was set to the requirements in Section 402.1.3.10 of the 2001 IECC, at a rate of 0.47 ACH, which is based on the weather factor specified in ASHRAE Standard 136-93 (ASHRAE 1993).

HVAC System Characteristics

The HVAC system for the pre-code as well as code-compliant models included a central air-conditioning system and a heating system. Two options for the heating system were considered:
a) natural gas (i.e., gas-fired furnace for space heating, and a gas-fired water heater for domestic hot water), and b) electricity (i.e., a heat pump for space heating, and an electric resistance water heater for domestic water heating). For the electric/gas house, the pre-code HVAC system had a SEER 10 air-conditioner and a gas-fired, forced-air furnace with a 0.78 Annual Fuel Utilization Efficiency (AFUE). One pilot light (100 Btu/hr) was considered for the furnace in the pre-code house . An electronic ignition was assumed in the code-compliant house. For the all-electric house, the pre-code and the code-compliant HVAC system had a SEER 10 air conditioner and a heat pump with a performance rating of 6.6 HSPF. The efficiencies for both the cooling and heating systems comply with the requirements provided in Table 503.2 of the 2001 IECC. For both types of houses, the capacity of the cooling system and heating system is 55,800 Btu/hr, which is 500 sq. ft. per ton. The heating and cooling set-points were 68°F for winter and 78°F for summer, a 5°F setback/setup was included for six hours at night (winter) and six hours during the day (summer). The equipment part-load curves used in the simulation were from Henderson et.al. (1999). The supply air in CFM/ton was set to 360 CFM/ton. The supply static of the system is set to 1 inch of water as per experiences with field measurements.

Air Distribution System Characteristics

The air distribution system of the pre-code as well as code-compliant models simulation models, includes the HVAC unit and the ducts, which were located in the unconditioned, vented attic. The attic was assumed to have an air infiltration rate of 15 ACH. This infiltration data was chosen to match measured data provided in a report by Kim (2006). The insulation values for the supply and return ducts were R-8 and R-4, respectively (IECC 2001). A 10% duct leakage on the supply and return was assumed (Parker, 1993).

DHW System Characteristics

For the electric/gas house, the domestic hot water (DHW) system for the pre-code as well as code-compliant model was a 40-gallon, tank type, natural gas-fired water heater with a standing pilot light (100 Btu/hr), with a calculated energy factor (EF) of the system of 0.54. For the all-electric house, the base-case DHW system is a 50- gallon, tank type, electric resistance water heater. The energy factor (EF) of the system is 0.86. The daily hot water use was calculated as 70 gallons/day, which is the amount required for a house with four bedrooms. The hot water supply temperature was 120°F. The method to simulate the DHW in DOE-2.1e used an energy factor based on Building America House Performance Analysis Procedures (NREL 2001), which assumed a constant hourly DHW use (no part-load efficiencies).

RESULTS

Table 2 summarizes the results of the simulations for the electric/gas house and the all-electric house for Houston and Dallas/Fort Worth. The results are reported for the pre-code, the code-compliant simulation model and the simulation model with the updated HVAC specifications from NAECA (2006) (i.e., the "code+" house). The results include annual energy consumption savings, and savings from the individual end-uses as calculated by DOE-2; including savings from the area lights, miscellaneous equipment, space heating, space cooling, pumps, vent fans, and domestic hot water. The results are also shown in Figure 3 and Figure 4 which show the end-use energy consumption for the cases analyzed.

Energy Use from the Pre-Code Simulation Model

Table 2 shows that the total annual energy consumption for the pre-code house was 94.3 MBtu for the electric / gas house for Houston. This includes a consumption of 23.8 MBtu for space cooling and 17.3 MBtu for space heating. For Dallas/Fort Worth the annual energy consumption for the electric / gas base-case pre-code house was 101.5 MBtu. This includes a consumption of 21.7 MBtu for space cooling and 25.4 MBtu for space heating.

The total annual energy consumption for the pre-code house was 75.9 MBtu for the all-electric house for Houston. This includes a consumption of 23.8 MBtu for space cooling and 6.3 MBtu for space heating. For Dallas/Fort Worth the annual energy consumption for the all-electric base-case pre-code house was 77.3 MBtu. This includes a consumption of 21.7 MBtu for space cooling and 9 MBtu for space heating.

Energy Use Reduction from Implementing the 2001 Code-Compliant Simulation

The total annual energy consumption for the code-compliant house was 80.7 MBtu for the electric / gas house for Houston. This includes a consumption of 18.2 MBtu for space cooling and 11.1 MBtu for space heating. This represents a total annual energy use decrease of 14.4%, which includes a space cooling consumption reduction of 23.5% and the space heating consumption reduction of 35.8%. For the house in Dallas/Fort Worth the annual energy consumption for the electric / gas base-case was 89.2 MBtu. This includes a consumption of 16.6 MBtu for space cooling and 19.7 MBtu for space heating, which is a total annual energy consumption decrease of 12.1%, and includes a the space cooling consumption reduction of 23.5% and the space heating consumption reduction of 22.4%. These results agree with the previous results reported by Ahmad et. al (2005).

The total annual energy consumption for the all-electric code-compliant house was 66.8 MBtu for Houston. This includes a consumption of 18.2 MBtu for space cooling and 4.6 MBtu for space heating. For the all-electric Houston house the annual energy consumption was decreased by 12.0%, this includes a reduction in the space cooling consumption by 23.5% and a space heating consumption reduction of 27.0%. For the Dallas/Fort Worth house the annual energy consumption for the all-electric code-compliant house was 69.2 MBtu. This includes a consumption of 16.6 MBtu for space cooling and 7.5 MBtu for space heating, which is a total annual energy consumption decrease of 10.5% and includes a space cooling consumption reduction of 23.5% and the space heating consumption reduction of 16.7%.

It is interesting to note the savings from the electric/gas house are greater that the savings obtained from the all-electric house due to a greater percentage of savings obtained from space heating for both Houston and Dallas. This also includes the removal of the furnace pilot light in the code-compliant simulation model for the electric/gas house.

Energy Use from Improved HVAC System Efficiency

On changing the SEER from 10 to 13 for the electric / gas building in Houston, annual energy consumption decreased by 18.8% . The space cooling energy consumption decreased by 41.2 %. The space heating energy consumption decreased by 34.8%. Similarly, for a building using natural gas heating in Dallas/Fort Worth, annual energy consumption decreased by 16.0 %. The space cooling energy consumption decreased by 41.0 %. The space heating energy decreased by 22.4 %.

For the all-electric house, in addition to changing the SEER, the HSPF is changed from 6.6 to 7.7. For Houston, the total annual energy consumption decreased by 18.2%. The space cooling decreased by 41.2% and the space heating decreased by 34.9%. For the all-electric building in Dallas/Fort Worth, the total annual energy consumption decreased by 16.6%. The space cooling decreased by 41.0% and the space heating decreased by 26.3%.

In a similar fashion as the savings with 2001 IECC prior to 2006, the savings from the electric/gas house are greater that the savings obtained from the all-electric house due to a greater percentage of savings obtained from space heating for Houston. However, for Dallas the trend is reversed with energy savings obtained from the all-electric house are greater than the energy savings obtained from the electric/gas house. This is because Dallas has more heating degree days than Houston which magnifies the savings obtained from a higher efficiency HSPF. In this case the whole impact of improved HSPF is demonstrated.

SUMMARY

This paper presents results that show the annual electricity and natural gas savings from implementation of the 2001 IECC to a single-family house with improved SEER and HSPF value, which use a code-traceable DOE-2 simulation for two locations in Texas. The paper performs a sensitivity analysis which includes the impact of changing the SEER and HSPF values in code-compliant construction (i.e. SEER 13, HSPF 7.7) as required by NAECA (2006).

By enhancing the SEER for the air-conditioner in a house utilizing natural gas for space heating, the annual energy consumption decreased by 18.77% for Houston and decreased by 15.76% for Dallas/Fort Worth when compared to the performance of a similar pre-code residential house. By enhancing the SEER for the air-conditioner and HSPF for the heat pump in a house utilizing a heat pump for space heating, the annual energy consumption decreased by 18.18% for Houston and by 16.56% for Dallas/Fort Worth.

AKNOWLEDGEMENTS

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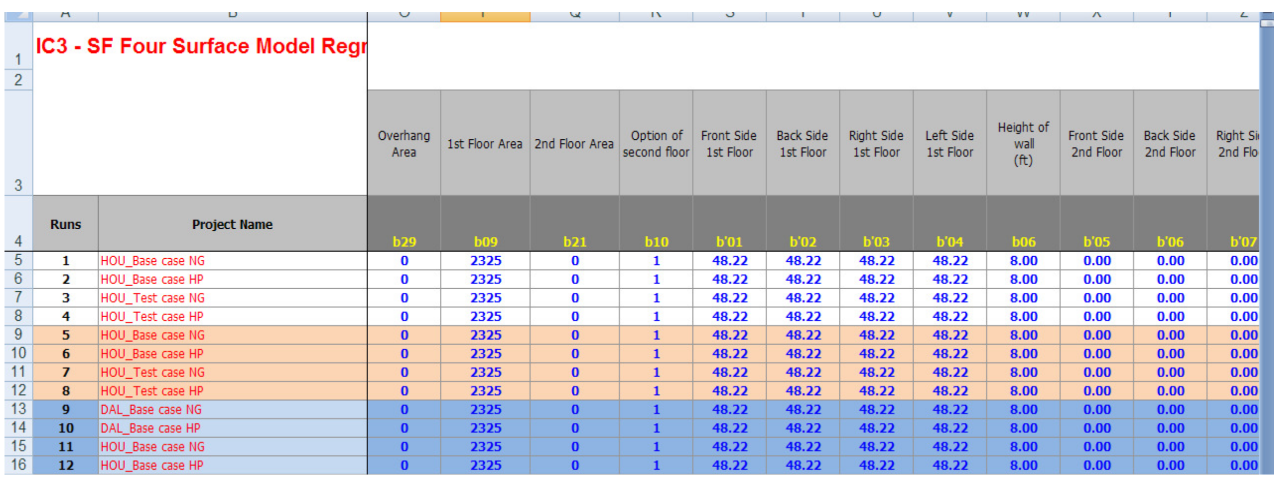
Table 2: Summary of the results

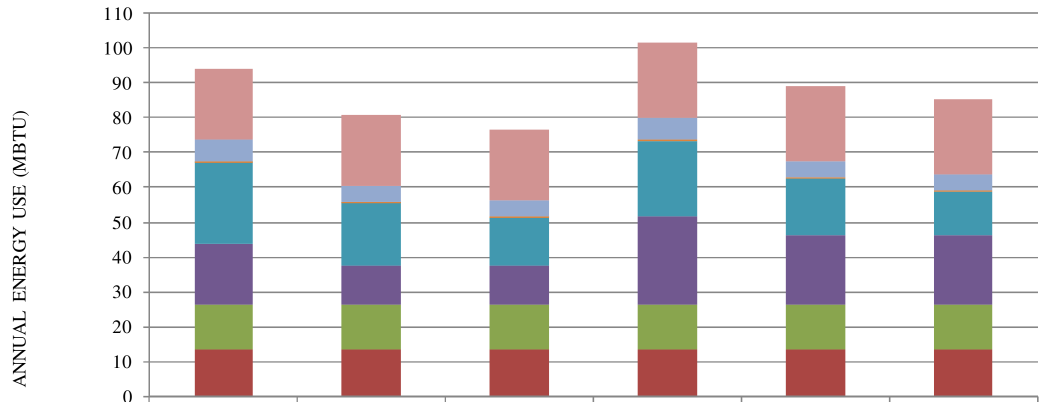
	FOR HOUSTON									
	NATURAL GAS					HEAT PUMP				
	PRE-CODE	CODE	CODE+	(PRECODE - CODE) /PRECODE)%	(PRECODE - CODE+) /PRECODE)%	PRE-CODE	CODE	CODE+	(PRECODE - CODE) /PRECODE)%	(PRECODE - CODE+) /PRECODE)%
AREA LIGHTS	13.2	13.2	13.2	0.0%	0.0%	13.2	13.2	13.2	0.0%	0.0%
MISC EQUIPMT	13.2	13.2	13.2	0.0%	0.0%	13.2	13.2	13.2	0.0%	0.0%
SPACE HEAT	17.3	11.1	11.1	35.8%	35.8%	6.3	4.6	4.1	27.0%	34.9%
SPACE COOL	23.8	18.2	14.0	23.5%	41.2%	23.8	18.2	14.0	23.5%	41.2%
PUMPS & MISC	0.2	0.2	0.2	0.0%	0.0%	0.2	0.2	0.2	0.0%	0.0%
VENT FANS	6.2	4.5	4.5	27.4%	27.4%	6.4	4.7	4.7	26.6%	26.6%
DHW	20.4	20.4	20.4	0.0%	0.0%	12.8	12.8	12.8	0.0%	0.0%
BEPS TOTAL	94.3	80.7	76.6	14.4%	18.8%	75.9	66.8	62.1	12.0%	18.2%
	FOR DALLAS									
	NATURAL GAS					HEAT PUMP				
	PRE-CODE	CODE	CODE+	(PRECODE - CODE) /PRECODE)%	(PRECODE - CODE+) /PRECODE)%	PRE-CODE	CODE	CODE+	(PRECODE - CODE) /PRECODE)%	(PRECODE - CODE+) /PRECODE)%
AREA LIGHTS	13.2	13.2	13.2	0.0%	0.0%	13.2	13.2	13.2	0.0%	0.0%
MISC EQUIPMT	13.2	13.2	13.2	0.0%	0.0%	13.2	13.2	13.2	0.0%	0.0%
SPACE HEAT	25.4	19.7	19.7	22.4%	22.4%	9.0	7.5	6.6	16.7%	26.7%
SPACE COOL	21.7	16.6	12.8	23.5%	41.0%	21.7	16.6	12.8	23.5%	41.0%
PUMPS & MISC	0.3	0.3	0.3	0.0%	0.0%	0.3	0.3	0.3	0.0%	0.0%
VENT FANS	6.3	4.7	4.7	25.4%	25.4%	6.6	4.9	4.9	25.8%	25.8%
DHW	21.5	21.5	21.5	0.0%	0.0%	13.6	13.6	13.6	0.0%	0.0%
BEPS TOTAL	101.5	89.2	85.3	12.1%	16.0%	77.3	69.2	64.5	10.5%	16.6%



IC3 - SF Four Surface Model Regr

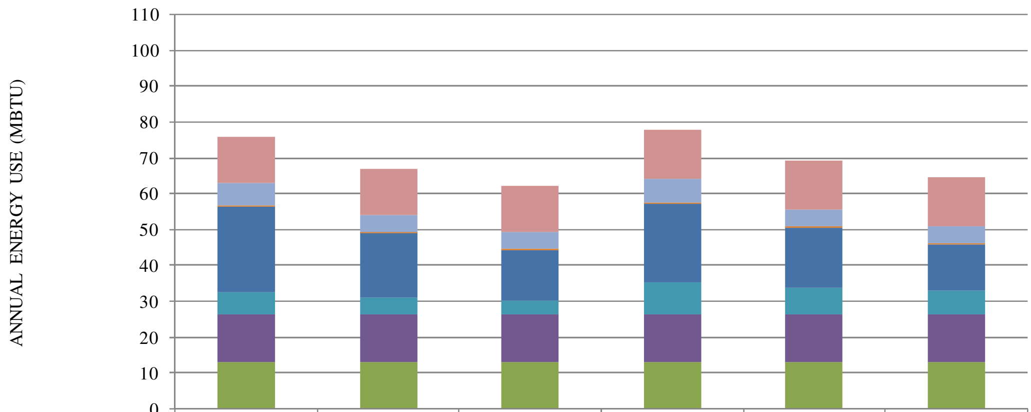
Runs	Project Name	Overhang Area	1st Floor Area	2nd Floor Area	Option of second floor	Front Side 1st Floor	Back Side 1st Floor	Right Side 1st Floor	Left Side 1st Floor	Height of wall (ft)	Front Side 2nd Floor	Back Side 2nd Floor	Right Si 2nd Flo
		b29	b09	b21	b10	b'01	b'02	b'03	b'04	b06	b'05	b'06	b'07
1	HOU_Base case NG	0	2325	0	1	48.22	48.22	48.22	48.22	8.00	0.00	0.00	0.00
2	HOU_Base case HP	0	2325	0	1	48.22	48.22	48.22	48.22	8.00	0.00	0.00	0.00
3	HOU_Test case NG	0	2325	0	1	48.22	48.22	48.22	48.22	8.00	0.00	0.00	0.00
4	HOU_Test case HP	0	2325	0	1	48.22	48.22	48.22	48.22	8.00	0.00	0.00	0.00
5	HOU_Base case NG	0	2325	0	1	48.22	48.22	48.22	48.22	8.00	0.00	0.00	0.00
6	HOU_Base case HP	0	2325	0	1	48.22	48.22	48.22	48.22	8.00	0.00	0.00	0.00
7	HOU_Test case NG	0	2325	0	1	48.22	48.22	48.22	48.22	8.00	0.00	0.00	0.00
8	HOU_Test case HP	0	2325	0	1	48.22	48.22	48.22	48.22	8.00	0.00	0.00	0.00
9	DAL_Base case NG	0	2325	0	1	48.22	48.22	48.22	48.22	8.00	0.00	0.00	0.00
10	DAL_Base case HP	0	2325	0	1	48.22	48.22	48.22	48.22	8.00	0.00	0.00	0.00
11	HOU_Base case NG	0	2325	0	1	48.22	48.22	48.22	48.22	8.00	0.00	0.00	0.00
12	HOU_Base case HP	0	2325	0	1	48.22	48.22	48.22	48.22	8.00	0.00	0.00	0.00

Figure 2: Example of the DDP Spreadsheet



	HOU PRECODE	HOU CODE	HOU CODE+	DAL PRECODE	DAL CODE	DAL CODE+
BEPS_TOTAL	94.3	80.7	76.6	101.5	89.2	85.3
DHW	20.4	20.4	20.4	21.5	21.5	21.5
VENT FANS	6.2	4.5	4.5	6.3	4.7	4.7
PUMPS & MISC	0.2	0.2	0.2	0.3	0.3	0.3
SPACE COOL	23.8	18.2	14	21.7	16.6	12.8
SPACE HEAT	17.3	11.1	11.1	25.4	19.7	19.7
MISC EQUIPMT	13.2	13.2	13.2	13.2	13.2	13.2
AREA LIGHTS	13.2	13.2	13.2	13.2	13.2	13.2

Figure 3: Annual Energy Consumption Comparison for an Air-Conditioned House Using Natural Gas for Space Heating in Houston and Dallas.



	HOU PRECODE	HOU CODE	HOU CODE+	DAL PRECODE	DAL CODE	DAL CODE+
BEPS_TOTAL	75.9	66.8	62.1	77.3	69.2	64.5
DHW	12.8	12.8	12.8	13.6	13.6	13.6
VENT FANS	6.4	4.7	4.7	6.6	4.9	4.9
PUMPS & MISC	0.2	0.2	0.2	0.3	0.3	0.3
SPACE COOL	23.8	18.2	14	21.7	16.6	12.8
SPACE HEAT	6.3	4.6	4.1	9	7.5	6.6
MISC EQUIPMT	13.2	13.2	13.2	13.2	13.2	13.2
AREA LIGHTS	13.2	13.2	13.2	13.2	13.2	13.2

Figure 4: Annual Energy Consumption Comparison for an Air-Conditioned House Using a Heat Pump for Space Heating in Houston and Dallas.

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