



Home Innovation
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Cost-Optimized 50% IECC Prescriptive Analysis

Prepared for
National Association of Home Builders

Prepared by
Home Innovation Research Labs
(formerly the NAHB Research Center)

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Objective

The objective of this analysis is to quantify the incremental construction cost and energy cost savings associated with constructing a house 50% more energy efficient than a 2006 IECC baseline (50% Savings). A methodology established by Home Innovation Research Labs, formerly the NAHB Research Center, was used to determine the incremental energy cost savings. Two 50% Savings cost optimization analyses were performed; the first used current Federal minimum equipment efficiencies and the second included efficiency optimization of the space heating, space cooling and water heating equipment.

Background

A strong push is being made by many advocacy groups, including the U.S. Department of Energy (DOE), to increase the stringency of the International Energy Conservation Code (IECC) to achieve a 50% Savings. There is a question as to what changes would be necessary to achieve the target savings and if it can be done cost effectively.

Energy Evaluation Methodology

A methodology was developed by Home Innovation Research Labs (NAHB Research Center 2012-1) to calculate energy savings with 2006 IECC as the primary baseline. This methodology defines a *Standard Reference House*, including the building geometry and energy performance parameters. In addition, a calculation formula was included to determine a “percent energy savings” when comparing editions of the energy code. Energy performance parameters from the IECC were used where available. For parameters not defined in the IECC, DOE’s Building America Benchmark (Hendron 2008) protocols were used.

Standard Reference House

The building geometry (Figure 1) used in this analysis is documented in the methodology paper and was developed using Home Innovation Research Labs 2008 and 2009 Annual Builder Practices Survey (ABPS) results. The parameters represent the average (mean) values from the ABPS for building areas and features not dictated by the 2006 IECC. Table 1 lists various floor, attic, wall, and window areas used in the *Standard Reference House*.

Table 1. Wall and Floor Square Footage

	Annual Builder Practices Survey (ABPS)	Standard Reference House
1 st Floor CFA	1,780	1,776
2 nd Floor CFA	572	576
Total CFA (w/o Conditioned Basement)	2,352	2,352
Slab/Basement/Crawl Floor Area		1,776
Total CFA (with Conditioned Basement)		4,128
Attic Floor Area		1,776
1 st Floor Wall Area	2,006	1,764
2 nd Floor Wall Area	586	816
Total Above-Grade Wall Area	2,592	2,580
Basement Wall Area (8ft wall height)		1,568
Crawlspace Wall Area (4ft wall height)		784
Window Area (crawlspace and slab-on-grade) (18%/15%)		464/387
Window Area (finished Basement) (18%/15%)		647/548

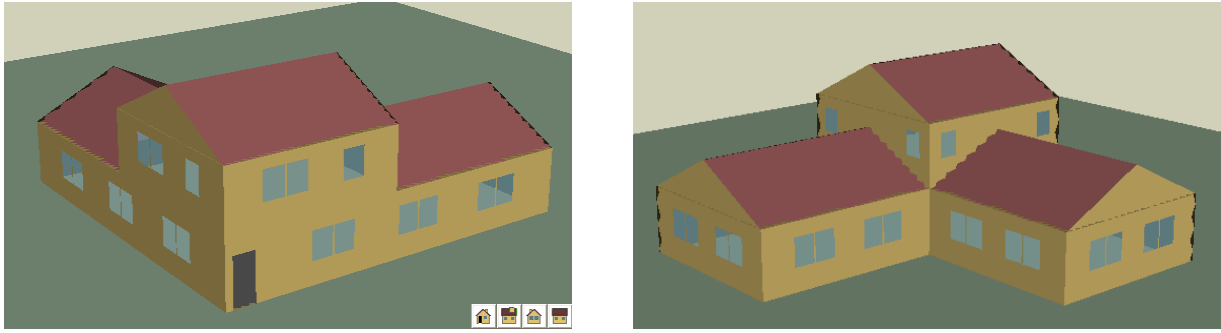


Figure 1. Simulation Model of Standard Reference House

Representative Cities

Eight cities (Table 2) representing each of the DOE Climate Zones (Figure 2) were selected to quantify energy savings.

Table 2. Representative Climate Zone Cities

Climate Zone	Moisture Region	State	City	HDD(65)	CDD(65)
1	Moist	Florida	Miami	120	4,396
2	Dry	Arizona	Phoenix	977	4,790
3	Moist	Tennessee	Memphis	2,851	2,221
4	Moist	Maryland	Baltimore	4,460	1,314
5	Moist	Illinois	Chicago	6,174	911
6	Dry	Montana	Helena	7,474	353
7	N/A	Minnesota	Duluth	9,371	185
8	N/A	Alaska	Fairbanks	12,818	49

Note: HDD and CDD data from TMY3 Dataset

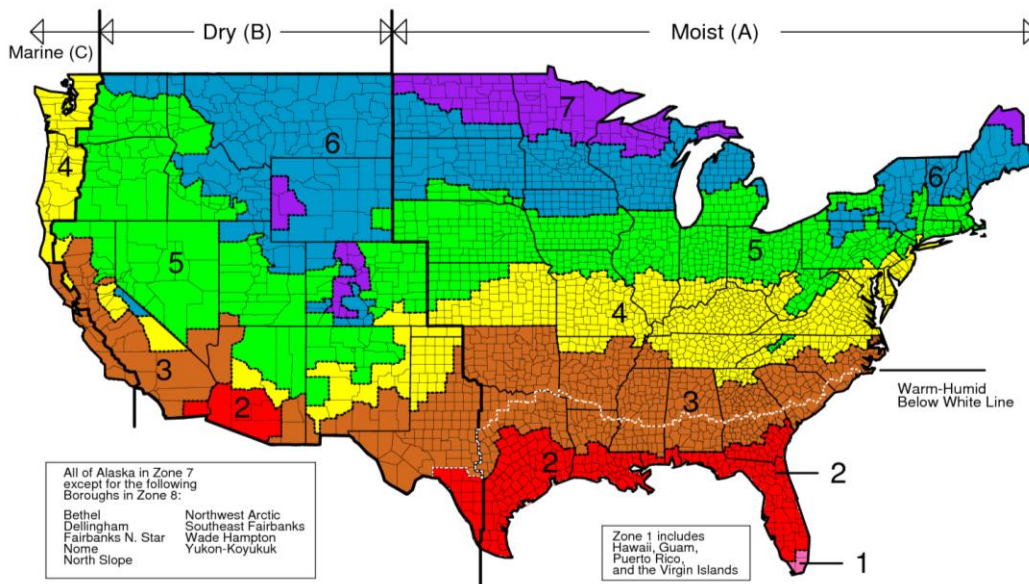


Figure 2. DOE Climate Zone Map

Cost Optimization

BEopt version 0.9.5.2 was used to perform the optimized energy savings analysis. BEopt was developed by the National Renewable Energy Laboratory in order to calculate energy savings as well as perform cost optimizations. It has a sequential search optimization technique which finds minimum-cost building designs at target energy savings and uses the Department of Energy's DOE2.2 simulation engine to perform the energy consumption analysis.

Weighted Averaging

Weighted averaging was applied both within and across climate zones. Within climate zones, wall construction factors for light-framed and mass walls, as well as various foundation types (slab, crawlspaces, and basements), were applied based on the current home construction mix as determined by Home Innovation's Annual Builder Practices Survey (ABPS). Once the savings within a climate zone were determined, a weighted calculation according to building starts (Briggs 2002) for each climate zone was performed in order to obtain a national weighted average.

Construction Costs Associated with 50% Savings

Energy savings of 50% were targeted for each climate zone. Although this analysis optimized the construction cost within the climate zones, it did not optimize the costs across climate zones. So, each climate zone requires a different level of effort to achieve 50% Savings.

Appendix A includes the baseline 2006 IECC prescriptive table and Appendices B, C, and D contain the 2009 IECC, 2012 IECC, and optimized 50% Savings prescriptive tables, respectively. Table 3 shows the incremental cost for changes made between the 2006 IECC and optimized 50% Savings solution specified by climate zone. All costs listed below are based on a unit basis and totals for the *Standard Reference House*. Costs from the ASHRAE RP-1481 have been escalated for inflation using RSMMeans adjustment factors.

50% Savings Calculation

Percent savings can be calculated a variety of ways. This analysis utilized the equation outlined in Home Innovation's methodology which takes the annual household energy cost savings of the two scenarios and divides it by the annual space Heating, space Cooling and Water heating. The following nomenclature is used to categorize the energy use:

$$\begin{aligned} 50\% \text{ Savings} &= 0.5 * \text{HCWU}_{2006} \\ &\text{-or-} \\ 50\% \text{ Savings} &= (\text{TEU}_{2006} - \text{TEU}_{50\%}) / \text{HCWU}_{2006} \end{aligned}$$

Where:

- TEU₂₀₀₆ = Total Energy Usage using the 2006 IECC
- TEU_{50%} = Total Energy Usage of a house constructed 50% more energy efficient than the 2006 IECC
- HCWU₂₀₀₆ = Heating, Cooling, and Water heating energy Usage using the 2006 IECC

Energy cost savings are calculated using the Energy Information Administration's latest posted calendar year (2011) residential consumer price data for electricity (\$0.118/kWh) and natural gas (\$1.08/therm).

Table 3. Itemized 50% Savings Incremental Construction Costs (Standard Equipment Efficiency Analysis)

Affected Climate Zone(s)	Item	Code Requirement		Cost			Source
		2006 IECC	Proposed 50%	Unit Cost *	Unit	Per House	
1,2,3	Air Sealing	N/R	3 ACH 50	\$ 0.41	sq ft floor	\$ 955	ASHRAE 1481 RP
4,5,6,7,8	Air Sealing	N/R	2 ACH 50	\$ 0.57	sq ft floor	\$ 1,337	NAHB RC (2010)
ALL	Blower Door Testing	N/R	Required	\$ 186.04	per house	\$ 186	Southface
3	Ceiling Insulation	R-30	R-38	\$ 0.28	sq ft attic	\$ 501	ASHRAE 1481 RP
4,5	Ceiling Insulation	R-38	R-60	\$ 0.87	sq ft attic	\$ 1,542	ASHRAE 1481 RP
6,7,8	Ceiling Insulation	R-49	R-60	\$ 0.34	sq ft attic	\$ 601	ASHRAE 1481 RP
ALL	High Efficacy Lighting	10% (base)	100%	\$ 1.13	% cfl	\$ 90	Local Survey
1,2,3,4	Duct Sealing	15% (base)	Inside	\$ 1,691.23	per house	\$ 1,691	Building America
5,6,7,8	Duct Sealing	15% (base)	4cfm/100sf	\$ 901.99	per house	\$ 902	Building America
ALL	Duct Testing	N/R	Required	\$ 186.04	per house	\$ 186	Southface
2	Floor Insulation	R-13	R-19	\$ 0.11	sq ft bsmt	\$ 200	ASHRAE 1481 RP
4	Floor Insulation	R-19	R-30	\$ 0.55	sq ft bsmt	\$ 981	ASHRAE 1481 RP
5,6	Floor Insulation	R-30	R-38	\$ 0.56	sq ft bsmt	\$ 1,001	ASHRAE 1481 RP
7,8	Floor Insulation	R-30	R-49	\$ 0.72	sq ft bsmt	\$ 1,282	ASHRAE 1481 RP
1	Mass Wall	R-3	R-4	\$ 0.11	sq ft wall	\$ 291	ASHRAE 1481 RP
2	Mass Wall	R-4	R-10	\$ 0.68	sq ft wall	\$ 1,745	ASHRAE 1481 RP
5	Mass Wall	R-13	R-25	\$ 0.56	sq ft wall	\$ 1,454	ASHRAE 1481 RP
ALL	Mechanical Ventilation	N/R	Required	\$ 430.17	per house	\$ 430	Russell (2005)
ALL	Prog Thermostat	N/R	Required	\$ 28.19	per house	\$ 28	Local Survey
ALL	R-3 Plumbing	N/R	R-3	\$ 1,165.82	per house	\$ 1,166	NAHB RC (2010)
2,3	Wall- Above Grade	R-13	R-19 or R-13+R-5	\$ 1.33	sq ft AG wall	\$ 3,433	ASHRAE 1481 RP
4	Wall- Above Grade	R-13	R-19+R-10	\$ 6.29	sq ft AG wall	\$ 16,232	ASHRAE 1481 RP
5,6	Wall- Above Grade	R-19 or R-13+R-5	R-19+R-10	\$ 5.16	sq ft AG wall	\$ 13,323	ASHRAE 1481 RP
7,8	Wall- Above Grade	R-21	R-19+R-10	\$ 4.96	sq ft AG wall	\$ 12,799	ASHRAE 1481 RP
4,5,6,7,8	Wall- Basement (ci/cavity)	R-10/R-13	R-15/R-19	\$ 1.18	sq ft BM wall	\$ 1,856	ASHRAE 1481 RP
5,6,7,8	Wall- Crawl Space (ci/cavity)	R-10/R-13	R-15/R-19	\$ 1.18	sq ft CS wall	\$ 928	ASHRAE 1481 RP
4,5	Slab (R-value/depth)	R-10, 2ft	R-10, 4ft	\$ 2.11	sq ft perim	\$ 725	ASHRAE 1481 RP
6,7,8	Slab (R-value/depth)	R-10, 4ft	R-15, 4ft	\$ 3.24	sq ft perim	\$ 2,330	ASHRAE 1481 RP
1	Window	U 1.20	0.40	\$ 3.15	sq ft window	\$ 1,219	ASHRAE 90.1 ENV
	SHGC	0.40	0.25				
2	Window	U 0.75	0.40	\$ 2.00	sq ft window	\$ 774	Paquette (2010)
	SHGC	0.40	0.25				
3	Window	U 0.65	0.30	\$ 3.00	sq ft window	\$ 1,161	Paquette (2010)
	SHGC	0.40	0.30				
4	Window	U 0.40	0.30	\$ 1.00	sq ft window	\$ 387	Paquette (2010)
	SHGC	NR	0.40				
5,6,7,8	Window	U 0.35	0.30	\$ 0.50	sq ft window	\$ 194	ASHRAE 90.1 ENV
	SHGC	NR	0.40				

* Unit cost from sources have been adjusted for inflation at a rate listed in RS Means

Table 4. Itemized 50% Savings Incremental Construction Costs (High Equipment Efficiency Analysis)

Affected Climate Zone(s)	Item	Code Requirement		Cost			Source
		2006 IECC	Proposed 50%	Unit Cost *	Unit	Per House	
1	Air Sealing	N/R	5 ACH 50	\$ 0.26	sq ft floor	\$ 610	ASHRAE 1481 RP
2,3	Air Sealing	N/R	3 ACH 50	\$ 0.41	sq ft floor	\$ 955	ASHRAE 1481 RP
4,5,6,7,8	Air Sealing	N/R	2 ACH 50	\$ 0.57	sq ft floor	\$ 1,337	NAHB RC (2010)
ALL	Blower Door Testing	N/R	Required	\$ 186.04	per house	\$ 186	Southface
4,5	Ceiling Insulation	R-38	R-49	\$ 0.53	sq ft attic	\$ 941	ASHRAE 1481 RP
ALL	High Efficacy Lighting	10% (base)	100%	\$ 1.13	% cfl	\$ 90	Local Survey
1,2,3,4,5	Duct Sealing	15% (base)	Inside	\$ 1,691.23	per house	\$ 1,691	Building America
6,7,8	Duct Sealing	15% (base)	4cfm/100sf	\$ 901.99	per house	\$ 902	Building America
ALL	Duct Testing	N/R	Required	\$ 186.04	per house	\$ 186	Southface
5,6,7,8	Floor Insulation	R-30	R-38	\$ 0.56	sq ft bsmt	\$ 1,001	ASHRAE 1481 RP
1	Mass Wall	R-3	R-4	\$ 0.11	sq ft wall	\$ 291	ASHRAE 1481 RP
ALL	Mechanical Ventilation	N/R	Required	\$ 430.17	per house	\$ 430	Russell (2005)
ALL	Prog Thermostat	N/R	Required	\$ 28.19	per house	\$ 28	Local Survey
ALL	R-3 Plumbing	N/R	R-3	\$ 1,165.82	per house	\$ 1,166	NAHB RC (2010)
4	Wall- Above Grade	R-13	R19 or R13+R5	\$ 1.33	sq ft AG wall	\$ 3,433	ASHRAE 1481 RP
6	Wall- Above Grade	R-19 or R-13+R-5	R-19+R-5	\$ 2.31	sq ft AG wall	\$ 5,963	ASHRAE 1481 RP
7,8	Wall- Above Grade	R-21	R-19+R-5	\$ 2.11	sq ft AG wall	\$ 5,440	ASHRAE 1481 RP
5,6,7,8	Wall- Basement (ci/cavity)	R-10/R-13	R-15/R-19	\$ 1.18	sq ft BM wall	\$ 1,856	ASHRAE 1481 RP
5,6,7,8	Wall- Crawl Space (ci/cavity)	R-10/R-13	R-15/R-19	\$ 1.18	sq ft CS wall	\$ 928	ASHRAE 1481 RP
5	Slab (R-value/depth)	R-10, 2ft	R-10, 4ft	\$ 2.11	sq ft perim	\$ 725	ASHRAE 1481 RP
7,8	Slab (R-value/depth)	R-10, 4ft	R-15, 4ft	\$ 3.24	sq ft perim	\$ 2,330	ASHRAE 1481 RP
1	Window	U 1.20 SHGC 0.50	0.50 0.25	\$ 2.86	sq ft window	\$ 1,107	ASHRAE 90.1 ENV
2	Window	U 0.75 SHGC 0.40	0.40 0.25	\$ 2.00	sq ft window	\$ 774	Paquette (2010)
3	Window	U 0.65 SHGC 0.40	0.30 0.40	\$ 2.50	sq ft window	\$ 968	Paquette (2010)
4	Window	U 0.40 SHGC NR	0.30 0.40	\$ 1.00	sq ft window	\$ 387	Paquette (2010)
5,6,7,8	Window	U 0.35 SHGC NR	0.30 0.40	\$ 0.50	sq ft window	\$ 194	ASHRAE 90.1 ENV
1	Heat Pump	13\7.7	14\8.0	\$ 136.43	per house	\$ 136.43	ASHRAE 1481 RP
	Furnace	78	78	\$ -	per house		ASHRAE 1481 RP
	Air Conditioner	13	14	\$ 237.90	per house	\$ 238	ASHRAE 1481 RP
2,3	Heat Pump	13\7.7	15\8.5	\$ 1,457.84	per house	\$ 1,458	ASHRAE 1481 RP
	Furnace	78	78	\$ -	per house		ASHRAE 1481 RP
	Air Conditioner	13	15	\$ 518.64	per house	\$ 519	ASHRAE 1481 RP
4,5	Heat Pump	13\7.7	18\9.5	\$ 2,470.32	per house	\$ 2,470	ASHRAE 1481 RP
	Furnace	78	95	\$ 1,829.91	per house		ASHRAE 1481 RP
	Air Conditioner	13	15	\$ 518.64	per house	\$ 2,349	ASHRAE 1481 RP
6,7,8	Heat Pump	13\7.7	18\9.5	\$ 2,470.32	per house	\$ 2,470	ASHRAE 1481 RP
	Furnace	78	95	\$ 1,829.91	per house		ASHRAE 1481 RP
	Air Conditioner	13	13	\$ -	per house	\$ 1,830	ASHRAE 1481 RP

* Unit cost from sources have been adjusted for inflation at a rate listed in RS Means

Equipment Efficiency

Historically the IECC had allowed for performance based code compliance which was determined strictly by total annual energy usage of the dwelling. Changes have been made over time to limit energy neutral trade-offs in the code. The 2009 IECC was modified to no longer allow credit towards code compliance for the energy saved due to high efficiency heating, cooling and water heating equipment. This report analyzed the cost for compliance both with and without the option to use high efficiency equipment.

Cost of Compliance

Table 5 shows the difference in cost between using high efficiency equipment to reach the same level of performance as a dwelling only being able to use the building envelope to achieve 50% Savings. A detailed breakdown of the specific costs and measures can be found in Appendix D and E.

Table 5. Incremental Construction Cost for the 50% Savings Design

Climate Zone/City	Construction Cost – w/ Standard Equipment	Construction Cost – w/ High Efficiency Equipment
1 Miami	\$4,974	\$4,669
2 Phoenix	\$7,540	\$5,491
3 Memphis	\$8,660	\$5,569
4 Baltimore	\$23,349	\$8,572
5 Chicago	\$18,978	\$7,119
6 Helena	\$18,981	\$12,766
7 Duluth	\$18,500	\$12,327
8 Fairbanks	\$18,500	\$12,327
Weighted Average	\$14,681	\$7,031

Cost Effectiveness

While various cost effectiveness evaluation criteria can be used, this analysis employs the simple payback method. The simple payback analysis is easy to understand and it does not make future assumptions such as general inflation rates, life expectancy of building components, or fuel escalation rates. Table 6 summarizes the energy cost savings, construction cost, and resulting simple payback for each climate zone by climate zone and a weighted national average.

Table 6. Cost Effectiveness for 50% Savings Design

Climate Zone	Annual Energy Savings	Standard Efficiency Equipment Incremental Cost	Simple Payback (yrs)	High Efficiency Equipment Incremental Cost	Simple Payback (yrs)
1	\$646	\$4,974	7.7	\$4,669	7.2
2	\$777	\$7,540	9.7	\$5,491	7.1
3	\$847	\$8,660	10.2	\$5,569	6.6
4	\$850	\$23,349	27.5	\$8,572	10.1
5	\$1,035	\$18,978	18.3	\$7,119	6.9
6	\$964	\$18,981	19.7	\$12,766	13.2
7	\$1,337	\$18,500	13.8	\$12,327	9.2
8	\$1,756	\$18,500	10.5	\$12,327	7.0
Weighted Avg	\$907	\$14,681	16.2	\$7,031	7.9

The simple paybacks in Table 6 are based on an overall average for all changes in the 2012 IECC relative to a 2006 IECC baseline. Consequently, some changes result in shorter paybacks than the average simple payback and some in longer paybacks. This analysis did not calculate the individual payback period for each modification to the 2012 IECC.

Longer Paybacks

As the codes continue to increase in stringency, so does the time it takes for the energy savings investment to pay back. Consequently, if the energy code is developed in a rational manner, the cost effectiveness of each successive code decreases. In Table 7, the simple payback for the optimized 50% Savings solution is longer when comparing to a more recent version of the code. The basis for the values in Table 7 was developed from two IECC cost-effective analysis studies performed by Home Innovation Research Labs (NAHB Research Center 2012-2, 2012-3).

The national average simple payback to get from the 2006 IECC to the 50% Savings (over the 2006 IECC) is 16.2 years when using standard efficiency equipment; however, if the starting point is the 2012 IECC, the simple payback for that incremental change to achieve the same 50% Savings over the 2006 IECC the payback is extended to over 40 years. The same trend is true when using higher efficiency equipment; however, the paybacks are shorter in all cases indicating that high efficiency equipment is more cost effective than building envelope improvements.

Table 7. Simple Payback of the 50% Savings Solutions Relative to Different Energy Code Baselines

Climate Zone	Standard Efficiency Equipment			High Efficiency Equipment		
	2006 IECC	2009 IECC	2012 IECC	2006 IECC	2009 IECC	2012 IECC
1	7.7	10.0	12.9	7.2	9.6	12.7
2	9.7	12.9	16.1	7.1	10.0	10.6
3	10.2	12.8	27.5	6.6	8.1	8.2
4	27.5	38.4	81.7	10.1	13.8	23.4
5	18.3	22.0	50.4	6.9	8.5	17.3
6	19.7	27.4	60.5	13.2	19.0	51.9
7	13.8	17.4	42.6	9.2	10.8	20.0
8	10.5	12.6	23.5	7.0	8.6	16.4
Weighted Avg	16.2	21.1	43.7	7.9	10.4	16.8

Relative to the 2006 IECC, some southern climate zones could have achieved a 50% Savings within a 10 year simple payback; however, this would not have been on an incremental basis. This is reflected in Table 7 where Climate Zones 1, 2, & 3 could achieve 50% Savings in less than 10 years, but there are points between the 2006 IECC and 50% Savings where the payback exceeds 10 years when evaluating efficiency changes individually and incrementally. For example, in Climate Zone 3 it takes 9.9 years to payback the investment to achieve a 50% Savings, but to get to the same level of efficiency starting from the 2012 IECC, it will take over 27 years. So efficiency changes that were made to get from the 2006 IECC to the 2012 IECC level took much less than 10 years and the changes necessary to get from the 2012 IECC to 50% will take 27.5, but the overall average is 9.9 years. If an incremental analysis is performed, somewhere between the 2006 IECC and the 50% Savings there is a point where the incremental savings exceeds a 10 year payback.

Figure 3 summarizes the analysis by showing the national average annual cost impact to the consumer who has taken out a 30 year loan at a 5% rate to finance the incremental cost of the energy saving upgrades. This analysis only accounts for the cash flow for year one. It does not account for inflation, fluctuations in energy prices nor does it take into consideration the market value of the upgrades at the time of resale.

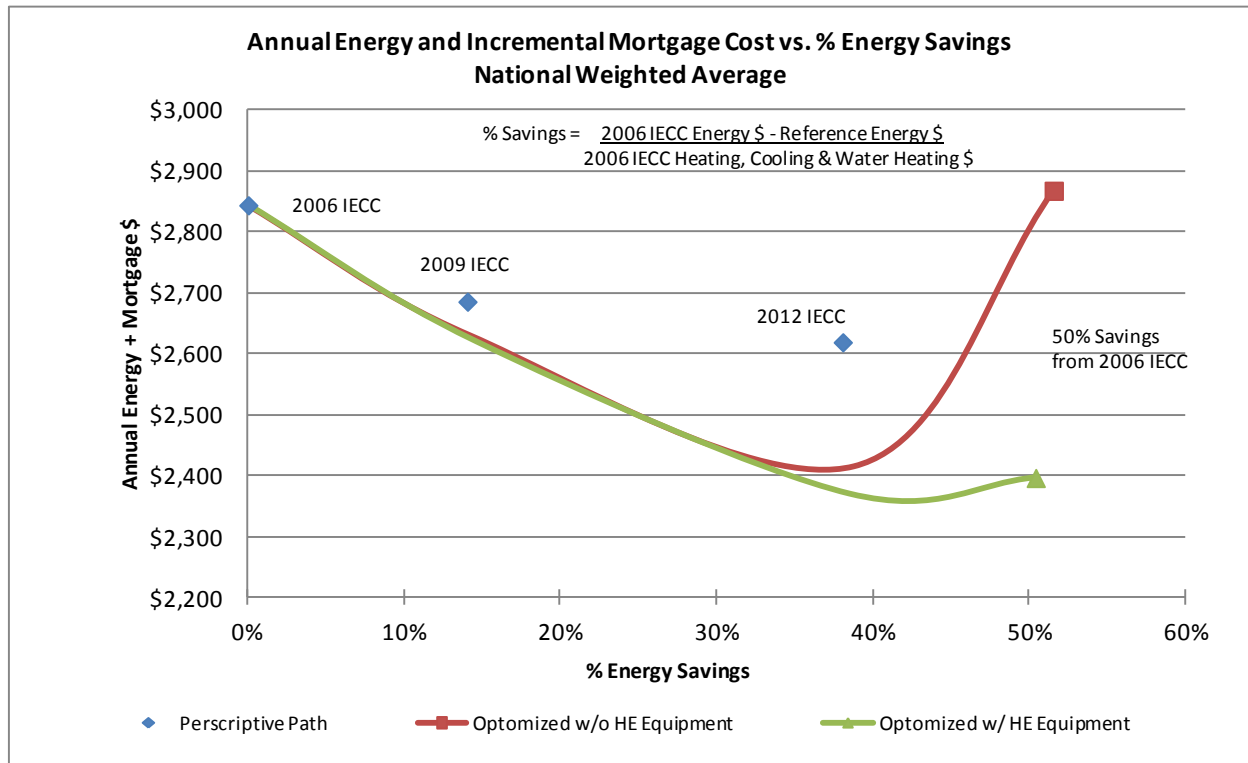


Figure 3. Energy and Mortgage Cost vs. % Energy Savings

The red line shows the optimized cost of ownership when using standard efficiency heating and cooling equipment. The point where the curve hits its lowest point (around 35%) represents the lowest cost of ownership. A house built more (or less) efficient will result in reduced cash flow to the consumer.

The green line reflects the annual cost over the specified energy savings range when including higher efficiency (HE) equipment in the optimized solutions. With the ability to use high efficiency equipment to achieve code compliance, the builder will have the ability to cost optimize the design of the home and result in a lower cost of ownership for the consumer. As the homes become more efficient, the need for high efficiency equipment is more pronounced.

The blue diamonds show the annual energy cost plus incremental mortgage cost for each of the last three codes and a cost optimized 50% Savings relative to the 2006 baseline (red square and green triangle). The 2006 and 2009 IECC are close to the optimization line, meaning that the requirements are nearly cost optimized (based on the options selected in the analysis); however, the 2012 IECC is not close to the optimization line. This implies that some of new prescriptive requirements in the 2012 IECC are not optimized and if an unrestricted energy code were to allow for true optimization, the consumer could save approximately \$200/year with the same energy consumption.

Conclusions

The energy savings calculation methodology used in this analysis provides detailed incremental construction cost, energy cost savings, and a simple payback for an optimized (minimized cost) 50% energy savings over the 2006 IECC. The national weighted additional cost to construct to the 50% relative to the 2006 IECC is over \$14,000 and in excess of \$23,000 in Climate Zone 4. The national weighted average annual energy savings from the 2006 IECC baseline to the 50% target is \$907 per year.

As energy codes become more stringent, there are diminishing returns on efficiency investments. When using the 2006 as the starting point, the national average simple payback to achieve 50% Savings is just over 16 years; if the starting point is the 2012 IECC, the simple payback is nearly 44 years. This is a strong indicator that energy code efficiency levels are approaching (or have exceeded) their practical maximums.

The 2012 IECC resulted in increased energy savings; however, prescriptive and mandatory requirements were not optimized. Cost-ineffective requirements place cost burdens on the builder that are passed along to the consumer which may never payback. In order to prevent this, the energy code must be flexible in order to allow the builder to cost optimize the energy performance of the house.

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**Appendix A:
Prescriptive Requirements for 2006 IECC**

2006 International Energy Conservation Code

Climate Zone	Fenestration U-Factor	Skylight U-Factor	Glazed ^b Fenestration SHGC	Ceiling R-Value	Wood Frame Wall R-Value	Mass Wall R-Value	Floor R-Value	Basement ^c Wall R-Value	Slab ^d R-Value & Depth	Crawl ^e Space Wall R-Value
1	1.20	0.75	0.40	30	13	3	13	0	0	0
2	0.75	0.75	0.40	30	13	4	13	0	0	0
3	0.65	0.65	0.40 ^e	30	13	5	19	0	0	5/13
4 Less Marine	0.40	0.60	NR	38	13	5	19	10/13	10/2	10/13
5 & 4 Marine	0.35	0.60	NR	38	19 or 13+5 ^g	13	30 ^f	10/13	10/2	10/13
6	0.35	0.60	NR	49	19 or 13+5 ^g	15	30 ^f	10/13	10/2	10/13
7 & 8	0.35	0.60	NR	49	21	19	30 ^f	10/13	10/2	10/13

R-Values are mins. U-Factors are max. R19 permitted in 2x6 cavity

b Applies to all Fenestration

c First is continuous, second is framing cavity

d R-5 shall be added to slab edge for heated slabs

e No SHGC for Marine zones

f Or insulation to fill the framing cavity, R-19 minimum

g First is cavity, second is sheathing

**Appendix B:
Optimized Prescriptive Requirements to Achieve 50% Savings with
Standard Equipment**

Climate Zone	Fenestration U-Factor		Glazed Fenestration SHGC		Ceiling R-Value		Wood Frame Wall R-Value		Mass Wall R-Value		Floor R-Value		Basement Wall R-Value		Slab R-Value & Depth		Crawl Space Wall R-Value		Air Leakage ACH50		Duct Leakage or Location		High Efficacy Lighting	
	IECC 2006	50%	IECC 2006	50%	IECC 2006	50%	IECC 2006	50%	IECC 2006	50%	IECC 2006	50%	IECC 2006	50%	IECC 2006	50%	IECC 2006	50%	IECC 2006	50%	IECC 2006	50%	IECC 2006	50%
1	1.20	0.40	0.40	0.25	30	Same	13	Same	3	4	13	Same	0	0	0	Same	0	0	NR	3	15%	Inside	10%	100%
2	0.75	0.40	0.40	0.25	30	Same	13	19 or 13+5	4	10	13	19	0	0	0	Same	0	0	NR	3	15%	Inside	10%	100%
3	0.65	0.30	0.40	0.30	30	38	13	19 or 13+5	5		19	Same	0	0	0	Same	5/13		NR	3	15%	Inside	10%	100%
4 Less Marine	0.40	0.30	NR	Same	38	60	13	19+10	5		19	30	10/13	15/19	10/2	10/4	10/13		NR	2	15%	Inside	10%	100%
5 & 4 Marine	0.35	0.30	NR	Same	38	60	19 or 13+5	19+10	13	25	30	38	10/13	15/19	10/2	10/4	10/13	15/19	NR	2	15%	4%	10%	100%
6	0.35	0.30	NR	Same	49	60	19 or 13+5	19+10	15		30	38	10/13	15/19	10/4	15/4	10/13	15/19	NR	2	15%	4%	10%	100%
7 & 8	0.35	0.30	NR	Same	49	60	21	19+10	19		30	49	10/13	15/19	10/4	15/4	10/13	15/19	NR	2	15%	4%	10%	100%

option not typical and not under the bias of this study
 Same no upgrade/alteration is needed above the 2006 code

**Appendix C:
Optimized Prescriptive Requirements to Achieve 50% Savings with
High Efficiency Equipment**

Climate Zone	Fenestration U-Factor		Glazed Fenestration SHGC		Ceiling R-Value		Wood Frame Wall R-Value		Mass Wall R-Value		Floor R-Value		Basement Wall R-Value		Slab R-Value & Depth		Crawl Space Wall R-Value		Air Leakage ACH50		Duct Leakage or Location		High Efficacy Lighting		Gas Furnace Efficiency (AFUE)		A/C Efficiency (SEER)		Heat Pump Efficiency (SEER/HSPF)	
	IECC 2006	50%	IECC 2006	50%	IECC 2006	50%	IECC 2006	50%	IECC 2006	50%	IECC 2006	50%	IECC 2006	50%	IECC 2006	50%	IECC 2006	50%	IECC 2006	50%	IECC 2006	50%	IECC 2006	50%	IECC 2006	50%	IECC 2006	50%	IECC 2006	50%
1	1.20	0.50	0.40	0.25	30	Same	13	Same	3	4	13	Same	0	0	0	Same	0	0	NR	5	15%	Inside	10%	100%	78	80	13	14	137.7	148.0
2	0.75	0.40	0.40	0.25	30	Same	13	Same	4	Same	13	Same	0	0	0	Same	0	0	NR	3	15%	Inside	10%	100%	78	80	13	15	137.7	158.5
3	0.65	0.30	0.40	Same	30	Same	13	Same	5	5	19	Same	0	0	0	Same	5/13	0	NR	3	15%	Inside	10%	100%	78	80	13	15	137.7	158.5
4 Less Marine	0.40	0.30	NR	Same	38	49	13	19 or 13+5	5	5	19	Same	10/13	Same	10/2	Same	10/13	0	NR	2	15%	Inside	10%	100%	78	95	13	15	137.7	188.5
5 & 4 Marine	0.35	0.30	NR	Same	38	49	19 or 13+5	Same	13	13	30	38	10/13	15/19	10/2	10/4	10/13	15/19	NR	2	15%	Inside	10%	100%	78	95	13	15	137.7	188.5
6	0.35	0.30	NR	Same	49	Same	19 or 13+5	19+5	15	15	30	38	10/13	15/19	10/4	Same	10/13	15/19	NR	2	15%	4%	10%	100%	78	95	13	Same	137.7	188.5
7 & 8	0.35	0.30	NR	Same	49	Same	21	19+5	19	19	30	38	10/13	15/19	10/4	15/4	10/13	15/19	NR	2	15%	4%	10%	100%	78	95	13	Same	137.7	188.5

Same option not typical and not under the bias of this study
no upgrade/abatement is needed above the 2006 code

Appendix D:
Itemized Incremental Construction Costs with Standard Equipment

Climate Zone 1, Light Frame and Mass Walls

Framed Walls	Cost		Code Requirement	Foundation Distribution					Cost Source
	Unit Cost	Unit		0% Conditioned Basement	0% Conditioned Crawlspace	90% Slab on Grade	0% Unconditioned Basement	10% Vented Crawlspace	
35% U-Factor SHGC	\$ 3.15	sq ft w window	2006 IECC 1.20 50% Solution 0.50			\$ 1,219		\$ 1,219	ASHRAE 90.1 Env
Ceilings			0.40 0.035						
Frame Walls			0.082 N/A						
Mass Wall			N/A						
Floors			0.064 0.360						
Bsmt Walls			0						
Slab			0						
Crawl Wall			0.477						
CFL	\$ 1.00	% cfl	10% (base) 15% (base)			\$ 90		\$ 90	Local Survey
Ducts	\$ 1,691	per house	Required			\$ 1,691		\$ 1,691	Building America
Blower Door	\$ 186	per house	Required			\$ 186		\$ 186	Southface
Air Sealing	\$ 0.41	sq ft floor	3 ACH 50			\$ 955		\$ 955	ASHRAE 1481 RP
Mechanical Ventilation	\$ 430	per house	Required			\$ 430		\$ 430	Russell (2005)
Duct Blaster	\$ 186	per house	Required			\$ 186		\$ 186	Southface
R-3 Plumbing		per house	R-0						
Prog Thermostat	\$ 28	per house	Required			\$ 28		\$ 28	Local Survey
Incremental Cost						\$ 4,785		\$ 4,785	\$ 4,785

Mass Walls	Cost		Code Requirement	Foundation Distribution					Cost Source
	Unit Cost	Unit		0% Conditioned Basement	0% Conditioned Crawlspace	90% Slab on Grade	0% Unconditioned Basement	10% Vented Crawlspace	
65% U-Factor SHGC	\$ 3.15	sq ft w window	2006 IECC 1.20 50% Solution 0.50			\$ 1,219		\$ 1,219	ASHRAE 90.1 Env
Ceilings			0.40 0.035						
Frame Walls			N/A						
Mass Wall	\$ 0.11	sq ft wall	R-3 R-4			\$ 291		\$ 291	ASHRAE 1481 RP
Floors			0.064 0.360						
Bsmt Walls			0						
Slab			0						
Crawl Wall			0.477						
CFL	\$ 1.00	% cfl	10% (base) 15% (base)			\$ 90		\$ 90	Local Survey
Ducts	\$ 1,691	per house	Required			\$ 1,691		\$ 1,691	Building America
Blower Door	\$ 186	per house	Required			\$ 186		\$ 186	Southface
Air Sealing	\$ 0.41	sq ft floor	3 ACH 50			\$ 955		\$ 955	ASHRAE 1481 RP
Mechanical Ventilation	\$ 430	per house	Required			\$ 430		\$ 430	Russell (2005)
Duct Blaster	\$ 186	per house	Required			\$ 186		\$ 186	Southface
R-3 Plumbing		per house	R-0						
Prog Thermostat	\$ 28	per house	Required			\$ 28		\$ 28	Local Survey
Incremental Cost						\$ 5,076		\$ 5,076	\$ 5,076

Climate Zone 1 Weighted Average Incremental Cost= \$ 4,974

Climate Zone 2, Light Frame and Mass Walls

Framed Walls		Cost		Code Requirement		Foundation Distribution					Cost Source
	Unit Cost	Unit	2006 IECC	50% Solution	0%	0% Conditioned Basement	0% Conditioned Crawlspace	90% Slab on Grade	0% Unconditioned Basement	10% Vented Crawlspace	
Window	\$ 2.00	sq ft w/indow	0.75	0.35				\$ 774		\$ 774	Paquette (2010)
SHGC			0.40	0.25							
Ceilings		sq ft attic	0.035	0.035							
Frame Walls	\$ 1.33		0.082	0.060				\$ 3,433		\$ 3,433	ASHRAE 1481 RP
Mass Wall			N/A	N/A				\$ -		\$ -	
Floors	\$ 0.11		0.064	0.047						\$ 200	ASHRAE 1481 RP
Bsmt Walls			0.360	0.360							
Slab			0	0							
Crawl Wall			0.477	0.477							
CFL	\$ 1.00	% cfl	10%	100%				\$ 90		\$ 90	Local Survey
Ducts	\$ 1,691	per house	15.0%	Inside				\$ 1,691		\$ 1,691	Building America
Blower Door	\$ 186	per house	N/R	Required				\$ 186		\$ 186	Southface
Air Sealing	\$ 0.41	sq ft floor	N/R	3 ACH 50				\$ 955		\$ 955	ASHRAE 1481 RP
Mechanical Ventilation	\$ 430	per house	N/R	Required				\$ 430		\$ 430	Russell (2005)
Duct Blaster	\$ 186	per house	N/R	Required				\$ 186		\$ 186	Southface
R-3 Plumbing			N/R	R-0							
Prog Thermostat	\$ 28	per house	N/R	Required				\$ 28		\$ 28	NAHB RC (2010)
Incremental Cost								\$ 7,773		\$ 7,973	\$ 7,973

Mass Walls		Cost		Code Requirement		Foundation Distribution					Cost Source
	Unit Cost	Unit	2006 IECC	50% Solution	0%	0% Conditioned Basement	0% Conditioned Crawlspace	90% Slab on Grade	0% Unconditioned Basement	10% Vented Crawlspace	
Window	\$ 2.00	sq ft w/indow	0.75	0.35				\$ 774		\$ 774	Paquette (2010)
SHGC			0.40	0.25							
Ceilings		sq ft attic	0.035	0.035							
Frame Walls			N/A	N/A							
Mass Wall	\$ 0.68	sq ft wall	R-4	R-10				\$ 1,745		\$ 1,745	ASHRAE 1481 RP
Floors	\$ 0.11		0.064	0.047						\$ 200	ASHRAE 1481 RP
Bsmt Walls			0.360	0.360							
Slab			0	0							
Crawl Wall			0.477	0.477							
CFL	\$ 1.00	% cfl	10% (est)	100%				\$ 90		\$ 90	Local Survey
Ducts	\$ 1,691	per house	15.0%	Inside				\$ 1,691		\$ 1,691	Building America
Blower Door	\$ 186	per house	N/R	Required				\$ 186		\$ 186	Southface
Air Sealing	\$ 0.41	sq ft floor	N/R	3 ACH 50				\$ 955		\$ 955	ASHRAE 1481 RP
Mechanical Ventilation	\$ 430	per house	N/R	Required				\$ 430		\$ 430	Russell (2005)
Duct Blaster	\$ 186	per house	N/R	Required				\$ 186		\$ 186	Southface
R-3 Plumbing			N/R	R-0							
Prog Thermostat	\$ 28	per house	N/R	Required				\$ 28		\$ 28	NAHB RC (2010)
Incremental Cost								\$ 6,086		\$ 6,286	\$ 6,106

Climate Zone 2 Weighted Average Incremental Cost= \$ 7,540

Climate Zone 3 and 4

Framed Walls	Cost		Code Requirement	Foundation Distribution						Cost Source
	Unit Cost	Unit		0%	0%	75%	15%	10%		
100% U-Factor SHGC	\$ 3.00	sq ft w/indow	2006 IECC 0.65 0.40 e	50% Solution 0.30		\$ 1,161	\$ 1,161	\$ 1,161	\$ 1,161	Paquette (2010)
Ceilings	\$ 0.28	sq ft attic	0.035	0.030		\$ 501	\$ 501	\$ 501	\$ 501	ASHRAE 1481 RP
Frame Walls	\$ 1.33	sq ft wall	0.062	0.060		\$ 3,433	\$ 3,433	\$ 3,433	\$ 3,433	ASHRAE 1481 RP
Mass Wall			N/A	N/A						
Floors			0.047	0.047						
Bsmt Walls		sq ft base w/	0.360	0.360						
Slab			0	0						
Crawl Wall			0.136	0.136						
GFL	\$ 1.00	% cfl	10% (base)	100%		\$ 90	\$ 90	\$ 90	\$ 90	Local Survey
Ducts	\$ 1,691	per house	15% (base)	Inside		\$ 1,691	\$ 1,691	\$ 1,691	\$ 1,691	Building America
Blower Door	\$ 186	per house	N/R	Required		\$ 186	\$ 186	\$ 186	\$ 186	Southface
Air Sealing	\$ 0.41	per house	N/R	3 ACH 50		\$ 955	\$ 955	\$ 955	\$ 955	ASHRAE 1481 RP
Mechanical Ventilation	\$ 430	sq ft floor	N/R	Required		\$ 430	\$ 430	\$ 430	\$ 430	Russell (2005)
Duct Blaster	\$ 186	per house	N/R	Required		\$ 186	\$ 186	\$ 186	\$ 186	Southface
R-3 Plumbing		per house	N/R	R-0						NAHB RC (2010)
Prog Thermostat	\$ 28	per house	N/R	Required		\$ 28	\$ 28	\$ 28	\$ 28	Local Survey
Incremental Cost						\$ 8,660	\$ 8,660	\$ 8,660	\$ 8,660	\$ 8,660

Climate Zone 3 Weighted Average Incremental Cost= \$ 8,660

Framed Walls	Cost		Code Requirement	Foundation Distribution						Cost Source
	Unit Cost	Unit		35%	0%	25%	20%	20%		
100% U-Factor SHGC	\$ 1.00	sq ft w/indow	2006 IECC 0.40 N/R	50% Solution 0.30 0.40		\$ 387	\$ 387	\$ 387	\$ 387	Paquette (2010)
Ceilings	\$ 0.87	sq ft attic	0.030	0.017		\$ 1,542	\$ 1,542	\$ 1,542	\$ 1,542	ASHRAE 1481 RP
Frame Walls	\$ 6.29	sq ft wall	0.062	0.042		\$ 16,232	\$ 16,232	\$ 16,232	\$ 16,232	ASHRAE 1481 RP
Mass Wall			N/A	N/A						
Floors	\$ 0.55		0.047	0.033						
Bsmt Walls	\$ 1.18		0.059	0.040		\$ 1,856				ASHRAE 1481 RP
Slab	\$ 2.11		10/2	10/4		\$ 793				ASHRAE 1481 RP
Crawl Wall			0.065	0.065						
GFL	\$ 1.00	% cfl	10% (base)	100%		\$ 90	\$ 90	\$ 90	\$ 90	Local Survey
Ducts	\$ 1,691	per house	15% (base)	Inside		\$ 1,691	\$ 1,691	\$ 1,691	\$ 1,691	Building America
Blower Door	\$ 186	per house	N/R	Required		\$ 186	\$ 186	\$ 186	\$ 186	Southface
Air Sealing	\$ 0.57	per house	N/R	2 ACH 50		\$ 1,337	\$ 1,337	\$ 1,337	\$ 1,337	ASHRAE 1481 RP
Mechanical Ventilation	\$ 430	sq ft floor	N/R	Required		\$ 430	\$ 430	\$ 430	\$ 430	Russell (2005)
Duct Blaster	\$ 186	per house	N/R	Required		\$ 186	\$ 186	\$ 186	\$ 186	Southface
R-3 Plumbing		per house	N/R	R-0						NAHB RC (2010)
Prog Thermostat	\$ 28	per house	N/R	Required		\$ 28	\$ 28	\$ 28	\$ 28	Local Survey
Incremental Cost						\$ 23,965	\$ 22,902	\$ 23,090	\$ 23,090	\$ 23,349

Climate Zone 4 Weighted Average Incremental Cost= \$ 23,349

Climate Zone 5, Light Frame and Mass Walls

Framed Walls	Cost		Code Requirement	Foundation Distribution						Cost Source
	Unit Cost	Unit		2006 IECC	45% Conditioned Basement	5% Conditioned Crawlspace	10% Slab on Grade	35% Unconditioned Basement	5% Vented Crawlspace	
Window	0.50	sq ft w indow	0.35	\$ 194	\$ 194	\$ 194	\$ 194	\$ 194	ASHRAE 90.1 Env	
U-Factor SHGC										
Ceilings	0.87	sq ft attic	0.030	\$ 1,542	\$ 1,542	\$ 1,542	\$ 1,542	\$ 1,542	ASHRAE 1481 RP	
Frame Walls	5.16	sq ft wall	0.060	\$ 13,323	\$ 13,323	\$ 13,323	\$ 13,323	\$ 13,323	ASHRAE 1481 RP	
Mass Wall			N/A							
Floors	0.56		0.033						ASHRAE 1481 RP	
Bsmt Walls	1.18	sq ft base w/	0.059	\$ 1,856					ASHRAE 1481 RP	
Slab	2.11		10/2			\$ 725			ASHRAE 1481 RP	
Crawl Wall	1.18	sq ft base w/	0.065						ASHRAE 1481 RP	
CFL	1.00	% cfl	10% (base)	\$ 90	\$ 90	\$ 90	\$ 90	\$ 90	Local Survey	
Ducts	902	per house	15% (base)	\$ 902	\$ 902	\$ 902	\$ 902	\$ 902	Building America	
Blower Door	186	per house	N/R	\$ 186	\$ 186	\$ 186	\$ 186	\$ 186	Southface	
Air Sealing	0.57	per house	Required	\$ 1,337	\$ 1,337	\$ 1,337	\$ 1,337	\$ 1,337	ASHRAE 1481 RP	
Mechanical Ventilation	430	sq ft floor	2 ACH 50	\$ 430	\$ 430	\$ 430	\$ 430	\$ 430	Russell (2005)	
Duct Blaster	186	per house	Required	\$ 186	\$ 186	\$ 186	\$ 186	\$ 186	Southface	
R-3 Plumbing		per house	R-0						NAHB RC (2010)	
Prog Thermostat	28	per house	Required	\$ 28	\$ 28	\$ 28	\$ 28	\$ 28	Local Survey	
Incremental Cost				\$ 20,073	\$ 19,145	\$ 18,942	\$ 19,218	\$ 19,218	\$ 19,572	

Mass Walls	Cost		Code Requirement	Foundation Distribution						Cost Source
	Unit Cost	Unit		2006 IECC	45% Conditioned Basement	5% Conditioned Crawlspace	10% Slab on Grade	35% Unconditioned Basement	5% Vented Crawlspace	
Window	0.50	sq ft w indow	0.35	\$ 194	\$ 194	\$ 194	\$ 194	\$ 194	ASHRAE 90.1 Env	
U-Factor SHGC										
Ceilings	0.87	sq ft attic	0.030	\$ 1,542	\$ 1,542	\$ 1,542	\$ 1,542	\$ 1,542	ASHRAE 1481 RP	
Frame Walls		sq ft wall	N/A							
Mass Wall	0.56	per house	R-13	\$ 1,454	\$ 1,454	\$ 1,454	\$ 1,454	\$ 1,454	ASHRAE 1481 RP	
Floors	0.56		0.033						ASHRAE 1481 RP	
Bsmt Walls	1.18	sq ft base w/	0.059	\$ 1,856					ASHRAE 1481 RP	
Slab	2.11		10/2			\$ 725			ASHRAE 1481 RP	
Crawl Wall	1.18	sq ft base w/	0.065						ASHRAE 1481 RP	
CFL	1.00	% cfl	10% (base)	\$ 90	\$ 90	\$ 90	\$ 90	\$ 90	Local Survey	
Ducts	902	per house	15% (base)	\$ 902	\$ 902	\$ 902	\$ 902	\$ 902	Building America	
Blower Door	186	per house	Required	\$ 186	\$ 186	\$ 186	\$ 186	\$ 186	Southface	
Air Sealing	0.57	per house	2 ACH 50	\$ 1,337	\$ 1,337	\$ 1,337	\$ 1,337	\$ 1,337	ASHRAE 1481 RP	
Mechanical Ventilation	430	sq ft floor	Required	\$ 430	\$ 430	\$ 430	\$ 430	\$ 430	Russell (2005)	
Duct Blaster	186	per house	Required	\$ 186	\$ 186	\$ 186	\$ 186	\$ 186	Southface	
R-3 Plumbing		per house	R-0						NAHB RC (2010)	
Prog Thermostat	28	per house	Required	\$ 28	\$ 28	\$ 28	\$ 28	\$ 28	Local Survey	
Incremental Cost				\$ 8,205	\$ 7,277	\$ 7,074	\$ 7,350	\$ 7,350	\$ 7,704	

Climate Zone 5 Weighted Average Incremental Cost= \$ 18,978

Climate Zones, 6, 7, and 8

Framed Walls	Cost		Code Requirement	Foundation Distribution							Cost Source		
	Unit Cost	Unit		75%	5%	5%	10%	5%	5%				
100%													
Window	U-Factor SHGC	0.50	sq ft w window	2006 IECC	50% Solution	194	194	194	194	194	194	194	ASHRAE 90.1 Env
						0.35	0.30						
						N/R	0.40						
Ceilings		0.34				0.026	0.017	601	601	601	601	601	ASHRAE 1481 RP
Frame Walls		5.16	sq ft of wall			0.060	0.042	13,323	13,323	13,323	13,323	13,323	ASHRAE 1481 RP
Mass Wall						N/A	N/A						
Floors		0.56				0.033	0.028						ASHRAE 1481 RP
Bsmt Walls		1.18	sq ft base w l			0.059	0.040	1,856					ASHRAE 1481 RP
Slab		3.24				10/4	15/4						ASHRAE 1481 RP
Crawl Wall		1.18	sq ft base w l			0.065	0.040						ASHRAE 1481 RP
Ducts		1.00	% cfl			10% (base)	100%	90	90	90	90	90	Local Survey
Blower Door		902	per house			4cfm/100sf		902	902	902	902	902	Building America
Air Sealing		186	per house			Required		186	186	186	186	186	Southface
Mechanical Ventilation		0.57	per house			N/R		1,337	1,337	1,337	1,337	1,337	ASHRAE 1481 RP
Duct Blaster		430	sq ft floor			Required		430	430	430	430	430	Russell (2005)
R-3 Plumbing		186	per house			N/R		186	186	186	186	186	Southface
Prog Thermostat		28	per house			Required		28	28	28	28	28	Local Survey
Incremental Cost								19,132	18,204	19,606	18,277	18,277	18,981
Climate Zone 6 Weighted Average Incremental Cost=								\$ 19,132	\$ 18,204	\$ 19,606	\$ 18,277	\$ 18,277	\$ 18,981

Framed Walls	Cost		Code Requirement	Foundation Distribution							Cost Source		
	Unit Cost	Unit		75%	5%	5%	10%	5%	5%				
100%													
Window	U-Factor SHGC	0.50	sq ft w window	2006 IECC	50% Solution	194	194	194	194	194	194	194	ASHRAE 90.1 Env
						0.35	0.30						
						N/R	0.40						
Ceilings		0.34				0.026	0.017	601	601	601	601	601	ASHRAE 1481 RP
Frame Walls		4.96	sq ft of wall			0.057	0.042	12,799	12,799	12,799	12,799	12,799	ASHRAE 1481 RP
Mass Wall						N/A	N/A						
Floors		0.72	sq ft floor			0.033	0.020						ASHRAE 1481 RP
Bsmt Walls		1.18	sq ft base w l			0.059	0.040	1,856					ASHRAE 1481 RP
Slab		3.24				10/4	15/4						ASHRAE 1481 RP
Crawl Wall		1.18	sq ft base w l			0.065	0.040						ASHRAE 1481 RP
Ducts		1.00	% cfl			10% (base)	100%	90	90	90	90	90	Local Survey
Blower Door		902	per house			4cfm/100sf		902	902	902	902	902	Building America
Air Sealing		186	per house			Required		186	186	186	186	186	Southface
Mechanical Ventilation		0.57	per house			N/R		1,337	1,337	1,337	1,337	1,337	ASHRAE 1481 RP
Duct Blaster		430	sq ft floor			Required		430	430	430	430	430	Russell (2005)
R-3 Plumbing		186	per house			N/R		186	186	186	186	186	Southface
Prog Thermostat		28	per house			Required		28	28	28	28	28	Local Survey
Incremental Cost								18,609	17,681	19,082	18,034	18,034	18,500
Climate Zones 7 & 8 Weighted Average Incremental Cost=								\$ 18,609	\$ 17,681	\$ 19,082	\$ 18,034	\$ 18,034	\$ 18,500

Appendix E:
Itemized Incremental Construction Costs with High Efficiency Equipment

Climate Zone 1, Light Frame and Mass Walls

Framed Walls	Cost		Code Requirement	Foundation Distribution					Cost Source	
	Unit Cost	Unit		Heating Fuel %	0% Basement	0% Conditioned Crawlspace	90% Slab on Grade	0% Unconditioned Basement		10% Vented Crawlspace
35% Window	2.86	sq ft window	2006 IECC 1.20							
U-Factor	0.40		0.50							
SHGC	0.035		0.25							
Ceilings	0.035		0.035							
Frame Walls	0.082		0.082							
Mass Wall	N/A		N/A							ASHRAE 1481 RP
Floors	0.064		0.064							
Bsmt Walls	0.360		0.360							
Slab	0		0							
Crawl Wall	0.477		0.477							
CFL	1.00	% cfl	10% (base)							90 Local Survey
Ducts	1.691	per house	15% (base)							1,691 Building America
Blower Door	186	per house	Required							186 Southface
Air Sealing	0.26	sq ft floor	N/R							610 ASHRAE 1481 RP
Mechanical Ventilation	430	per house	Required							430 Russell (2005)
Duct Blaster	186	per house	Required							186 Southface
R-3 Plumbing	N/R	per house	R-0							
Prog Thermostat	28	per house	Required							28 Local Survey
Electric Heat Pump	136	per house	13/7.7	85%						116
Gas Furnace	238	per house	78	15%						36
Electric Air Conditione		per house	13.0							ASHRAE 1481 RP
Incremental Cost										\$ 4,480

Mass Walls	Cost		Code Requirement	Foundation Distribution					Cost Source	
	Unit Cost	Unit		Heating Fuel %	0% Basement	0% Conditioned Crawlspace	90% Slab on Grade	0% Unconditioned Basement		10% Vented Crawlspace
65% Window	2.86	sq ft window	2006 IECC 1.20							
U-Factor	0.40		0.50							
SHGC	0.035		0.25							
Ceilings	0.035		0.035							
Frame Walls	N/A		N/A							
Mass Wall	0.11	sq ft wall	R-3							
Floors	0.064		0.064							
Bsmt Walls	0.360		0.360							
Slab	0		0							
Crawl Wall	0.477		0.477							
CFL	1.00	% cfl	10% (base)							90 Local Survey
Ducts	1.691	per house	15% (base)							1,691 Building America
Blower Door	186	per house	Required							186 Southface
Air Sealing	0.26	sq ft floor	N/R							610 ASHRAE 1481 RP
Mechanical Ventilation	430	per house	Required							430 Russell (2005)
Duct Blaster	186	per house	Required							186 Southface
R-3 Plumbing	N/R	per house	R-0							
Prog Thermostat	28	per house	Required							28 Local Survey
Electric Heat Pump	136	per house	13/7.7	85%						116
Gas Furnace	238	per house	78	15%						36
Electric Air Conditione		per house	13.0							ASHRAE 1481 RP
Incremental Cost										\$ 4,771

Climate Zone 1 Weighted Average Incremental Cost= \$ 4,669

Climate Zone 2, Light Frame and Mass Walls

Framed Walls	Cost		Code Requirement	Foundation Distribution					Cost Source		
	Unit Cost	Unit		Heating Fuel %	0% Conditioned Basement	0% Conditioned Crawlspace	90% Slab on Grade	0% Unconditioned Basement		10% Vented Crawlspace	
85% Window	U-Factor	\$ 2.00	sq ft window	0.75			\$ 774			\$ 774	Paquette (2010)
	SHGC			0.40							
Ceilings			sq ft attic	0.035							
Frame Walls				0.082							
Mass Wall				N/A							
Floors				0.064							ASHRAE 1481 RP
Bsmt Walls				0.360							ASHRAE 1481 RP
Slab				0							
Crawl Wall				0.477							
CFL		\$ 1.00	% cfl	10%			\$ 65			\$ 65	Local Survey
Ducts		\$ 1,691	per house	15.0%	Inside		\$ 1,691			\$ 1,691	Building America
Blower Door		\$ 186	per house	N/R	Required		\$ 186			\$ 186	Southface
Air Sealing		\$ 0.41	sq ft floor	N/R	3 ACH 50		\$ 955			\$ 955	ASHRAE 1481 RP
Mechanical Ventilation		\$ 430	per house	N/R	Required		\$ 430			\$ 430	Russell (2005)
Duct Blaster		\$ 186	per house	N/R	Required		\$ 186			\$ 186	Southface
R-3 Plumbing				N/R	R-0						NAHB RC (2010)
Prog Thermostat		\$ 28	per house	N/R	Required		\$ 28			\$ 28	Local Survey
Electric Heat Pump		\$ 1,458	per house	13/7.7	15/8.5		\$ 1,020			\$ 1,020	
Gas Furnace		\$ 519	per house	78	80						
Electric Air Conditione			per house	13.0	15.0		\$ 156			\$ 156	ASHRAE 1481 RP
Incremental Cost							\$ 5,491			\$ 5,491	\$ 5,491

Mass Walls	Cost		Code Requirement	Foundation Distribution					Cost Source		
	Unit Cost	Unit		Heating Fuel %	0% Conditioned Basement	0% Conditioned Crawlspace	90% Slab on Grade	0% Unconditioned Basement		10% Vented Crawlspace	
15% Window	U-Factor	\$ 2.00	sq ft window	0.75			\$ 774			\$ 774	Paquette (2010)
	SHGC			0.40							
Ceilings			sq ft attic	0.035							
Frame Walls				N/A							
Mass Wall				R-4							
Floors				0.064							ASHRAE 1481 RP
Bsmt Walls				0.360							ASHRAE 1481 RP
Slab				0							
Crawl Wall				0.477							
CFL		\$ 1.00	% cfl	10% (est)			\$ 65			\$ 65	Local Survey
Ducts		\$ 1,691	per house	15.0%	Inside		\$ 1,691			\$ 1,691	Building America
Blower Door		\$ 186	per house	N/R	Required		\$ 186			\$ 186	Southface
Air Sealing		\$ 0.41	sq ft floor	N/R	3 ACH 50		\$ 955			\$ 955	ASHRAE 1481 RP
Mechanical Ventilation		\$ 430	per house	N/R	Required		\$ 430			\$ 430	Russell (2005)
Duct Blaster		\$ 186	per house	N/R	Required		\$ 186			\$ 186	Southface
R-3 Plumbing				N/R	R-0						NAHB RC (2010)
Prog Thermostat		\$ 28	per house	N/R	Required		\$ 28			\$ 28	Local Survey
Electric Heat Pump		\$ 1,458	per house	13/7.7	15/8.5		\$ 1,020			\$ 1,020	ASHRAE 1481 RP
Gas Furnace		\$ 519	per house	78	80						
Electric Air Conditione			per house	13.0	15.0		\$ 156			\$ 156	ASHRAE 1481 RP
Incremental Cost							\$ 5,491			\$ 5,491	\$ 5,491

Climate Zone 2 Weighted Average Incremental Cost= \$ 5,491

Climate Zones 3 and 4

Framed Walls	Cost		Code Requirement	Heating Fuel %	Foundation Distribution				Cost Source	
	Unit Cost	Unit			0% Conditioned Basement	0% Conditioned Crawlspace	75% Slab on Grade	15% Unconditioned Basement		10% Vented Crawlspace
100% Window	U-Factd SHGC	\$ 2.50	sq ft window	50% Solution						
				0.65						
				0.40 e						
Ceilings				0.035						
Frame Walls				0.082						
Mass Wall				N/A						
Floors				0.047						
Bsmt Walls				0.360						
Slab				0						
Crawl Wall				0.136						
CFL				100%						
Ducts				15% (base) Inside						
Blower Door				Required						
Air Sealing				3 ACH 50						
Mechanical Ventilation				Required						
Duct Blaster				Required						
R-3 Plumbing				R-0						
Prog Thermostat				Required						
Electric Heat Pump				137.7						
Gas Furnace				78						
Electric Air Conditione				13.0						
Incremental Cost				15.0						
Climate Zone 3 Weighted Average Incremental Cost=										\$ 5,569

Framed Walls	Cost		Code Requirement	Heating Fuel %	Foundation Distribution				Cost Source	
	Unit Cost	Unit			35% Conditioned Basement	0% Conditioned Crawlspace	25% Slab on Grade	20% Unconditioned Basement		10% Vented Crawlspace
100% Window	U-Factd SHGC	\$ 1.00	sq ft window	50% Solution						
				0.40						
				0.30						
				0.40						
Ceilings				0.030						
Frame Walls				0.026						
Mass Wall				0.057						
Floors				N/A						
Bsmt Walls				0.047						
Slab				0.059						
Crawl Wall				10/2						
CFL				0.065						
Ducts				10% (base) 15%						
Blower Door				Required						
Air Sealing				2 ACH 50						
Mechanical Ventilation				Required						
Duct Blaster				Required						
R-3 Plumbing				R-0						
Prog Thermostat				Required						
Electric Heat Pump				137.7						
Gas Furnace				78						
Electric Air Conditione				13.0						
Incremental Cost				17.0						
Climate Zone 4 Weighted Average Incremental Cost=										\$ 8,572

Climate Zone 5, Light Frame and Mass Walls

Framed Walls	Cost		Code Requirement	Heating Fuel %	Foundation Distribution					Cost Source	
	Unit Cost	Unit			45% Conditioned Basement	5% Conditioned Crawlspace	10% Slab on Grade	35% Unconditioned Basement	5% Vented Crawlspace		
95% U-Factor SHGC											
Window	\$ 0.50	sq ft window	2006 IECC 0.35	0.30	\$ 194	\$ 194	\$ 194	\$ 194	\$ 194	\$ 194	ASHRAE 90.1 Env
Ceilings	\$ 0.53	sq ft attic	N/R	0.40	\$ 941	\$ 941	\$ 941	\$ 941	\$ 941	\$ 941	ASHRAE 1481 RP
Frame Walls		sq ft wall	0.060	0.060							ASHRAE 1481 RP
Mass Wall			N/A	N/A							
Floors	\$ 0.56		0.033	0.028				\$ 1,001	\$ 1,001	\$ 1,001	ASHRAE 1481 RP
Bsmt Walls	\$ 1.18	sq ft base w	0.059	0.040	\$ 1,856						ASHRAE 1481 RP
Slab	\$ 2.11		10/2	10/4		\$ 928					ASHRAE 1481 RP
Crawl Wall	\$ 1.18	sq ft base w	0.065	0.040							ASHRAE 1481 RP
CFL	\$ 1.00	% cfl	10% (base)	100%	\$ 90	\$ 90	\$ 90	\$ 90	\$ 90	\$ 90	Local Survey
Ducts		per house	15% (base)	15%	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	Building America
Blower Door	\$ 186	per house	N/R	Required	\$ 186	\$ 186	\$ 186	\$ 186	\$ 186	\$ 186	Southface
Air Sealing	\$ 0.57	per house	N/R	2 ACH 50	\$ 1,337	\$ 1,337	\$ 1,337	\$ 1,337	\$ 1,337	\$ 1,337	ASHRAE 1481 RP
Mechanical Ventilation	\$ 430	sq ft floor	N/R	Required	\$ 430	\$ 430	\$ 430	\$ 430	\$ 430	\$ 430	Russell (2005)
Duct Blaster	\$ 186	per house	N/R	Required	\$ 186	\$ 186	\$ 186	\$ 186	\$ 186	\$ 186	Southface
R-3 Plumbing		per house	N/R	R-0							NAHB RC (2010)
Prog Thermostat	\$ 28	per house	N/R	Required	\$ 28	\$ 28	\$ 28	\$ 28	\$ 28	\$ 28	Local Survey
Electric Heat Pump	\$ 2,470	per house	13/7.7	18/9.5	\$ 494	\$ 494	\$ 494	\$ 494	\$ 494	\$ 494	ASHRAE 1481 RP
Gas Furnace	\$ 2,349	per house	78	95	\$ 1,879	\$ 1,879	\$ 1,879	\$ 1,879	\$ 1,879	\$ 1,879	ASHRAE 1481 RP
Electric Air Conditione		per house	13.0	17.0							
Incremental Cost					\$ 7,621	\$ 6,693	\$ 6,490	\$ 6,766	\$ 6,766	\$ 6,766	\$ 7,119

Mass Walls	Cost		Code Requirement	Heating Fuel %	Foundation Distribution					Cost Source	
	Unit Cost	Unit			45% Conditioned Basement	5% Conditioned Crawlspace	10% Slab on Grade	35% Unconditioned Basement	5% Vented Crawlspace		
5% U-Factor SHGC											
Window	\$ 0.50	sq ft window	2006 IECC 0.35	0.30	\$ 194	\$ 194	\$ 194	\$ 194	\$ 194	\$ 194	ASHRAE 90.1 Env
Ceilings	\$ 0.53	sq ft attic	0.030	0.026	\$ 941	\$ 941	\$ 941	\$ 941	\$ 941	\$ 941	ASHRAE 1481 RP
Frame Walls		sq ft wall	N/A	N/A							ASHRAE 1481 RP
Mass Wall		per house	R-13	R-13							ASHRAE 1481 RP
Floors	\$ 0.56		0.033	0.028				\$ 1,001	\$ 1,001	\$ 1,001	ASHRAE 1481 RP
Bsmt Walls	\$ 1.18	sq ft base w	0.059	0.040	\$ 1,856						ASHRAE 1481 RP
Slab	\$ 2.11		10/2	10/4		\$ 928					ASHRAE 1481 RP
Crawl Wall	\$ 1.18	sq ft base w	0.065	0.040							ASHRAE 1481 RP
CFL	\$ 1.00	% cfl	10% (base)	100%	\$ 90	\$ 90	\$ 90	\$ 90	\$ 90	\$ 90	Local Survey
Ducts		per house	15% (base)	15%	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	Building America
Blower Door	\$ 186	per house	N/R	Required	\$ 186	\$ 186	\$ 186	\$ 186	\$ 186	\$ 186	Southface
Air Sealing	\$ 0.57	per house	N/R	2 ACH 50	\$ 1,337	\$ 1,337	\$ 1,337	\$ 1,337	\$ 1,337	\$ 1,337	ASHRAE 1481 RP
Mechanical Ventilation	\$ 430	sq ft floor	N/R	Required	\$ 430	\$ 430	\$ 430	\$ 430	\$ 430	\$ 430	Russell (2005)
Duct Blaster	\$ 186	per house	N/R	Required	\$ 186	\$ 186	\$ 186	\$ 186	\$ 186	\$ 186	Southface
R-3 Plumbing		per house	N/R	R-0							NAHB RC (2010)
Prog Thermostat	\$ 28	per house	N/R	Required	\$ 28	\$ 28	\$ 28	\$ 28	\$ 28	\$ 28	Local Survey
Electric Heat Pump	\$ 2,470	per house	13/7.7	18/9.5	\$ 494	\$ 494	\$ 494	\$ 494	\$ 494	\$ 494	ASHRAE 1481 RP
Gas Furnace	\$ 2,349	per house	78	95	\$ 1,879	\$ 1,879	\$ 1,879	\$ 1,879	\$ 1,879	\$ 1,879	ASHRAE 1481 RP
Electric Air Conditione		per house	13.0	17.0							
Incremental Cost					\$ 7,621	\$ 6,693	\$ 6,490	\$ 6,766	\$ 6,766	\$ 6,766	\$ 7,119

Climate Zone 5 Weighted Average Incremental Cost= \$ 7,119

Climate Zones 6, 7, and 8

Framed Walls	Cost		Code Requirement	Foundation Distribution					Heating Fuel %	Cost Source
	Unit Cost	Unit		75%	5%	5% Slab on Grade	10% Unconditioned Basement	5% Vented Crawlspace		
100%			2006 IECC							
Window	\$ 0.50	sq ft window	0.35	\$ 194	\$ 194	\$ 194	\$ 194	\$ 194	ASHRAE 90.1 Env	
U-Fac										
SHGC										
Ceilings										
Frame Walls	\$ 2.31	sq ft of wall	0.026	\$ -	\$ -	\$ -	\$ -	\$ -		
Mass Wall				\$ 5,963	\$ 5,963	\$ 5,963	\$ 5,963	\$ 5,963	ASHRAE 1481 RP	
Floors	\$ 0.56									
Bsmt. Walls	\$ 1.18	sq ft base w	0.059							
Slab				\$ 1,856				\$ 1,001		
Crawl Wall	\$ 1.18	sq ft base w	0.065							
CFL	\$ 1.00	% cfl	10% (base)	\$ 90	\$ 90	\$ 90	\$ 90	\$ 90	ASHRAE 1481 RP	
Ducts	\$ 902	per house	15% (base)	\$ 902	\$ 902	\$ 902	\$ 902	\$ 902	Local Survey	
Blower Door	\$ 186	per house	Required	\$ 186	\$ 186	\$ 186	\$ 186	\$ 186	Building America	
Air Sealing	\$ 0.57	per house	2 ACH 50	\$ 1,337	\$ 1,337	\$ 1,337	\$ 1,337	\$ 1,337	Southface	
Mechanical Ventilation	\$ 430	sq ft floor	Required	\$ 430	\$ 430	\$ 430	\$ 430	\$ 430	ASHRAE 1481 RP	
Duct Blaster	\$ 186	per house	Required	\$ 186	\$ 186	\$ 186	\$ 186	\$ 186	Russell (2005)	
R-3 Plumbing									Southface	
Prog Thermostat	\$ 28	per house	Required	\$ 28	\$ 28	\$ 28	\$ 28	\$ 28	NAHB RC (2010)	
Electric Heat Pump	\$ 2,470	per house	13/7.7	\$ 124	\$ 124	\$ 124	\$ 124	\$ 124	Local Survey	
Gas Furnace				\$ 1,738	\$ 1,738	\$ 1,738	\$ 1,738	\$ 1,738	ASHRAE 1481 RP	
Electric Air Conditioner	\$ 1,830	per house	78							
Incremental Cost			13.0	\$ 13,034	\$ 12,106	\$ 11,178	\$ 12,179	\$ 12,179	\$ 12,766	
Climate Zone 6 Weighted Average Incremental Cost=									\$ 12,766	

Framed Walls	Cost		Code Requirement	Foundation Distribution					Heating Fuel %	Cost Source
	Unit Cost	Unit		75%	5%	5% Slab on Grade	10% Unconditioned Basement	5% Vented Crawlspace		
100%			2006 IECC							
Window	\$ 0.50	sq ft window	0.35	\$ 194	\$ 194	\$ 194	\$ 194	\$ 194	ASHRAE 90.1 Env	
U-Fac										
SHGC										
Ceilings										
Frame Walls	\$ 2.11	sq ft of wall	0.057	\$ 5,440	\$ 5,440	\$ 5,440	\$ 5,440	\$ 5,440	ASHRAE 1481 RP	
Mass Wall										
Floors	\$ 0.56	sq ft floor	0.033							
Bsmt. Walls	\$ 1.18	sq ft base w	0.059							
Slab	\$ 3.24									
Crawl Wall	\$ 1.18	sq ft base w	0.065							
CFL	\$ 1.00	% cfl	10% (base)							
Ducts	\$ 902	per house	15% (base)	\$ 902	\$ 902	\$ 902	\$ 902	\$ 902	Local Survey	
Blower Door	\$ 186	per house	Required	\$ 186	\$ 186	\$ 186	\$ 186	\$ 186	Building America	
Air Sealing	\$ 0.57	per house	2 ACH 50	\$ 1,337	\$ 1,337	\$ 1,337	\$ 1,337	\$ 1,337	Southface	
Mechanical Ventilation	\$ 430	sq ft floor	Required	\$ 430	\$ 430	\$ 430	\$ 430	\$ 430	ASHRAE 1481 RP	
Duct Blaster	\$ 186	per house	Required	\$ 186	\$ 186	\$ 186	\$ 186	\$ 186	Russell (2005)	
R-3 Plumbing									Southface	
Prog Thermostat	\$ 28	per house	Required	\$ 28	\$ 28	\$ 28	\$ 28	\$ 28	NAHB RC (2010)	
Electric Heat Pump	\$ 2,470	per house	13/7.7	\$ -	\$ -	\$ -	\$ -	\$ -	Local Survey	
Gas Furnace				\$ 1,830	\$ 1,830	\$ 1,830	\$ 1,830	\$ 1,830	ASHRAE 1481 RP	
Electric Air Conditioner	\$ 1,830	per house	78							
Incremental Cost			13.0	\$ 12,478	\$ 11,550	\$ 12,952	\$ 11,623	\$ 11,623	\$ 12,327	
Climate Zones 7 & 8 Weighted Average Incremental Cost=									\$ 12,327	



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