RECOMMENDATIONS FOR 15% ABOVE-CODE ENERGY EFFICIENCY MEASURES FOR SINGLE-FAMILY RESIDENCES

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ABSTRACT

This paper presents an overview of the recommendations for achieving 15% above-code energy performance for single-family residences. The analysis was performed using a simulation model of an International Energy Conservation Code (IECC)-compliant, single family residence in Houston, Texas. To accomplish the 15% annual energy use reductions, twelve measures were considered, which include: tankless water heater, solar domestic hot water system, gas water heater without the standing pilot light, ducts in the conditioned space, improved duct sealing, increased air tightness, window shading and redistribution, improved window performance, improved heating and cooling system efficiency. After the total annual energy use was determined for each measure, they were then grouped to accomplish a 15% total annual energy use reduction.

INTRODUCTION

In the U.S. residential sector, up to 50% of the energy use can be reduced using available technologies. Anderson et al. (2004) demonstrated 40-50% whole house energy savings in five locations in different climate zones across the United States. Malhotra and Haberl (2006) demonstrated up to 55% energy use reduction in hot and humid climates[1]. In order to realize energy savings of such order, certain procedure have to be developed for cost-effective implementation of energy-efficient technologies in new construction. This requires setting smaller goals towards improving building energy performance, and developing set of easy-to-follow and implement recommendations for achieving the targeted level of energy savings.

This paper presents an overview of the recommendations for achieving 15% above-code energy performance for single-family residences complying with the 2000 International Energy Conservation Code, as modified by the 2001 Supplement[2] (ICC 1999; 2001). The analysis was performed using a DOE-2 simulation model of a 2,325 sq. ft, one story, single family *standard* residential building in Houston, Texas[3]. To accomplish the 15% annual energy use reductions twelve measures for were considered, which include: tankless water heater, solar domestic hot water system, gas water heater without the standing pilot light, ducts in the conditioned space, improved duct sealing, increased air tightness, window shading and redistribution, improved window performance, improved heating and cooling system efficiency[4]. After the total annual energy use was determined for each measure, they were then grouped to accomplish a 15% total annual energy use reduction.

BASE-CASE BUILDING DESCRIPTION

The base-case building simulation model in this analysis is based on the *standard* design as defined in Chapter 4 of the 2001 IECC and certain assumptions. The base-case building is a 2,325 sq. ft., square-shape, one story, single-family, detached house oriented N, S, E, W, with floor-to-ceiling height of 8 ft. The house has an attic with a roof pitched at 23 degrees, which contains the HVAC systems and ductwork. The base-case building envelope and system characteristics were determined from the general characteristics and the climate-specific characteristics as specified in 2001 IECC. Details of the base-case model are summarized in Table A. 1.

Building Envelope Characteristics

The house was assumed to have light-weight wood frame construction with 2x4 studs spaced at

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[1] An extensive review of literature about these technologies is included in Malhotra (2005).

[2] In the remainder of this paper, this will be denoted as the 2001 IECC.

[3] The complete analysis by Malhotra et al. (2007) includes recommendations for 15% above-code energy performance for all 41 non-attainment and affected counties in Texas.

[4] Selection of measures for this analysis is, partly, limited to the simulation capabilities of the DOE-2.1e program.

16" on center, a slab-on-grade floor and an unconditioned, vented attic. The house has fascia brick exterior and asphalt shingle roofing. The window area is equal to 18% of the floor area[5] distributed equally on all four sides with no exterior shading[6]. Two 20 sq. ft. doors of 0.2 Btu/h-sq. ft.-°F U-value[7] were assumed on the north and south walls.

Based on the climate-specific characteristics for the standard design, the base-case was modeled with 0.085 Btu/h-sq. ft.-°F wall assembly U-factor, 0.47 Btu/h-sq. ft.-°F fenestration system U-factor, 0.40 fenestration system solar heat gain coefficient (SHGC), R-30 ceiling insulation and no slab perimeter insulation[8]. The air infiltration rate was 0.47 ACH, which is based on the weather factor specified in ASHRAE Standard 136 (ASHRAE 1993)[9].

The house was simulated as a single-zone building in delayed construction mode to take into account the thermal mass of the construction materials[10]. The fenestration characteristics were simulated by creating custom windows with double pane, low-e glazing and aluminum frames with thermal break, using the WINDOW5 program[11].

HVAC System Characteristics

The base-case HVAC system includes a central air-conditioning system and a heating system. Two options for the heating fuel type were considered: a) natural gas (gas-fired furnace for space heating, and gas water heater for domestic water heating), and b) electricity (heat pump for space heating, and electric water heater for domestic water heating)[12].For an electric/gas house, the base-case HVAC system comprises of a SEER 13 air-conditioner and a gas-fired, forced-air furnace of 0.78 Annual Fuel Utilization Efficiency (AFUE)[13]. For an all-electric house, the base-case HVAC system comprises of a SEER 13 air conditioner with a heat pump of 7.7 Heating Season Performance Factor (HSPF)[13]. For both types of houses, the capacity of the cooling system is 55,800 Btu/hr, which assumes 500 sq. ft. per ton. The capacity of the heating system is 72,540 Btu/hr, which assumes 1.3 x cooling capacity. The heating and cooling set-points were 68°F for winter and 78°F for summer, with a 5°F setback/setup (for winter and summer, respectively) for six hours early in the morning[14].

Air Distribution System Characteristics

The base-case air distribution system, which includes the HVAC unit and the ducts, is located in the unconditioned, vented attic. The attic was assumed to have an air infiltration rate of 15 ACH[15]. The insulation for supply and return ducts are R-8 and R-4, respectively[16]. A 10% duct leakage was assumed for the base-case house[17].

DHW System Characteristics

For an electric/gas house, the base-case domestic hot water (DHW) system is a 40-gallon[18], storage type, natural gas water heater with a standing pilot light that consumes 500 Btu/hr[19], with a calculated energy factor (EF) of the system of 0.54[20]. For an all-electric house, the base-case DHW system is a 50-gallon[18], storage type, electric water heater. The energy factor (EF) of the system is 0.86[20]. The daily hot water use was calculated as 70 gallons/day[21], which assumes that the house has four bedrooms. The hot water supply temperature is 120°F[21].

The method to simulate DHW in DOE-2.1e using the energy factor is based on Building America House Performance Analysis Procedures (NREL 2001) that assumes a constant hourly DHW use and eliminates the efficiency dependence on part-loads.

SUMMARY OF ENERGY EFFICIENCY MEASURES

Table 1 lists individual measures considered for electric/gas and all-electric single-family residences. These include measures for the DHW system, air distribution system, building envelop and fenestration, and HVAC system. One or more of these measures were applied to the base-case house

[5] This amounts to 418.5 sq. ft. window area and 27% window-to-wall area ratio for the base case building size and configuration.
[6] These requirements are specified in Section 402.1.1, p.63, and Section 402.1.3.1.1 and 402.1.3.1.3, p.64, of the 2001 IECC.
[7] This is specified in Section 402.1.3.4.3, p.64, of the 2001 IECC.
[8] These include Table 402.1.1(1) and Table 402.1.1 (2), p.63, Section 402.1.3.1.4, p.64, and Table 502.2.4(6), p.83.
[9] This requirement can be found in Section 402.1.3.10, p.65.
[10] This is accomplished using DOE-2 Custom Weighting Factors.
[11] More information on the Window 5 program can be found at http://windows.lbl.gov/software/window/window.html.
[12] In the remainder of this paper, these houses will be referred to as (a) electric/gas house, and (b) all-electric house, respectively.
[13] The efficiency of HVAC system is determined by NAECA 2006.
[14] As defined by Table 402.1.3.5, p.64, of the 2001 IECC.
[15] This infiltration rate was chosen to match measured data by Kim (2006).
[16] This requirement can be found in Table 503.3.3.3 (ICC 2001)
[17] This is based on the information found in Parker et al. (1993).
[18] The size of the DHW tank are adopted from HUD-FHA minimum water heater capacities for a four bedroom 2.5 bath single family living unit (Table 4, p.49.9, ASHRAE 2003)
[19] This value is consistent with information provided by DHW manufacturers.
[20] The EF of the DHW system was calculated from the minimum performance requirement using Table 504.2, p.91.
[21] This is specified in Section 402.1.3.7, p.65 of the 2001 IECC.

in different combinations for achieving a goal of 15% above-code energy performance. The description of these measures is provided in the following section.

Table 1. Energy Efficiency Measures

NATURAL GAS HEATING/ NATURAL GAS DHW SYSTEM	HEAT PUMP/ELECTRIC DHW SYSTEM
A. Domestic Hot Water System Measures	
1. Tankless Gas Water Heater	1. Tankless Electric Water Heater
2. Solar DHW System	2. Solar DHW System
3. Removal of Pilot Light	
B. Air Distribution System Measures	
4. HVAC Unit and Ducts in Cond. Space	4. HVAC Unit and Ducts in Cond. Space
5. Improved Duct Sealing	5. Improved Duct Sealing
C. Envelope and Fenestration Measures	
6. Increased Air-tightness	6. Increased Air-tightness
7. Window Shading (4' Overhang)	7. Window Shading (4' Overhang)
8. Window Shading & Redistribution	8. Window Shading & Redistribution
9. Improved Window Performance	9. Improved Window Performance
D. HVAC System Measures	
10. AC Eff.: SEER 13 to SEER 15	12. SEER 15 AC/8.5 HSPF Heat Pump
11. Furnace Eff.: 0.78 AFUE to 0.93 AFUE	

1) Use of a Tankless Water Heater

For an electric/gas house, this measure was simulated by eliminating the standing pilot light, with a resultant change in the DHW Energy Factor (EF) from 0.54 to 0.85[22]. For an all-electric house, this measure was simulated by increasing the DHW energy factor from 0.86 to 0.95[22].

2) Addition of a Solar DHW System

For this measure, a solar thermal DHW system, comprising of two 32 sq. ft. of flat plate solar collectors, was simulated using the F-Chart program (Klein and Beckman 1983). In this analysis, the collector tilt was assumed to be the same as the latitude for that location, considering a hot water use of 70 gallons/day, year around. Table 2 lists the characteristics of the solar thermal system for Houston. In this analysis, any supplementary hot water heating was provided by the base-case water heating system. Also, additional electricity use was taken into account for operating the pump.

Table 2. Solar DHW System Characteristics

Number of collector panels	2
Collector panel area	32 sq. ft.
Collector slope	30 deg.
Collector azimuth (South=0)	0 deg.
Number of glazing	1
Collector flow rate/area	11 lb/hr-sq. ft.
Water set temperature	120 deg. F
Daily hot water usage	70 gal.

3) Removal of Standing Pilot Light from Gas Domestic Water Heater

This measure is applicable only for the electric/gas house that has a gas DHW heater with a standing pilot light. This analysis assumed the same DHW Energy Factor as the base-case house, with the removal of calculated hourly energy use equivalent to an average pilot light (i.e. 500 Btu/h[19]).

4) Ducts in the Conditioned Space

This measure analyzed the energy savings that would occur if the ductwork and HVAC system was moved from the attic location assumed in the base-case house to a location within the thermal envelope of the conditioned space.

5) Improved Duct Sealing

This measure was simulated by changing the 10% duct leakage of the base-case house to a 5% duct leakage. In this analysis it was assumed that the ducts remained in the attic and that the improved duct sealing was accomplished with foil-backed butyl tape and mastic to seal the duct leaks.

6) Increased Air-tightness

This measure was simulated by specifying a fixed infiltration rate of 0.35 ACH (compared to 0.47 ACH for the base case), which is the minimum ventilation rate required by ASHRAE Standard 62 (ASHRAE 2001).

7) Addition of Window Shading.

This measure was simulated by modeling 4 ft. roof overhangs on all four sides. The gross window area, orientation, and other characteristics were kept the same as the base-case house, which did not have overhangs. The depth of overhangs was determined from the recommendations by Malhotra and Haberl (2006). However, the overhang depth on *all* sides is not optimized for construction cost.

8) Window Shading and Redistribution.

For this measure, the house was simulated with the same window area as the base-case house (i.e., an 18% window-to-wall area distributed 25% on each orientation) with the windows distributed 45% on the south, 25% on the north, 15% each on east and west orientations. A 4 ft. roof overhang was also included on all four sides.

9) Improved Window Performance.

For this measure, the base-case house was simulated with custom windows that were argon-filled, double-pane, low-e glazing with a 0.42 Btu/h-sq. ft.-°F fenestration system U-factor, and a 0.33 SHGC. The frame type remained the same as the base-case house.

[22] The EF for the tankless water heater is based on a survey of manufacturers.

Table 3. Simulation Input for an Electric/Gas House

EEM #	Energy Efficiency Measure	DHW System Energy Factor	DHW System Type		DHW Pilot Light	Duct Location (Uncond. Vented Attic/ Cond. Room)	Duct Leakage (%)	Infiltration Rate (ACH/hr)	Exterior Shading (ft.)	Window Distribution (S:N:E:W)	Window U-Factor (Btu/hr-ft2-°F)	Glazing SHGC	AC Eff. (SEER)	Furnace Eff. (AFUE)
	Basecase	0.54	Tanktype	Gas	Yes	Vented Attic	10%	0.462	None	Equal	0.47	0.4	13	0.78
Domestic Hot Water System Measures														
1	Tankless Gas Water Heater	0.85	Tankless	Gas	No	Vented Attic	10%	0.462	None	Equal	0.47	0.4	13	0.78
2	Solar DHW System	0.54 (Aux.)	Tanktype (Aux.)	Solar	Yes (Aux.)	Vented Attic	10%	0.462	None	Equal	0.47	0.4	13	0.78
3	Removal of Pilot Light	0.54	Tanktype	Gas	No	Vented Attic	10%	0.462	None	Equal	0.47	0.4	13	0.78
Air Distribution System Measures														
4	HVAC Unit and Ducts in Cond. Space	0.54	Tanktype	Gas	Yes	Room	None	0.462	None	Equal	0.47	0.4	13	0.78
5	Improved Duct Sealing	0.54	Tanktype	Gas	Yes	Vented Attic	5%	0.462	None	Equal	0.47	0.4	13	0.78
Envelope and Fenestration Measures														
6	Increased Air-tightness	0.54	Tanktype	Gas	Yes	Vented Attic	10%	0.35	None	Equal	0.47	0.4	13	0.78
7	Window Shading (4' Overhang)	0.54	Tanktype	Gas	Yes	Vented Attic	10%	0.462	4' Eaves	Equal	0.47	0.4	13	0.78
8	Window Shading & Redistribution	0.54	Tanktype	Gas	Yes	Vented Attic	10%	0.462	4' Eaves	45:25:15:15	0.47	0.4	13	0.78
9	Improved Window Performance	0.54	Tanktype	Gas	Yes	Vented Attic	10%	0.462	None	Equal	0.42	0.33	13	0.78
HVAC System Measures														
10	AC Eff.: SEER 13 to SEER 15	0.54	Tanktype	Gas	Yes	Vented Attic	10%	0.462	None	Equal	0.47	0.4	15	0.78
11	Furnace Eff.: 0.78 AFUE to 0.93 AFUE	0.54	Tanktype	Gas	Yes	Vented Attic	10%	0.462	None	Equal	0.47	0.4	13	0.93

Table 4. Simulation Input for an All-electric House

EEM #	Energy Efficiency Measure	DHW System Energy Factor	DHW System Type		DHW Pilot Light	Duct Location (Uncond. Vented Attic/ Cond. Room)	Duct Leakage (%)	Infiltration Rate (ACH/hr)	Exterior Shading (ft.)	Window Distribution (S:N:E:W)	Window U-Factor (Btu/hr-ft2-°F)	Glazing SHGC	AC Eff. (SEER)	Heat Pump Eff. (HSPF)
	Basecase	0.86	Tanktype	Elec.	No	Vented Attic	10%	0.462	None	Equal	0.47	0.4	13	7.7
Domestic Hot Water System Measures														
1	Tankless Electric Water Heater	0.95	Tankless	Elec.	No	Vented Attic	10%	0.462	None	Equal	0.47	0.4	13	7.7
2	Solar DHW System	0.86 (Aux.)	Tanktype (Aux.)	Solar	No (Aux.)	Vented Attic	10%	0.462	None	Equal	0.47	0.4	13	7.7
Air Distribution System Measures														
4	HVAC Unit and Ducts in Cond. Space	0.86	Tanktype	Elec.	No	Room	None	0.462	None	Equal	0.47	0.4	13	7.7
5	Improved Duct Sealing	0.86	Tanktype	Elec.	No	Vented Attic	5%	0.462	None	Equal	0.47	0.4	13	7.7
Envelope and Fenestration Measures														
6	Increased Air-tightness	0.86	Tanktype	Elec.	No	Vented Attic	10%	0.35	None	Equal	0.47	0.4	13	7.7
7	Window Shading (4' Overhang)	0.86	Tanktype	Elec.	No	Vented Attic	10%	0.462	4' Eaves	Equal	0.47	0.4	13	7.7
8	Window Shading & Redistribution	0.86	Tanktype	Elec.	No	Vented Attic	10%	0.462	4' Eaves	45:25:15:15	0.47	0.4	13	7.7
9	Improved Window Performance	0.86	Tanktype	Elec.	No	Vented Attic	10%	0.462	None	Equal	0.42	0.33	13	7.7
HVAC System Measures														
12	SEER 15 AC/8.5 HSPF Heat Pump	0.86	Tanktype	Elec.	No	Vented Attic	10%	0.462	None	Equal	0.47	0.4	15	8.5

10) <u>Improved Air Conditioner Efficiency.</u>

For this analysis, the SEER 13 air conditioner in the electric/gas base-case house was replaced with a similarly sized SEER 15 air conditioner.

11) <u>Improved Furnace Efficiency.</u>

For this analysis, the gas-fired furnace in the electric/gas base-case house (0.78 AFUE) was replaced with a similarly sized furnace with an AFUE of 0.93.

12) <u>Improved Efficiency of the Heat Pump.</u>

For an all-electric house, the base-case heat pump with an HSPF of 7.7 was replaced with a similarly-sized heat pump with an HSPF of 8.5.

<u>SIMULATION INPUT</u>

The twelve measures described above were simulated by modifying the selected parameters used for the DOE-2 simulation model of the base-case house. Table 3 and Table 4 list the values for simulating these measures in a house located in Houston (Harris county, Texas), with (a) natural gas heating/natural gas DHW system, and (b) heat pump heating/electric DHW system, respectively. The first row of values in both tables presents information used in the base-case runs. The remaining rows present information used in the simulation of the individual energy efficiency measures. The shaded cell in each row indicates the change in the value used to simulate the measure.

Table 5. Summary of Results for an Electric/Gas House

EEM #	Energy Efficient Measures	Energy Use (MBtu/yr)					Energy Use (Utility Units)			Energy Savings					Increased Marginal Cost ($)	Increased New System Cost ($)	Payback (yrs)
		Cooling	Heating	DHW	Other	Total	kWh/yr	therms/yr	$/yr	MBtu/yr	%	kWh/yr	therms/yr	$/yr			
	Basecase	15.9	9.4	24.8	29.0	78.9	13,115	341	$2,308								
	(% of Total)	20.2%	11.9%	31.4%	36.8%												
DHW System Measures																	
1	Tankless Gas Water Heater	15.9	9.4	17.4	29.0	71.6	13,115	268	$2,235	7.3	9.3%	0	73	$73	$1,000 - $3,500		13.7 - 47.9
2	Solar DHW System	15.9	9.4	12.6	29.0	66.9	13,523	206	$2,235	12.0	15.2%	-408	135	$74		$2,900 - $5,200	39.3 - 70.5
3	Removal of Pilot Light	15.9	9.4	20.4	29.0	74.5	13,115	298	$2,265	4.3	5.5%	0	43	$43	$200 - $600		4.7 - 14.0
Air Distribution System Measures Measures																	
4	HVAC Unit and Ducts in Cond. Space	11.3	7.2	24.8	29.0	72.2	11,785	320	$2,088	6.7	8.5%	1,330	21	$221	$1,000 - $7,000		4.5 - 31.7
5	Improved Duct Sealing	13.5	8.4	24.8	29.0	75.5	12,403	331	$2,191	3.4	4.3%	712	10	$117		$450 - $650	3.9 - 5.6
Envelope and Fenestration Measures																	
6	Increased Air-tightness	15.4	8.3	24.8	28.9	77.2	12,956	330	$2,273	1.7	2.1%	159	11	$35		$350 - $1,500	10.0 - 43.0
7	Window Shading (4' Overhang)	13.0	11.0	24.8	28.6	77.2	12,150	358	$2,181	1.7	2.1%	965	-17	$128		$3,100 - $3,500	24.3 - 27.4
8	Window Shading & Redistribution	12.7	10.2	24.8	28.5	76.0	12,047	349	$2,156	2.8	3.6%	1,068	-8	$152		$3,100 - $3,500	20.4 - 23.0
9	Improved Window Performance	13.9	9.5	24.8	28.7	76.8	12,458	343	$2,212	2.1	2.6%	657	-2	$97	$800 - $1,100		8.3 - 11.4
HVAC System Measures																	
10	AC Eff.: SEER 13 to SEER 15	13.8	9.4	24.8	29.0	76.8	12,495	341	$2,215	2.1	2.7%	620	0	$93	$900 - $2,500		9.7 - 26.9
11	Furnace Eff.: 0.78 AFUE to 0.93 AFUE	15.9	7.8	24.8	29.0	77.4	13,115	326	$2,293	1.5	1.9%	0	15	$15	$600 - $1,500		40.0 - 100.0

Table 6. Summary of Results for an All-electric House

EEM #	Energy Efficient Measures	Energy Use (MBtu/yr)					Energy Use (Utility Units)			Energy Savings					Increased Marginal Cost ($)	Increased New System Cost ($)	Payback (yrs)
		Cooling	Heating	DHW	Other	Total	kWh/yr	therms/yr	$/yr	MBtu/yr	%	kWh/yr	therms/yr	$/yr			
	Basecase	15.9	6.3	12.6	29.0	63.7	18,653	0	$2,798								
	(% of Total)	25.0%	9.9%	19.8%	45.6%												
DHW System Measures																	
1	Tankless Electric Water Heater	15.9	6.3	11.7	29.0	62.7	18,370	0	$2,756	1.0	1.5%	283	0	$42	$700 - $1,400		16.5 - 33.0
2	Solar DHW System	15.9	6.3	5.7	29.0	56.7	16,624	0	$2,494	6.9	10.9%	2,029	0	$304		$2,900 - $5,200	9.5 - 17.1
Air Distribution System Measures Measures																	
4	HVAC Unit and Ducts in Cond. Space	11.3	5.3	12.6	29.0	58.2	17,038	0	$2,556	5.5	8.7%	1,615	0	$242	$1,000 - $7,000		4.1 - 28.9
5	Improved Duct Sealing	13.5	5.6	12.6	29.0	60.6	17,762	0	$2,664	3.0	4.8%	891	0	$134		$450 - $650	3.4 - 4.9
Envelope and Fenestration Measures																	
6	Increased Air-tightness	15.4	5.7	12.6	28.9	62.5	18,321	0	$2,748	1.1	1.8%	332	0	$50		$350 - $1,500	7.0 - 30.1
7	Window Shading (4' Overhang)	13.0	7.2	12.6	28.6	61.3	17,965	0	$2,695	2.3	3.7%	688	0	$103		$3,100 - $3,500	30.0 - 33.9
8	Window Shading & Redistribution	12.7	6.7	12.6	28.5	60.5	17,714	0	$2,657	3.2	5.0%	939	0	$141		$3,100 - $3,500	22.0 - 24.8
9	Improved Window Performance	13.9	6.4	12.6	28.7	61.6	18,042	0	$2,706	2.1	3.3%	611	0	$92	$800 - $1,100		8.7 - 12.0
HVAC System Measures																	
12	SEER 15 AC/8.5 HSPF Heat Pump	13.8	5.8	12.6	29.0	61.1	17,895	0	$2,684	2.6	4.1%	758	0	$114	$1,500 - $2,400		13.2 - 21.1

The simulations used TMY2 hourly weather data for Houston Intercontinental Airport. The cost analysis was based on utility costs of $0.15/kWh for electricity and $1.00/therm for natural gas.

RESULTS

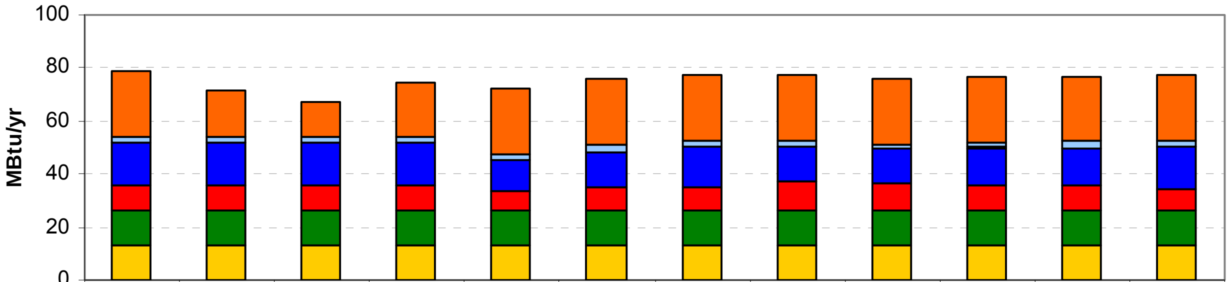
Table 5 and Table 6 summarize the results of simulation and cost analysis for (a) an electric/gas house, and (b) an all-electric house, respectively, and include: the annual energy use[23], calculated energy savings, increased cost of implementation and the calculated payback period for the each measure. These results are graphically represented in Figure 1 through Figure 8. Figure 1 and Figure 2 show the impact of energy efficiency measures (EEMs) on different energy end-uses; Figure 3 and Figure 4 show the first costs and energy cost savings for different measures; Figure 5 and Figure 6 show the corresponding payback period in years, for (a) an electric/gas house, and (b) an all-electric house, respectively.

Base Case Energy Use

Table 5 shows that the base case total annual energy consumption was 78.9 MBtu for an electric/gas house. This includes: 20.2% for cooling, 11.9% for heating, 31.4% for domestic water heating and 36.8% for other end-uses (that includes 33.5% for lighting and equipment, and 3.3% for heating and cooling fans, pump and miscellaneous). Table 6 shows that for an all-electric house, the base case total energy consumption was 63.7 MBtu that includes: 25.0% for cooling, 9.9% for heating, 19.8% for domestic water heating and 45.6% for other end-uses (that includes 41.5% for lighting and equipment, and 4.1% for heating and cooling fans, pump and miscellaneous).

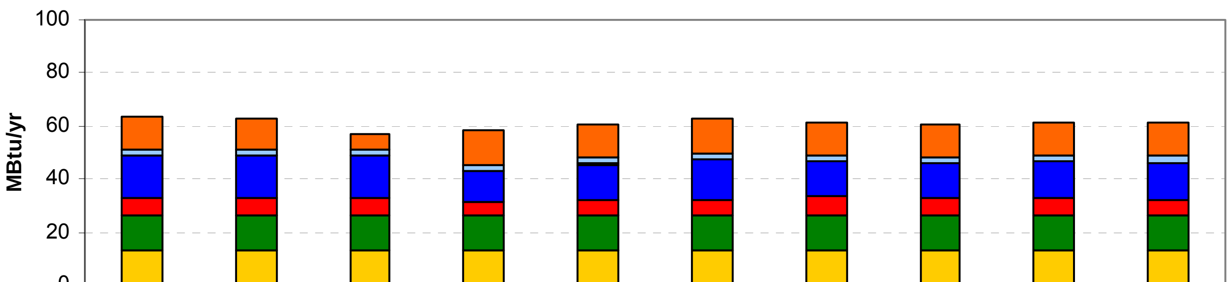
This is noted that due to the lower fuel efficiency of gas, space heating and domestic water heating energy use were larger fraction of the total, and cooling energy use was smaller fraction of the total in an electric/gas house compared to an all-electric house. This suggested that measures that reduce space heating and domestic water heating use would have large impact on the total energy use in an electric/gas house, and the measures that reduce the cooling energy use would have higher impact on the total energy use in an all-electric house.

[23] These values were obtained from BEPS and BEPU reports in the DOE-2 output.



	Basecase	Tankless Gas Water Heater	Solar DHW System	Removal of Pilot Light	HVAC Unit and Ducts in Cond.	Improved Duct Sealing	Increased Air-tightness	Window Shading (4' Overhang)	Window Shading & Redistributi	Improved Window Performance	AC Eff.: SEER 13 to SEER 15	Furnace Eff.: 0.78 AFUE to 0.93
Total	78.9	71.6	66.9	74.5	72.2	75.5	77.2	77.2	76.0	76.8	76.8	77.4
DHW	24.8	17.4	12.6	20.4	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8
Fans	2.4	2.4	2.4	2.4	2.4	2.4	2.3	2	1.9	2.1	2.4	2.4
Misc.	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Cooling	15.9	15.9	15.9	15.9	11.3	13.5	15.4	13	12.7	13.9	13.8	15.9
Heating	9.4	9.4	9.4	9.4	7.2	8.4	8.3	11.0	10.2	9.5	9.4	7.8
Equip.	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2
Lighting	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2

Figure 1. Energy Use for Various EEMs for an Electric/Gas House



	Basecase	Tankless Electric Water Heater	Solar DHW System	HVAC Unit and Ducts in Cond. Space	Improved Duct Sealing	Increased Air-tightness	Window Shading (4' Overhang)	Window Shading & Redistribution	Improved Window Performance	SEER 15 AC/8.5 HSPF Heat Pump
Total	63.7	62.7	56.7	58.2	60.6	62.5	61.3	60.5	61.6	61.1
DHW	12.6	11.7	5.7	12.6	12.6	12.6	12.6	12.6	12.6	12.6
Fans	2.4	2.4	2.4	2.4	2.4	2.3	2	1.9	2.1	2.4
Misc.	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Cooling	15.9	15.9	15.9	11.3	13.5	15.4	13	12.7	13.9	13.8
Heating	6.3	6.3	6.3	5.3	5.6	5.7	7.2	6.7	6.4	5.8
Equip.	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2
Lighting	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2

Figure 2. Energy Use for Various EEMs for an All-electric House

Energy Savings form Various EEMs

Table 5 and Table 6 show that for both types of houses, the solar DHW system had the largest annual total energy savings of 15.2% in an electric/gas house, and 10.9% in an all-electric house. Tankless water heater resulted in large total energy savings of 9.3%, only in electric/gas house. These savings include 5.5% savings due to elimination of the standing pilot light and the remainder due to significant increase in the EF from the base case (i.e. from 0.54 to 0.85).

Locating the HVAC unit and ducts in the conditioned space also resulted in large savings of 8.5% in an electric/gas house, and 8.7% in an all-electric house. Improved duct sealing resulted in 4.3% savings in an electric/gas house, and 4.8% in an all-electric house.

Among the envelope measures, increased air-tightness resulted in small total energy savings of 2.1% in an electric/gas house, and 1.8% in an all-electric house. Contrary to the last paragraph in the previous section, fenestration measures were found more effective in an all-electric house than in an electric/gas house. This is because the cooling energy savings from these measures were offset by the heating energy penalty, and the heating energy penalty was more pronounced in the electric/gas house due to lower heating fuel efficiency.

Addition of overhangs was more effective with more windows on the south and least on the east and west. With the window redistribution, the total energy savings were 3.6% in an electric/gas house, and 5.0% in an all-electric house. Improved windows resulted in total energy savings of only 2.6% in an electric/gas house, and 3.3% in an all-electric house.

The equal cooling energy use reduction due to SEER 13 air conditioner was more pronounced in an all-electric house (2.7% in an electric/gas house, and 3.3% in an all-electric house). The savings from 0.93 AFUE furnace was only 1.9% in an electric/gas house and less than 1% in an all-electric house due to 7.7 HSPF heat pump. However, the combined effect of heating and cooling system improvement was comparable (approx. 4 to 4.5%) in both types of houses.

Cost Effectiveness of Various EEMs

This is to be noted that due to the difference in the unit cost of electricity and gas, the energy cost savings for a measure are not always of the same order as the energy savings, and depend on the fuel type associated with the end use affected from that measure. Measures that reduce electricity use for space cooling (in both types of house), heating (in all-electric house) result in large energy cost saving compared to the measures that reduce only gas use.

For example, Figure 3 and Figure 4 show that DHW system measures, which resulted in the large energy savings in an electric/gas house, had small energy cost savings. Even, the solar DHW system that resulted in highest energy use reduction was not very effective in reducing the energy cost. This is because the cost savings from large reduction in gas use was offset by the increased cost of electricity use for operating the pump.

Although, solar DHW system, moving the HVAC unit and ductwork to the conditioned space, and window shading and redistribution had high first cost (ranging from $2,900 to $5,200; $1,000 to $7,000; and $3,100 to $3,500; respectively), they resulted in the largest electricity savings in an all-electric house, and therefore, were the most effective in reducing the energy cost in an all-electric house. For an electric/gas house, moving the HVAC unit and ductwork to the conditioned space, and window shading and redistribution showed significant reduction in cooling electricity use, and therefore, were very effective in reducing the overall energy cost in an electric/gas house, too.

Further, cost-effectiveness of a measure depends on the energy cost savings vs. the cost of implementation. Simple payback for each measure was calculated for both types of houses. Figure 5 and Figure 6 show that most of the common measures had nearly equal payback period for both type of houses, except for the solar DHW system and increased air tightness that showed longer payback period for an electric/gas house. The shortest payback periods were for the improved duct sealing (3 to 6 years) and improved window performance (8 to 12 years). Using a gas water heater without a standing pilot light was a cost-effective measure for an electric/gas house with a payback period of 4.7 to 14 years. On the other hand, solar DHW system with a payback period of 9.5 to 17 years was a cost-effective measure for an all-electric house.

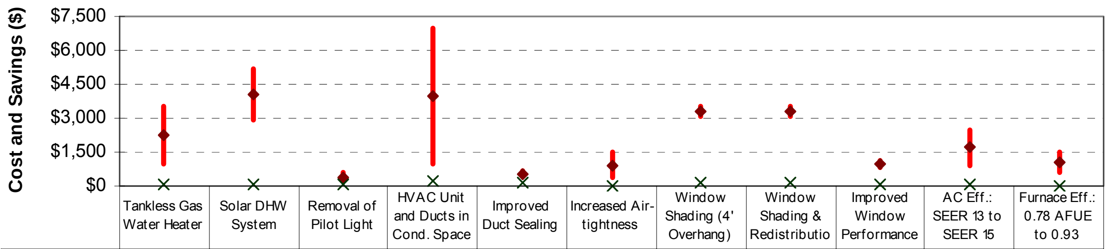
In summary, the most cost-effective measures include: moving HVAC unit and the ductwork to conditioned space which resulted in 8-9% energy savings, 9-11% energy cost savings, and a payback period ranged from 4-32 years for both type of houses. Improved duct sealing resulted in 4-5% energy savings and was the most cost-effective with 3-6 years payback period.

15% Above-Code Energy Savings

The results from individual measures were used to guide the selection of measures that could result in 15% above-code combined total energy savings. Another set of simulations was performed with the selected measures applied in combination, and the energy cost savings were calculated. Using the estimated first cost for the selected measures, the payback period for the combined application of measures was calculated. These steps were followed for different groups of measures that could result in 15% or more total energy savings above the 2001 IECC compliant base case house with electric/gas systems and all-electric systems.

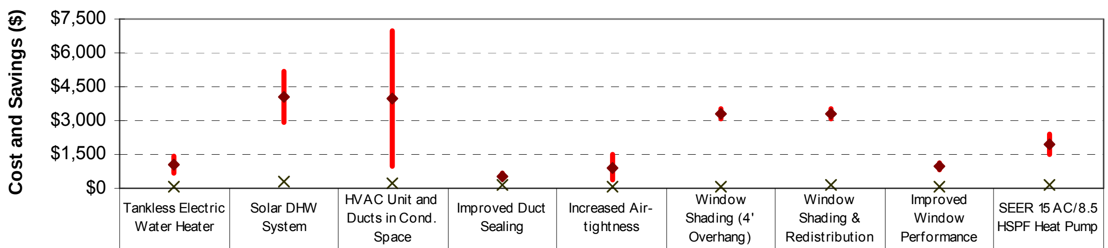
Figure 7 and Figure 8 present the 15% above-code savings charts[24] for an electric/gas house and an all-electric house, respectively in Houston, Texas. In each figure, the first table summarizes the results obtained from individual measures in terms of annual energy savings and the estimated costs for each measure implemented individually. The second table summarizes the results obtained by implementing three combinations of measures to achieve 15% or more total energy savings, and includes: energy savings, energy cost savings, estimated cost and payback period for each combination. Information regarding the ozone emissions for each of the combinations is also presented in terms of combined annual NOx emission savings and combined ozone season period NOx emission savings.

[24] Based on the code-specified base case house characteristics and the weather data for Houston, Texas, these charts are applicable to Brazoria, Fort Bend, Galveston, Harris, Montgomery and Waller counties. Malhotra et al. (2007) includes similar charts for other non-attainment and affected counties in Texas.



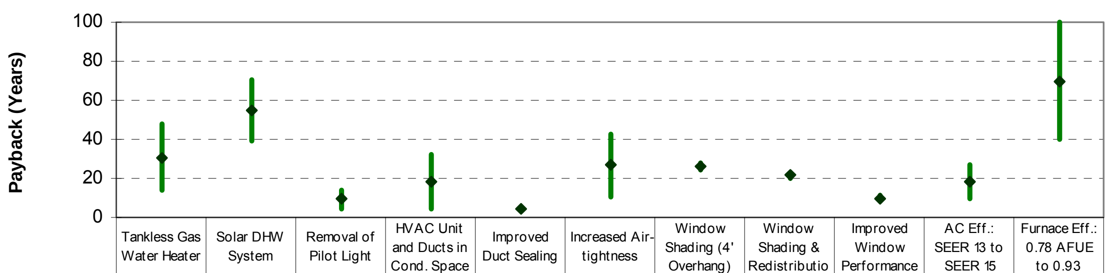
	Tankless Gas Water Heater	Solar DHW System	Removal of Pilot Light	HVAC Unit and Ducts in Cond. Space	Improved Duct Sealing	Increased Air-tightness	Window Shading (4' Overhang)	Window Shading & Redistributio	Improved Window Performance	AC Eff.: SEER 13 to SEER 15	Furnace Eff.: 0.78 AFUE to 0.93
Minimum Cost	$1,000	$2,900	$200	$1,000	$450	$350	$3,100	$3,100	$800	$900	$600
Maximum Cost	$3,500	$5,200	$600	$7,000	$650	$1,500	$3,500	$3,500	$1,100	$2,500	$1,500
◆ Average Cost	$2,250	$4,050	$400	$4,000	$550	$925	$3,300	$3,300	$950	$1,700	$1,050
× Energy Savings	$73	$74	$43	$221	$117	$35	$128	$152	$97	$93	$15

Figure 3. First Costs and Energy Cost Savings for Various EEMs for an Electric/Gas House



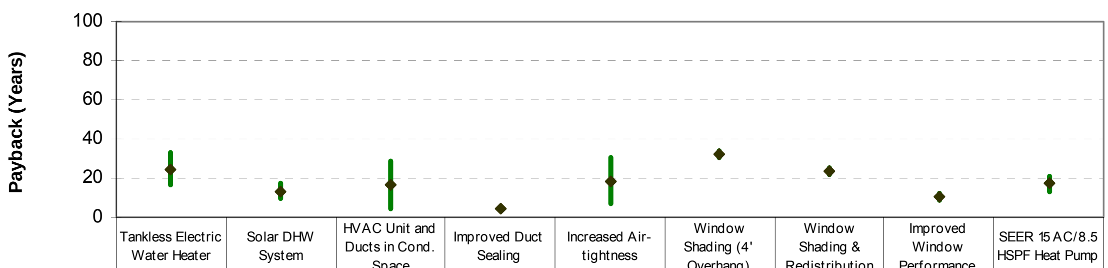
	Tankless Electric Water Heater	Solar DHW System	HVAC Unit and Ducts in Cond. Space	Improved Duct Sealing	Increased Air-tightness	Window Shading (4' Overhang)	Window Shading & Redistribution	Improved Window Performance	SEER 15 AC/8.5 HSPF Heat Pump
Minimum Cost	$700	$2,900	$1,000	$450	$350	$3,100	$3,100	$800	$1,500
Maximum Cost	$1,400	$5,200	$7,000	$650	$1,500	$3,500	$3,500	$1,100	$2,400
◆ Average Cost	$1,050	$4,050	$4,000	$550	$925	$3,300	$3,300	$950	$1,950
× Energy Savings	$42	$304	$242	$134	$50	$103	$141	$92	$114

Figure 4. First Costs and Energy Cost Savings for Various EEMs for an All-electric House



	Tankless Gas Water Heater	Solar DHW System	Removal of Pilot Light	HVAC Unit and Ducts in Cond. Space	Improved Duct Sealing	Increased Air-tightness	Window Shading (4' Overhang)	Window Shading & Redistributio	Improved Window Performance	AC Eff.: SEER 13 to SEER 15	Furnace Eff.: 0.78 AFUE to 0.93
Minimum	13.7	39.3	4.7	4.5	3.9	10.0	24.3	20.4	8.3	9.7	40.0
Maximum	47.9	70.5	14.0	31.7	5.6	43.0	27.4	23.0	11.4	26.9	100.0
◆ Average	31	55	9	18	5	27	26	22	10	18	70

Figure 5. Payback Period for Various EEMs in an Electric/Gas House



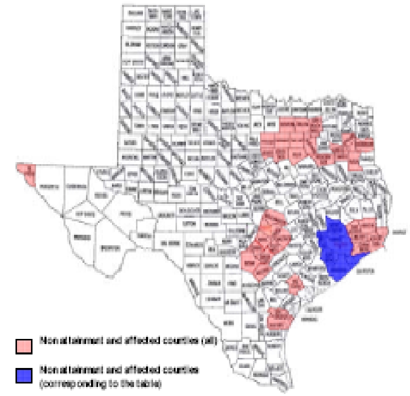
	Tankless Electric Water Heater	Solar DHW System	HVAC Unit and Ducts in Cond. Space	Improved Duct Sealing	Increased Air-tightness	Window Shading (4' Overhang)	Window Shading & Redistribution	Improved Window Performance	SEER 15 AC/8.5 HSPF Heat Pump
Minimum	16.5	9.5	4.1	3.4	7.0	30.0	22.0	8.7	13.2
Maximum	33.0	17.1	28.9	4.9	30.1	33.9	24.8	12.0	21.1
◆ Average	25	13	17	4	19	32	23	10	17

Figure 6. Payback Period for Various EEMs for an All-electric House

Natural Gas Heating (Brazoria, Fort Bend, Galveston, Harris, Montgomery and Waller Counties)

Description of Individual Measures

	Individual Measures	Annual Energy Savings (%)	Annual Energy Savings ($/year)[4]	Estimated Cost ($)	
				Marginal Cost[1]	New System Cost[2]
A	Domestic Hot Water Measures				
1	Tankless Gas Water Heater (without a Standing Pilot Light)	9.3%	$73	$1,000 - $3,500	
2	Solar Domestic Hot Water System	15.2%	$74		$2,900 - $5,200
3	Removal of Pilot Light from Domestic Hot Water System	5.5%	$43	$200 - $600	
B	Air Distribution System Measures				
4	Relocate HVAC Unit including Supply and Return Ducts in Conditioned Space	8.5%	$221	$1,000 - $7,000	
5	Improved Duct Sealing (10% to 5% Duct Leakage)	4.3%	$117		$450 - $650
C	Envelope and Fenestration Measures				
6	Reduced Air Infiltration (0.46 to 0.35 Air-changes/hr)	2.1%	$35		$350 - $1,500
7	Window Shading (None to 4 ft. Eaves on All Sides)	2.1%	$128		$3,100 - $3,500
8	Window Shading and Redistribution (Equal Windows on All Four Sides with No Shading to 45% Windows on the South with 4ft. Eaves on All Four Sides)	3.6%	$152		$3,100 - $3,500
9	Improved Windows (U-factor: 0.47 to 0.42 Btu/h-sf-F, SHGC: 0.4 to 0.33)	2.6%	$97	$800 - $1,100	
D	HVAC System Measures				
10	Air Conditioner (SEER 13 to SEER 15)	2.7%	$93	$900 - $2,500	
11	Furnace (0.78 AFUE to 0.93 AFUE)	1.9%	$15	$600 - $1,500	



Description of Combined Measures to Achieve 15% Above Code Savings

	Combination of Measures[3]	Combined Energy Savings (%)	Combined Energy Savings ($/year)	Combined Estimated Cost ($)		Combined Annual NO_x Emissions Savings (lbs/year)	Combined Ozone Season Period NO_x Emissions Savings (lbs/day)	Simple Estimated Payback (yrs)
				Marginal Cost[1]	New System Cost[2]			
	Combination 1							
1	Tankless Gas Water Heater (without a Standing Pilot Light)	17.6%	$295	$1,000 - $3,500		2.39	0.018	6.8 - 35.7
4	Relocate HVAC Unit including Supply and Return Ducts in Conditioned Space			$1,000 - $7,000				
	Combination 2							
2	Solar Domestic Hot Water System				$2,900 - $5,200			
5	Improved Duct Sealing (10% to 5% Duct Leakage)	21.8%	$269		$450 - $650	1.50	0.011	15.8 - 31.0
10	Air Conditioner (SEER 13 to SEER 15)			$900 - $2,500				
	Combination 3							
3	Removal of Pilot Light from Domestic Hot Water System			$200 - $600				
4	Relocate HVAC Unit including Supply and Return Ducts in Conditioned Space	16.6%	$383	$1,000 - $7,000		2.99	0.025	11.2 - 29.0
8	Window Shading and Redistribution (Equal Windows on All Four Sides with No Shading to 45% Windows on the South with 4ft. Eaves on All Four Sides)				$3,100 - $3,500			

Note:
1. Marginal cost = new system cost - original system cost
2. New system cost = new system cost only
3. See individual measures above for specific savings
   * Energy Cost: Electricity cost = $0.15/kWh
   Natural gas cost = $1.00/therm
4. Savings depend on fuel mix used. See detailed writeup

(Building Description)
* Building type: Residential
* Gross area: 2,323 sq-ft.
* Building dimension: 48.2ft x 48.2ft x 8ft (WxLxH)
* Number of floors: 1
* Floor-to-floor height: 8ft
* Window-to-wall ratio: 18%

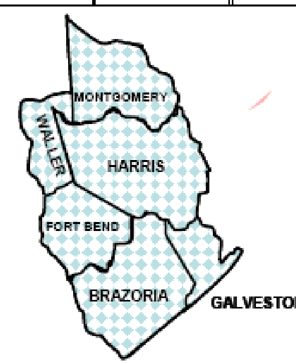


Table 5a: 15% Above Code Savings (Residential – Natural Gas Heating) for Brazoria, Fort Bend, Galveston, Harris, Montgomery and Waller Counties

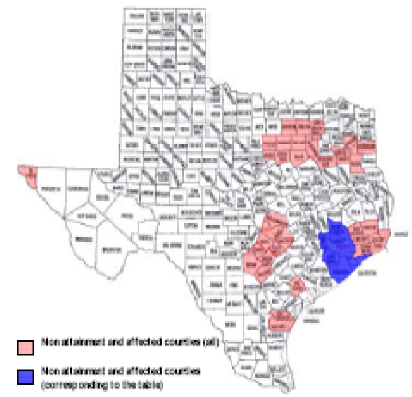
Energy Systems Laboratory - August 2007

Figure 7. Summary of Individual and Combined Measures for a Natural Gas House in Houston

Electric Heating (Brazoria, Fort Bend, Galveston, Harris, Montgomery and Waller Counties)

Description of Individual Measures

	Individual Measures	Annual Energy Savings (%)	Annual Energy Savings ($/year)	Estimated Cost ($): Marginal Cost[1]	Estimated Cost ($): New System Cost[2]
A	Domestic Hot Water Measures				
1	Tankless Electric Water Heater	1.5%	$42	$700 - $1,400	
2	Solar Domestic Hot Water System	10.9%	$304		$2,900 - $5,200
B	Air Distribution System Measures				
4	Relocate HVAC Unit including Supply and Return Ducts in Conditioned Space	8.7%	$242	$1,000 - $7,000	
5	Improved Duct Sealing (10% to 5% Duct Leakage)	4.8%	$134		$450 - $650
C	Envelope and Fenestration Measures				
6	Reduced Air Infiltration (0.46 to 0.35 Air-changes/hr)	1.8%	$50		$350 - $1,500
7	Window Shading (None to 4 ft. Eaves on All Sides)	3.7%	$103		$3,100 - $3,500
8	Window Shading and Redistribution (Equal Windows on All Four Sides with No Shading to 45% Windows on the South with 4ft. Eaves on All Four Sides)	5.0%	$141		$3,100 - $3,500
9	Improved Windows (U-factor: 0.47 to 0.42 Btu/h-sf-F, SHGC: 0.4 to 0.33)	3.3%	$92	$800 - $1,100	
D	HVAC System Measures				
12	Air Conditioner with Heat Pump (SEER 13/7.7 HSPF to SEER 15/8.5 HSPF)	4.1%	$114	$1,500 - $2,400	



Description of Combined Measures to Achieve 15% Above Code Savings

	Combination of Measures[3]	Combined Energy Savings (%)	Combined Energy Savings ($/year)	Combined Estimated Cost ($): Marginal Cost[1]	Combined Estimated Cost ($): New System Cost[2]	Combined Annual NO_x Emissions Savings (lbs/year)	Combined Ozone Season Period NO_x Emissions Savings (lbs/day)	Simple Estimated Payback (yrs)
	Combination 1							
2	Solar Domestic Hot Water System	15.7%	$438		$2,900 - $5,200	1.01	0.020	7.6 - 13.4
5	Improved Duct Sealing (10% to 5% Duct Leakage)				$450 - $650			
	Combination 2							
1	Tankless Electric Water Heater	15.4%	$431	$700 - $1,400		3.26	0.029	9.3 - 27.6
4	Relocate HVAC Unit including Supply and Return Ducts in Conditioned Space			$1,000 - $7,000				
9	Improved Windows (U-factor: 0.47 to 0.42 Btu/h-sf-F, SHGC: 0.4 to 0.33)			$800 - $1,100				
12	Air Conditioner with Heat Pump (SEER 13/7.7 HSPF to SEER 15/8.5 HSPF)			$1,500 - $2,400				
	Combination 3							
1	Tankless Electric Water Heater	15.1%	$422	$700 - $1,400		3.19	0.026	14.5 - 22.4
5	Improved Duct Sealing (10% to 5% Duct Leakage)				$450 - $650			
6	Reduced Air Infiltration (0.46 to 0.35 Air-changes/hr)				$350 - $1,500			
8	Window Shading and Redistribution (Equal Windows on All Four Sides with No Shading to 45% Windows on the South with 4ft. Eaves on All Four Sides)				$3,100 - $3,500			
12	Air Conditioner with Heat Pump (SEER 13/7.7 HSPF to SEER 15/8.5 HSPF)			$1,500 - $2,400				

Note:
1. Marginal cost = new system cost - original system cost
2. New system cost = new system cost only
3. See individual measures above for specific savings
   * Energy Cost: Electricity cost = $0.15/kWh
     Natural gas cost = $1.00/therm
4. Savings depend on fuel mix used. See detailed writeup

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* Building type: Residential
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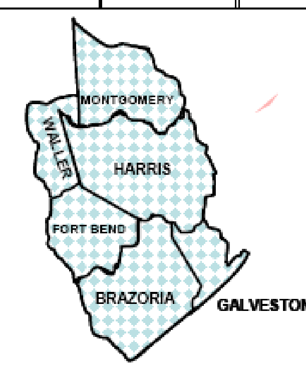

Table 5b: 15% Above Code Savings (Residential – Electric Heating) for Brazoria, Fort Bend, Galveston, Harris, Montgomery and Waller Counties

Energy Systems Laboratory - August 2007

Figure 8. Summary of Individual and Combined Measures for an All-electric House in Houston

SUMMARY

This paper presented an overview of the recommendations for achieving 15% above-code energy performance for single-family residences. The analysis was performed for a 2,325 sq. ft., one story, single family residence in Houston, Texas, with 18% window to floor area. To accomplish the 15% annual energy cost reductions, twelve measures were considered, including: tankless water heaters, solar water heaters, removal of the standing pilot light from the water heater, use of ducts in the conditioned space, duct sealing, decreased air infiltration, window shading and redistribution, improved window performance, improved air conditioner efficiency, and improved furnace efficiency.

This analysis identified the energy saving potential of individual measures which can guide the selection of measures to achieve 15% above-code annual energy savings in residential buildings.

The analysis demonstrates that for an electric/gas house, solar DHW system and tankless water heater resulted in 15.2% and 9.3% energy savings, followed by 8.5% savings from moving HVAC unit and ductwork in the conditioned space. Similarly, for an all-electric house, solar DHW system resulted in 10.9% energy savings, followed by 8.7% savings from moving HVAC unit and ductwork in the conditioned space These potential measures can be implemented individually or in combination with other measures for building envelope and/or HVAC system measures to accomplish 15% total energy use savings. It is to be noted that the energy cost savings and cost-effectiveness for individual measures were not of the same order as the energy use savings, since these depend on the fuel type used for the energy end use saved, and the first cost vs. energy cost savings, respectively.

Further, the high energy savings from DHW system measures demonstrate relatively low NAECA standards for domestic water heating equipment compared to the high efficiency products available in the market. However, the current NAECA standards for HVAC equipment performance seem to be in sync with the improved HVAC equipment efficiencies. Although, improvements in lighting and appliances are feasible, they are not recognized by the residential building codes and therefore, were not considered in this analysis.

ACKNOWLEDGEMENTS

Funding for this work was provided by the Texas State Legislature, as part of the Laboratory's SB5 effort. This work would not have been possible without the help from numerous individuals from several Texas state agencies, including: Steve Anderson (TCEQ), Alfred Reyes (TCEQ), Art Diem (US EPA), Julie Rosenberg (US EPA), Jay Zarnikau (Frontier and Associates), Theresa Gross (PUC), Jess Totten (PUC), Glenn Jennings (SECO), Warren Lasher (ERCOT), Dan Woodfin (ERCOT), and David Hitchcock (HARC).

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APPENDIX

Table A. 1.Base-case Summary

CHARACTERISTIC	BASECASE ASSUMPTIONS		COMMENTS	SOURCES
Building				
Building type	Single family, detached house			
Gross area	2,325 sq. ft. (48.22 ft. x 48.22 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		Assuming asphalt shingle roofing	
Ceiling insulation (hr-sq.ft.-°F/Btu)	R-30		Based on HDD65 and 27% window-to-wall area ratio	2001 IECC, Table 502.2.4(6), (p.83)
Wall absorptance	0.75		Assuming brick facia exterior	
Wall insulation (hr-sq.ft.-°F/Btu)	R-13		Based on HDD65	2001 IECC, Table 402.1.1(1), (p.63)
Slab Perimeter Insulation	None		Based on HDD65 and 27% window-to-wall area ratio	2001 IECC, Table 502.2.4(6), (p.83)
Ground reflectance	0.24		Assuming grass	DOE2.1e User Manual (LBL 1993)
U-Factor of glazing (Btu/hr-sq.ft.°F)	0.47		Based on HDD65	2001 IECC, Table 402.1.1(2), (p.63)
Solar Heat Gain Coefficient (SHGC)	0.4		0.4 for HDD < 3500, and 0.68 for HDD ≥ 3500	2001 IECC, Section 402.1.3.1.4, (p.64)
Window area	18% of conditioned floor area		This amounts to 418.5 sq. ft. window area and 27% window-to-wall area ratio for the assumed base case building configuration	2001 IECC, Section 402.1.1, (p.63)
Exterior shading	None			2001 IECC, Section 402.1.3.1.3, (p.64)
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)
Internal heat gains	0.88 W (modeled as 0.44 W for lighting and 0.44 W for equipment)		This assumes heat gains from lighting, equipment and occupants.	2001 IECC, Section 402.1.3.6, (p.65)
Number of occupants	None		Assuming internal gains include heat gain from occupants	2001 IECC, Section 402.1.3.6, (p.65)
Mechanical Systems	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)		
HVAC system efficiency	SEER 13 AC, 0.78 AFUE furnace	SEER 13 AC, 7.7 HSPF heat pump		NAECA (2006)
Cooling capacity (Btu/hr)	55,800		500 sq. ft./ton	
Heating capacity (Btu/hr)	72,540		1.3 x 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
DHW heater energy factor	0.54	0.86	(a) 0.62-0.0019V, (b) 0.93-0.00132V, Where V=storage volume (gal.)	2001 IECC, Table 504.2, (p.91)
Duct location	Unconditioned, vented attic			NAHB (2003)
Duct leakage (%)	10%			Parker et al. (1993)
Duct insulation (hr-sq.ft.-°F/Btu)	R-8 (supply) and R-4 (return)			2001 IECC