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Maximum Energy Efficiency Cost Effectiveness in New Home Construction

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Prepared for

ASHRAE SSPC 90.2
Energy Efficient Design of Low-Rise Residential Buildings

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Background

SSPC 90.2 is in the process of developing an update to ASHRAE Standard 90.2. This update is based on the stated objective that 90.2 will be a performance standard and that all prescriptive applications of the 90.2 Standard will meet the performance criteria. This objective was passed as an SSPC motion at its June 2013 meeting in Denver, as follows:

> "Standard 90.2 shall be a performance standard and shall have a performance compliance path. At least one prescriptive compliance path will be developed. All prescriptive compliance paths developed under the standard shall satisfy the performance compliance criteria."

By motion at its June 2014 meeting in Seattle, SSPC 90.2 voted to affirm that the 2006 IECC would serve as the baseline for determining savings targets for Standard 90.2. At previous meetings, SSPC 90.2 also adopted the recommendations of the Standard 90.2 Standards Advisory Panel (SAP) to seek 50% savings compared to this 2006 IECC baseline "subject to cost effectiveness."

At its December 20, 2012 meeting, SSPC 90.2 finalized the adoption of the economic parameters and energy prices by which cost effectiveness is to be determined. And at its January 2015 meeting in Chicago, SSPC 90.2 passed a motion requesting that an economic cost effectiveness analysis be performed "using the methods and procedures prescribed in Fairey, et al. (2014)" to determine the *maximum energy efficiency* that can be considered cost effective to the consumer for new residential construction. This report is prepared in response to that motion.

Finally, at its May 5, 2015, meeting, SSPC 90.2 adopted by motion the13 representative Typical Meteorological Year (TMY) cities that are used to conduct the simulations and analysis of energy savings and cost effectiveness contained in this report.

Abstract

EnergyGauge® USA (v.4.0.00) is used to examine the cost effectiveness of high performance homes that are improved to significantly exceed the minimum requirements of the 2015 IECC. The objective of the study is to determine the maximum level of energy efficiency that can be considered cost effective to the consumer. For these purposes, it is the cost effectiveness of the entire package of measures that is considered by the analysis rather than the cost effectiveness of individual measures. Optimization and rank ordering of the individual improvement measures in the package is not considered by the analysis.

One-story 2,000 ft^2, 3-bedroom and 2-story, 2,400 ft^2, 3- bedroom single-family homes in thirteen representative TMY cities, representing 8 IECC climate zones, are considered by the analysis. The energy use of the high performance Improved Homes is compared against the 2015 IECC Code Homes and against the SSPC 90.2 Reference Homes.

Simulations for each home are conducted for both a *best case* home orientation and a *worst case* home orientation. Improvements to the 2015 IECC homes are made such that the cost effectiveness of the improved homes have a savings to investment ratio (SIR) between 1.00 and 1.10 in order to determine the maximum efficiency that can be considered cost effective to the consumer. The incremental savings and improvement costs are estimated as the difference between the 2015 IECC Code Home and the Improved Home. Economic cost effectiveness calculations are performed in accordance with Appendix A, as taken from Section 4.6, ANSI/RESNET 301-2014.

The analysis shows that significant energy efficiency improvements relative to the 2015 IECC can be cost effectively achieved in all 13 representative TMY cities for all of the home configurations under all of the conditions evaluated.

Methodology

One-story, 2,000 ft^2, 3-bedroom frame homes and two-story, 2,400 ft^2, 3-bedroom frame homes are configured to simulate three different home archetypes in thirteen representative TMY cities across the eight climate zones of the United States. TMY3 data are used for the simulations. The three different archetypes are configured to be representative of the following:

1. SSPC 90.2 Reference Home as adopted by SSPC 90.2 – representing the 2006 IECC Standard Reference Design with 2006 equipment, lighting and appliances
2. 2015 IECC Code Home with envelope insulation as prescribed by Table R402.1.2 and with 2015 NAECA minimum equipment (baseline for cost effectiveness calculations)
3. Improved Home with enhanced envelope and equipment features.

The improvement analysis is conducted for two distinct sets of renewable energy conditions:

- Improved Homes without photovoltaic (PV) power production and
- Improved homes with PV power production and with net metering assumed.

Energy use results from each set of home configurations are used to conduct the analysis. For the economic analysis, energy savings and incremental costs are calculated as the difference between the 2015 IECC Code Home and the Improved Home. The 2015 IECC Code Home is used as the basis for the cost effectiveness calculations because it is the current national model energy code standard. To calculate the percentage energy and cost saving relative to the 90.2 Reference Home, the source energy use and energy cost differences between the SSPC 90.2 Reference Home and the Improved Home are used. These percentage savings values are needed to determine levels of savings that can serve as targets for Standard 90.2 compliance.

Home Configurations

Windows are configured in all home archetypes such that 35% of the total window area was located on the front and rear faces of the home and 15% was located on the side faces. This allows the simulations to examine a *best-case* orientation scenario with the front of the homes facing north and a *worst-case* scenario with the front facing east. The front of the homes also has a 20-foot adjoining garage wall. The foundation for the homes is varied by IECC climate zone with slab-on-grade foundations in zones 1 through 4 (except the Seattle homes, which are on a crawlspace) and with unconditioned basement foundations in zones 5 through 8.

Tables 1 through 7 present the characteristics for the home configurations used as the 90.2 Reference Home and 2015 IECC Code Home baselines for the study.

Table 1: Best-Case Home Characteristics

Component	1-story	2-Story
1st floor area (ft^2)	2,000	1,200
2nd floor area (ft^2)	0	1,200
Total above grade floor area (ft^2)	2,000	2,400
Total above grade volume (ft^3)	18,000	21,000
N-S wall length (ft)	50	40
E-W wall length (ft)	40	30
1st floor wall height (ft)	9	8
Height between floors (ft)	0	1.5
2nd floor wall height (ft)	0	8
Door area (ft^2)	40	40
Window/floor area ratio (%)	15%	15%
Total window area (ft^2)	300	360
N-S window fraction (%)	35%	35%
E-W window fraction (%)	15%	15%

Table 2: 90.2 Reference Home Component Thermal Characteristics

LOCATION	IECC CZ	Ceiling U-factor	Wall U-factor	Found. Type	Slab R-value	Floor U-factor	Fen U-factor	Fen SHGC
Miami, FL	1A	0.035	0.082	SOG	none	n/a	1.20	0.40
Houston, TX	2A	0.035	0.082	SOG	none	n/a	0.75	0.40
Phoenix, AZ	2B	0.035	0.082	SOG	none	n/a	0.75	0.40
Atlanta, GA	3A	0.035	0.082	SOG	none	n/a	0.65	0.40
El Paso, TX	3B	0.035	0.082	SOG	none	n/a	0.65	0.40
Los Angeles, CA	3C	0.035	0.082	SOG	none	n/a	0.65	0.40
Philadelphia, PA	4A	0.030	0.082	SOG	10, 2ft	n/a	0.40	0.40
Albuquerque, NM	4B	0.030	0.082	SOG	10, 2ft	n/a	0.40	0.40
Seattle, WA	4C	0.030	0.060	Crawl	n/a	0.033	0.35	0.40
Chicago, IL	5A	0.030	0.060	ucBsmt	n/a	0.033	0.35	0.40
Minneapolis, MN	6A	0.026	0.060	ucBsmt	n/a	0.033	0.35	0.40
Duluth, MN	7A	0.026	0.057	ucBsmt	n/a	0.033	0.35	0.40
Fairbanks, AK	8	0.026	0.057	ucBsmt	n/a	0.033	0.35	0.40

Table 3: 2015 IECC Code Home Component Thermal Characteristics

LOCATION	IECC CZ	Ceiling R-value	Wall R-value	Found. Type	Slab R-value	Floor R-value	Fen U-factor	Fen SHGC
Miami, FL	1A	30	13	SOG	none	n/a	0.50	0.25
Houston, TX	2A	38	13	SOG	none	n/a	0.40	0.25
Phoenix, AZ	2B	38	13	SOG	none	n/a	0.40	0.25
Atlanta, GA	3A	38	13+5	SOG	none	n/a	0.35	0.25
El Paso, TX	3B	38	13+5	SOG	none	n/a	0.35	0.25
Los Angeles, CA	3C	38	13+5	SOG	none	n/a	0.35	0.25
Philadelphia, PA	4A	49	13+5	SOG	10, 2ft	n/a	0.35	0.40
Albuquerque, NM	4B	49	13+5	SOG	10, 2ft	n/a	0.35	0.40
Seattle, WA	4C	49	13+5	Crawl	n/a	30	0.32	0.40
Chicago, IL	5A	49	13+5	ucBsmt	n/a	30	0.32	0.40
Minneapolis, MN	6A	49	13+10	ucBsmt	n/a	30	0.32	0.40
Duluth, MN	7A	49	13+10	ucBsmt	n/a	30	0.32	0.40
Fairbanks, AK	8	49	13+10	ucBsmt	n/a	38	0.32	0.40

Notes for Tables 2 and 3:

Wall R-value: 1st value is cavity fill and 2nd value is continuous insulation

LOCATION	IECC CZ	Ceiling R-value	Wall R-value	Found. Type	Slab R-value	Floor R-value	Fen U-factor	Fen SHGC

SOG = slab on grade
Crawl = crawlspace
ucBsmt = unconditioned basement

Table 4: Additional Reference Home Characteristics

Item	90.2 Reference	2015 IECC Code
Envelope Leakage	SLA = 0.00036	CZ 1-2: 5 ach50 CZ 3-8: 3 ach50
Air Distribution System Efficiency	DSE = 0.80	See Table 4
Programmable Thermostat	No	Yes
High Efficiency Lighting	10%	75%
Hot Water Pipe Insulation	No	Yes
Mechanical Ventilation	RESNET Std. 301-2014	ASHRAE Std. 62.2-2013
Sealed Air Handlers	No	Yes

Table 5: Air Distribution Systems (ADS) for 2015 Code Homes

Foundation Type	ADS location	Duct R-value	Duct leakage
Slab on grade	Attic	8	4 cfm25/100 ft^2
Crawlspace	Crawlspace	8	4 cfm25/100 ft^2
Basement	Basement	8	4 cfm25/100 ft2

Thermostat set point temperatures for all simulations are maintained at the 90.2 Reference Home (IECC 2006) values of 78 ^oF for cooling and 68 ^oF for heating. While the 2015 IECC uses 75 ^oF for cooling and 72 ^oF for heating, use of the 2015 IECC thermostat set points for this study would not allow for realistic comparisons with the 90.2 Reference Home.

Table 6: 90.2 Reference Home Equipment

LOCATION	IECC CZ	Heating System		Cooling System		Water Heater	
		Fuel	Eff	Fuel	SEER	Fuel	EF
Miami, FL	1A	elec	7.7	elec	13	elec (40)	0.92
Houston, TX	2A	elec	7.7	elec	13	elec (40)	0.92
Phoenix, AZ	2B	elec	7.7	elec	13	elec (40)	0.92
Atlanta, GA	3A	gas	78%	elec	13	gas (40)	0.59
El Paso, TX	3B	gas	78%	elec	13	gas (40)	0.59
Los Angeles, CA	3C	gas	78%	elec	13	gas (40)	0.59
Philadelphia, PA	4A	gas	78%	elec	13	gas (40)	0.59
Albuquerque, NM	4B	gas	78%	elec	13	gas (40)	0.59
Seattle, WA	4C	gas	78%	elec	13	gas (40)	0.59
Chicago, IL	5A	gas	78%	elec	13	gas (40)	0.59
Minneapolis, MN	6A	gas	78%	elec	13	gas (40)	0.59
Duluth, MN	7A	gas	78%	elec	13	gas (40)	0.59
Fairbanks, AK	8	gas	78%	elec	13	gas (40)	0.59

Table 7: 2015 IECC Code Home Equipment

LOCATION	IECC CZ	Heating System		Cooling System		Water Heater	
		Fuel	Eff	Fuel	SEER	Fuel	EF
Miami, FL	1A	elec	8.2	elec	14	elec (40)	0.95
Houston, TX	2A	elec	8.2	elec	14	elec (40)	0.95
Phoenix, AZ	2B	elec	8.2	elec	14	elec (40)	0.95
Atlanta, GA	3A	gas	80%	elec	14	gas (40)	0.62
El Paso, TX	3B	gas	80%	elec	14	gas (40)	0.62
Los Angeles, CA	3C	gas	80%	elec	14	gas (40)	0.62

LOCATION	IECC CZ	Heating System		Cooling System		Water Heater	
		Fuel	Eff	Fuel	SEER	Fuel	EF
Philadelphia, PA	4A	gas	80%	elec	14	gas (40)	0.62
Albuquerque, NM	4B	gas	80%	elec	14	gas (40)	0.62
Seattle, WA	4C	gas	80%	elec	13	gas (40)	0.62
Chicago, IL	5A	gas	80%	elec	13	gas (40)	0.62
Minneapolis, MN	6A	gas	80%	elec	13	gas (40)	0.62
Duluth, MN	7A	gas	80%	elec	13	gas (40)	0.62
Fairbanks, AK	8	gas	80%	elec	13	gas (40)	0.62

Notes for Tables 6 and 7:

Eff = heating system efficiency where gas-fired furnace is given as AFUE (%) and electric heat pump is given as HSPF

The most common efficiency improvements employed in the study comprised 100% high-efficiency lighting; higher efficiency heating, cooling and water heating equipment; interior, leak-free duct systems; enhanced envelope efficiencies; and ENERGY STAR refrigerators, dishwashers and clothes washers.

Efficiency measures are incorporated into the Improved Homes based on multiple factors. Since the objective is to reduce energy use in the Improved Homes as much as can be justified by consumer cost effectiveness (i.e. SIR), measures are added or subtracted on an iterative basis to achieve that end. For example, ERVs are incorporated in most homes to reduce the energy impacts of ASHRAE 62.2 mechanical ventilation requirements. However, in Los Angeles the energy reduction benefit of an ERV does not justify the incremental cost of the ERV ($650 for this study) because the heating and cooling loads in Los Angeles are so small. As another example, the energy savings from high efficiency gas furnaces are so large in the northern most climates that a number of relatively expensive envelope thermal improvement measures are justified with respect to the resulting SIR. Additionally, in some cases the improvement measures selected for the 1-story Improved Home are different than those selected for the 2-story Improved Home. In summary, the author made decisions on the efficiency measures included in each Improved Home based on multiple iterative simulations using the various efficiency measures available and the resulting cost effectiveness (SIR) that the measures achieved.

The selected improvement measures, their cost and the cost effectiveness results for each Improved Home are given for each representative TMY city in Appendices C and D.

Improvement Costs

Incremental improvement costs are determined using the methodology used by Fairey and Parker (2012). In most cases, improvement costs used in the investigation parallel those available from the National Renewable Energy Laboratory's (NREL) National Residential Efficiency Measure Database.[1]

For heating and air conditioning equipment costs, Fairey and Parker (2012) relied on a separate methodology whereby the costs are expressed as a function of the equipment capacity and efficiency along with an offset, derived using available retail data and estimated fixed costs. The data and analysis that underlie the heating and cooling equipment cost equations are presented in Appendix B. For certain other costs, the NREL cost data were reduced to equations based on component areas and incremental improvement changes. For example, examination of the NREL

[1] www.nrel.gov/ap/retrofits/index.cfm

data on blown cellulose insulation reveals that the cost is approximately $0.035/ft^2 per R-value. For these types of improvements these costs are cast in such terms. For most other costs, the costs contained in the NREL database are adopted.

For ENERGY STAR appliance costs, representative pricing from the internet is used to determine incremental costs. However, this is difficult because most new appliances are now ENERGY STAR compliant and it is often difficult to find appliances with similar features that are not rated as ENERGY STAR.

Attic radiant barrier systems (RBS) are employed to enhance efficiency in a number of cooling dominated and mixed climate homes. The cost of the RBS is determined as $0.25 per square foot of roof area. For each of the improved homes, the forced air distribution systems is brought into the conditioned space and tested to be leak free. The cost of this improvement is taken as $0.50 per square foot of conditioned floor area.

For HVAC equipment, the following equations are used to calculate installed costs (see Appendix B for derivations).

- Heat pumps: –5539 + 604*SEER + 699*tons
- Air conditioners (with strip heat): –1409 + 292*SEER + 520*tons
- Gas furnace/air conditioner: –6067 + 568*SEER + 517*tons + 4.04*kBtu + 1468*AFUE
- Gas furnace only: –3936 + 14.95*kBtu + 5865*AFUE

where:

tons = air conditioning capacity, which is limited to a minimum value of 1.5 tons
kBtu = gas furnace capacity, which is limited to a minimum value of 40 kBtu

The estimating equations are valid for heat pump and cooling system sizes of 1.5–5 tons. Similarly, the costs of gas heating equipment are based on heating capacities of 40–120 kBtu/h.

For envelope measures, incremental costs are determined as the difference between the measure cost for the 2015 IECC Code Home component and the measure cost for the Improved Home component. For example, if the ceiling insulation level requirement in the 2015 IECC home is R-30 and it is increased to R-38 in the Improved Home, the incremental cost would be the R-value difference (8) times $0.035 per square foot of ceiling area (for blown cellulose).

Wall R-value is increased in some Improved Homes in northern climates. Wall R-value may be increased in two ways: 1) the sheathing insulation R-value may be increased and 2) the wall cavity insulation R-value may be increased. Where the sheathing insulation R-value is increased, it is increased from R-5 (base case) to R-10. The incremental cost for this increase is taken as the difference in cost between the R-5 XPS base case ($1.30/ft^2) and the R-10 XPS improved case ($1.70/ft^2), as given in the NREL cost database.[2] The cost for the R-5 XPS base case sheathing can also be cross checked by examining the NAHB Research Center (2009) economic database developed in support of 90.2 (ASHRAE 1481-RP). Matrix B.1 of this report provides the cost values shown in Table 8.

[2] http://www.nrel.gov/ap/retrofits/measures.cfm?gId=12&ctId=410

Table 8: Construction cost for wood frame walls with fiberglass insulation

Construction	$/ft^2	Δ $/ft^2	
2x4, 16" oc; R-13	$5.72	---	base wall
add R-5 XPS	$6.95	$1.23	increase for sheathing on 2x4 walls
2x6, 24" oc; R21	$6.58	$0.86	increase for 2X6 studs + R-21
add R-5 XPS	$7.69	$1.97	increase for 2x6 + R-21 + R-5 sheathing

Table 8 data show the added cost for R-5 XPS sheathing to be $1.23/ft^2 of wall, which is very similar to the NREL cost database value of $1.30/ft^2. The ASHRAE 1481-RP report does not report construction costs for R-10 XPS so the values given in the NREL cost database are used for sheathing insulation improvements in the economic cost effectiveness analysis conducted here.

For wall cavity insulation, R-value may be increased from R-13 for 2x4 frame walls to R-21 for 2x6 frame walls. Table 8 shows that this increase in cavity wall R-value, including the change from 2x4 studs on 16" centers to 2x6 studs on 24" centers, has an incremental cost of $0.86/ft^2. The wall construction costs shown in Table 8 are used for wall cavity insulation improvements for the economic cost effectiveness analysis conducted here.

Floor R-value is also improved in some northern climate homes. The cost of floor R-Value improvements is derived from ASHRAE 1481-RP (Matrix C.1) as the average insulation cost per square foot per R-value for all configurations given in ASHRAE 1481-RP. This average cost is $0.045/ft^2/R.

Window thermal characteristics are also improved in some northern locations. Window improvement costs are given as a function of window U-factor by ASHRAE 1481-RP. Figure 1 of ASHRAE 1481-RP casts the incremental window cost above the cost of a standard, double pane window in terms of an exponential equation as a function of window U-factor, as follows:

$$\text{Incremental Window Cost} = 1851.9 * e^{(-19.29 * U)} \qquad \text{Eq. 1}$$

Equation 1 represents the incremental cost of improving the window U-Factor with respect to the cost of the standard, double pane window of the same frame type. Table 3 of ASHRAE 1481-RP provides 2009 construction costs for 5 standard, double pane, vinyl frame windows, with an average U-factor of 0.49 and an average cost of $15.09. Escalating this cost from 2009 to 2015 at a general inflation rate of 2.5% yields an average 2015 cost of $17.50. Thus the total cost of vinyl frame windows in new construction can be represented by the equation 2.

$$\text{Window Cost} = \$17.50 + 1851.9 * e^{(-19.29 * U)} \qquad \text{Eq. 2}$$

Incremental window improvement costs as a function of U-factor can also be derived from data provided in the NREL cost database.[3] Figure 1 shows the results from such an analysis of the incremental costs in the NREL cost database. While the resulting exponential equation has somewhat different coefficient values, the results are quite close and provide an additional level of confidence in the ASHRAE 1481-RP data in that they can be effectively confirmed using a second, independent data source. Figure 2 shows the similarity between the resulting equations along with the three window U-factors specified by the 2015 IECC, where climate zone 1 = 0.40, zones 2-4 = 0.35 and zones 5-8 = 0.32.

[3] http://www.nrel.gov/ap/retrofits/measures.cfm?gId=16&ctId=190

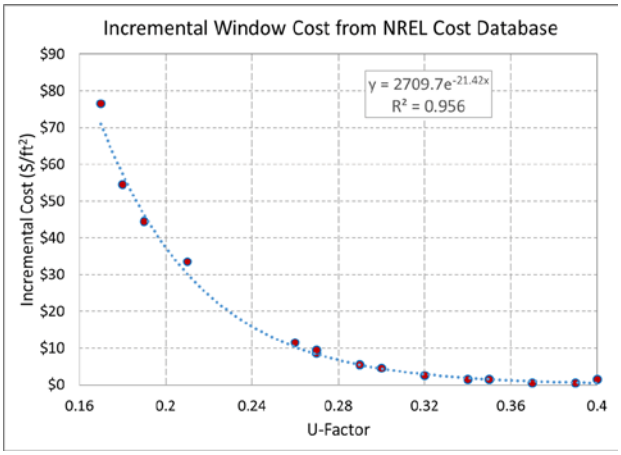

Figure 1: Incremental window cost versus window U-Factor derived from NREL cost database.

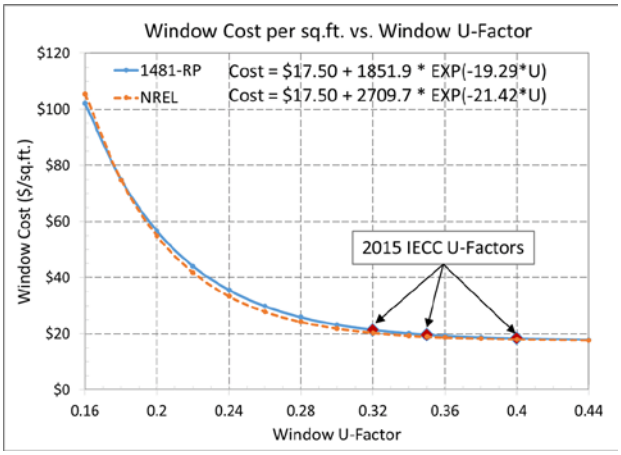

Figure 2: Comparison of ASHRAE 1481-RP window costs and NREL database window costs.

Equation 2 is used in this study to determine baseline and improved window costs where windows are improved.

The analysis is also conducted for two distinct sets of renewable energy conditions: 1) Improved Homes without photovoltaic (PV) power production; and 2) Improved homes with PV power production. Installed PV costs were taken at $4.00/Wp. This cost is somewhat greater than the costs reported by the Solar Market Research Report for the 3rd quarter of 2014, which shows residential turnkey Rooftop PV system costs steadily declining from $3.83/Wp during the 1st quarter of 2014 to $3.60/Wp in the 3rd quarter of the year.[4] A 30% income tax credit (ITC) is applied to the $4.00/Wp cost of PV systems. Net metering was assumed for the PV systems. PV power production was subtracted from the total electricity energy use of the home to arrive at the net electricity use for the homes given in Appendix D and in the tables contained in the body of the report.

Economic Analysis

Economic analysis is based on a 30-year life-cycle-cost analysis period as adopted by SSPC 90.2. The analysis is based on the P1, P2 method of determining present worth values derived by Duffie and Beckman (1980). The equations used to determine P1 and P2 are given in Appendix A. The economic parameter values adopted by SSPC 90.2 are used by the analysis. These economic parameter values are given in Table 9.

Table 9: Economic Parameter Values

General Inflation Rate (GR)	2.5%
Discount Rate (DR)	5.0%
Mortgage Interest Rate (MR)	5.0%
Down payment Rate (DnPmt)	10.0%
Energy Inflation Rate (ER)	2.5%
Effective Income Tax Rate (iTR)	25.0%
Property Tax Rate (pTR)	1.136%

The life-cycle-cost analysis includes replacement costs (escalated at the general inflation rate) for measures lasting less than the full analysis period (equal to standard residential mortgage period

[4] http://www.seia.org/research-resources/solar-market-insight-report-2014-q3

of 30 years in this case). For example, HVAC equipment, with an assumed service life of 15 years, would be replaced in year 16. High efficiency CFL lighting, with an assumed service life of 5 years, would be replaced five times during the analysis period. Where incremental maintenance is required, a maintenance fraction is also included in the analysis.

Energy prices used in the analysis are those adopted by SSPC 90.2. The prices used are $0.1180/kWh of electricity consumption and $1.078/therm of natural gas consumption. For the PV-equipped homes, electricity energy use is calculated assuming net metering such that the net electricity use reported for the homes is the total home energy use minus the useful PV power production. Source energy use is calculated using the source energy multipliers used by the U.S. DOE *Building America* program. These multipliers are 3.16 for electricity and 1.092 for natural gas. Energy prices and source energy multipliers are not varied by climate location.

Cost Effectiveness

For the purposes of this study 'cost effective' is defined as the case in which the present value of the life-cycle energy cost reductions (the savings) exceeds the present value of the life-cycle improvement costs (the investment). The ratio of these two present values (Savings / Investment) is referred to as the savings-to-investment ratio or SIR. If the SIR is greater than unity, there is a net financial benefit derived from the investment. The net present value (NPV) of the improvements is also calculated, where NPV equals the present value of the life-cycle energy cost savings minus the present value of the life-cycle improvement costs.

The goal of the analysis is to determine the maximum level of energy efficiency that can be considered cost effective to the consumer. To accomplish this, Improved Homes are improved to the point that the SIR for the improved home is between 1.0 and 1.1.

Figure 3 illustrates life-cycle cost economic analysis theory with respect to residential energy efficiency. The baseline home has no improvement costs, no energy savings and 100% of the baseline life-cycle total costs (the red dot on the plot). The Improvement Cost curve (dotted red line) represents the life-cycle costs of energy improvements that can be made to the baseline home. There are normally improvements that can be made to the baseline home that will reduce energy use at very low cost. However, as energy use continues to be reduced, the cost of the improvements per unit of energy savings increases, resulting in an Improvement Cost curve that is exponential in nature. The sum of the Improvement Cost curve and the Energy Cost line (dashed purple line) yield the Total Cost curve (solid green line). There is a point on the Total Cost curve where the life-cycle cost of the residence in minimized. For Figure 3, this point occurs at about 37% life-cycle energy cost savings (light green tringle). There is another point on the total cost curve where the Total life-cycle cost of the improved home is equal to the total cost of the baseline home (light blue diamond at about 59% life-cycle

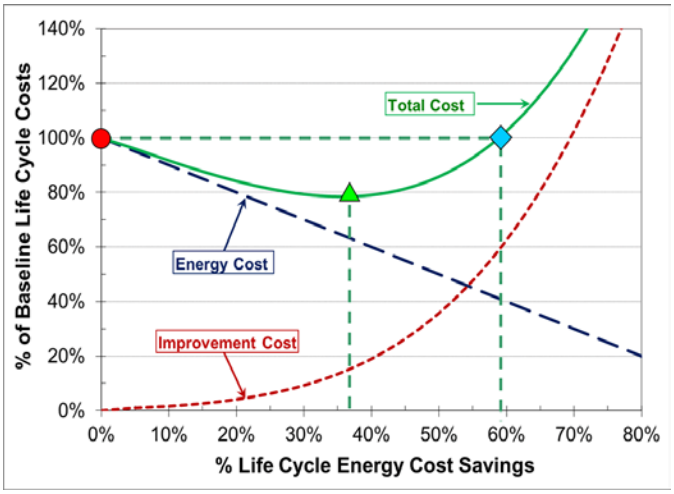

Figure 3: Generalized plot of life-cycle cost economic analysis theory.

energy cost savings). This point is often referred to as the neutral cost point. By definition it has an SIR of exactly 1.0 (i.e. life-cycle costs = life-cycle savings).

While Figure 3 is only illustrative, an SIR of 1.1 would occur on this plot at a life-cycle energy cost saving of approximately 57% or about 2% less than the neutral cost point.

Findings

The study finds that in all cases substantial energy savings over the minimum requirements of the 2015 IECC can be cost effective to the consumer. The detailed data for each home in each of the 13 representative TMY cities are given in Appendix C for the non-PV-equipped homes and in Appendix D for the PV-equipped homes. The four set of results (1-story, 2-story, *best-case*, and *worst-case*) are averaged to determine the average data for each of the 13 representative TMY cities. The average values for each of the 8 climate zones are then taken as the averages of the representative TMY cities in that climate zone. Once climate zone values are determined, it is possible to weight the results based on the fraction of new home starts (CZ Wgt.) in each climate zone (Drumheller 2012).

Tables 10 and 11 present the average site and source energy use values for non-PV-equipped homes and PV-equipped homes, respectively, in each of the climate zones.

Table 10: Climate zone average site and source energy use for non-PV-equipped homes

Climate Zone	CZ Wgt.	90.2 Reference Home			2015 Code Home			Improved Home		
		Site kWh/y	Site therms/y	Source MBtu	Site kWh/y	Site therms/y	Source MBtu	Site kWh/y	Site therms/y	Source MBtu
1	1.0%	16,343	0	176	13,095	0	141	8,653	0	93
2	21.4%	17,324	0	187	13,420	0	145	9,528	0	103
3	25.8%	9,805	409	150	7,818	296	117	6,463	200	91
4	22.8%	9,173	632	168	7,636	491	136	6,217	321	102
5	21.0%	11,794	902	226	9,101	691	173	7,315	488	132
6	6.8%	11,757	1,090	246	9,914	780	192	7,284	489	132
7	0.8%	11,018	1,327	263	9,553	940	205	6,943	593	139
8	0.5%	11,258	1,923	331	9,729	1,383	256	7,184	834	168
Average		**12,309**	**785**	**218**	**10,033**	**572**	**171**	**7,448**	**365**	**120**
Wgt'd average		**11,902**	**533**	**186**	**9,463**	**400**	**146**	**7,327**	**269**	**108**

Table 11: Climate zone average site and source energy use for PV-equipped homes

Climate Zone	CZ Wgt.	90.2 Reference Home			2015 Code Home			Improved Home		
		Site kWh/y	Site therms/y	Source MBtu	Site kWh/y	Site therms/y	Source MBtu	Site kWh/y	Site therms/y	Source MBtu
1	1.0%	16,343	0	176	13,095	0	141	5,256	0	57
2	21.4%	17,324	0	187	13,420	0	145	5,611	0	61
3	25.8%	9,805	409	150	7,818	296	117	3,650	199	61
4	22.8%	9,173	632	168	7,636	491	136	4,032	331	80
5	21.0%	11,794	902	226	9,101	691	173	4,874	496	107
6	6.8%	11,757	1,090	246	9,914	780	192	2,057	568	84
7	0.8%	11,018	1,327	263	9,553	940	205	2,076	678	96
8	0.5%	11,258	1,923	331	9,729	1,383	256	3,591	985	146
Average		**12,309**	**785**	**218**	**10,033**	**572**	**171**	**3,893**	**407**	**86**
Wgt'd average		**11,902**	**533**	**186**	**9,463**	**400**	**146**	**4,309**	**279**	**77**

Figure 4 presents the average percentage source energy and energy cost saving for the Improved Homes with respect to the 2015 IECC Code Homes in each of the 13 representative TMY cities.

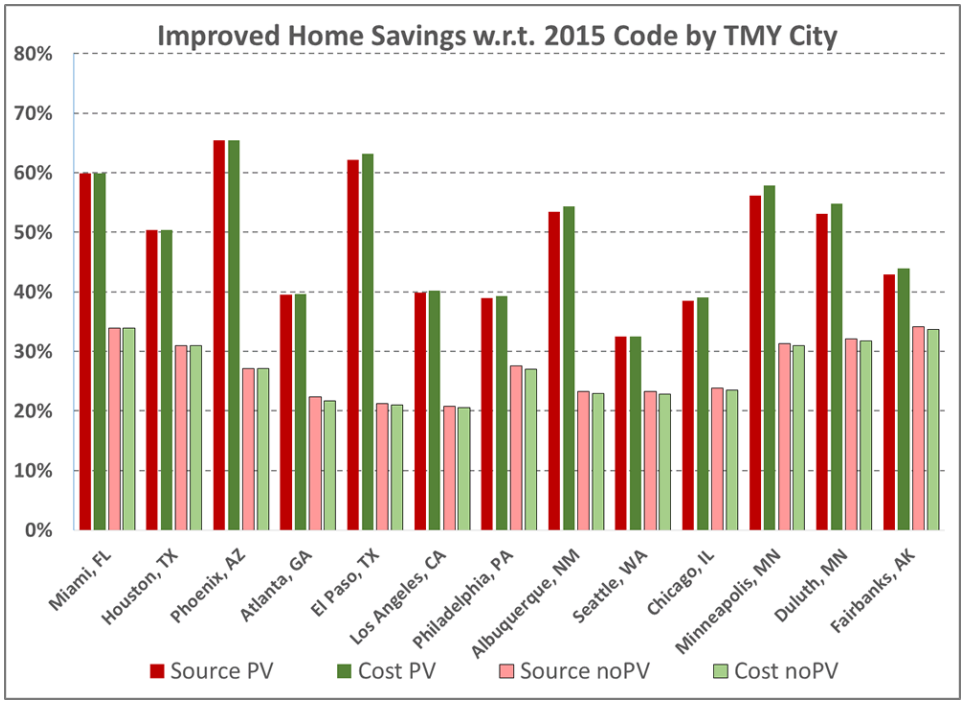

Figure 4: Source energy savings and energy cost savings for Improved Homes with respect to 2015 IECC Code Homes.

Savings over the 2015 IECC Code Homes range from 20% to 34% for the non-PV-equipped homes and from 33% to 65% for PV-equipped homes.

Tables 12 and 13 present the average life-cycle costs and life-cycle savings for the non-PV-equipped and PV-equipped Improved Homes, respectively, in each climate zone where improvement costs and energy savings are calculated with respect to the 2015 IECC Code Homes.

Table 12: Summary of Life-Cycle-Cost Analysis Results for non-PV-equipped Homes

Climate Zone	CZ Wgt.	Avg. LC Cost	Avg. LC Save	SIR	NPV	Simple Payback	% Source Savings*	% Cost Savings*
1	1.0%	$10,148	$10,762	1.06	$614	11.6	33.9%	33.9%
2	21.4%	$9,013	$9,431	1.05	$418	11.7	29.1%	29.0%
3	25.8%	$5,067	$5,357	1.06	$290	12.1	21.5%	21.2%
4	22.8%	$6,633	$7,083	1.07	$451	12.2	24.7%	24.4%
5	21.0%	$8,157	$8,689	1.07	$532	12.0	23.8%	23.5%
6	6.8%	$11,936	$12,632	1.06	$696	15.5	31.3%	31.0%
7	0.8%	$12,962	$13,793	1.06	$831	14.7	32.1%	31.8%
8	0.5%	$16,785	$17,973	1.07	$1,188	15.9	34.1%	33.7%
Average		**$10,088**	**$10,715**	**1.06**	**$627**	**13.7**	**28.8%**	**28.6%**
Wgt'd average		**$7,553**	**$7,997**	**1.06**	**$444**	**12.4**	**25.3%**	**25.4%**

* Savings are with respect to 2015 IECC Code Home (see also Appendix C)

Table 13: Summary of Life-Cycle-Cost Analysis Results for PV-equipped Homes

Climate Zone	CZ Wgt.	Avg. LC Cost	Avg. LC Save	SIR	NPV	Simple Payback	% Source Savings*	% Cost Savings*
1	1.0%	$17,721	$18,994	1.07	$1,273	12.5	59.9%	59.9%
2	21.4%	$17,642	$18,923	1.07	$1,281	12.5	57.9%	58.2%
3	25.8%	$11,702	$12,181	1.04	$480	13.0	47.2%	48.1%
4	22.8%	$11,713	$12,179	1.04	$466	12.8	41.6%	41.9%
5	21.0%	$13,689	$14,432	1.05	$743	12.7	38.5%	39.1%
6	6.8%	$21,923	$23,599	1.08	$1,676	12.7	56.2%	57.9%
7	0.8%	$22,143	$23,743	1.07	$1,600	12.7	53.1%	54.8%
8	0.5%	$21,983	$23,434	1.07	$1,451	12.8	42.9%	43.9%
Average		**$17,315**	**$18,436**	**1.06**	**$1,121**	**12.7**	**49.7%**	**50.5%**
Wgt'd average		**$14,278**	**$15,084**	**1.06**	**$806**	**12.7**	**47.1%**	**47.8%**

* Savings are with respect to 2015 IECC Code Home (see also Appendix D)

Tables 12 and 13 show Improved Home percentage savings relative to the 2015 Code Homes. However, SSPC 90.2 desires percentage savings relative to the 90.2 Reference Home. Since the data to derive percentage savings with respect (w.r.t.) to either the 2015 Code Home or the 90.2 Reference Home are available, Tables 14 and 15 are provided to examine these percentage savings calculations for the non-PV-equipped homes and the PV-equipped homes, respectively.

Table 14: Summary of Percentage Savings for non-PV-equipped Homes

Climate Zone	CZ Wgt.	Cost Savings			Source Savings		
		2015 w.r.t. 90.2 Ref	IMP w.r.t. 2015 Code	IMP w.r.t. 90.2 Ref	2015 w.r.t. 90.2 Ref	IMP w.r.t. 2015 Code	IMP w.r.t. 90.2 Ref
1	1.0%	19.9%	33.9%	47.1%	19.9%	33.9%	47.1%
2	21.4%	22.5%	29.0%	45.0%	22.4%	29.1%	45.0%
3	25.8%	22.3%	21.2%	38.7%	21.8%	21.5%	38.5%
4	22.8%	18.9%	24.4%	38.6%	18.9%	24.7%	39.0%
5	21.0%	23.1%	23.5%	41.2%	23.1%	23.8%	41.4%
6	6.8%	21.4%	31.0%	45.8%	21.9%	31.3%	46.3%
7	0.8%	21.5%	31.8%	46.5%	22.0%	32.1%	47.1%
8	0.5%	22.3%	33.7%	48.5%	22.8%	34.1%	49.1%
Average		**21.5%**	**28.6%**	**43.9%**	**21.6%**	**28.8%**	**44.2%**
Wgt'd average		**21.7%**	**25.4%**	**41.6%**	**21.5%**	**25.3%**	**41.4%**

Table 15: Summary Percentage of Savings for PV-equipped Homes

Climate Zone	CZ Wgt.	Cost Savings			Source Savings		
		2015 w.r.t. 90.2 Ref	IMP w.r.t. 2015 Code	IMP w.r.t. 90.2 Ref	2015 w.r.t. 90.2 Ref	IMP w.r.t. 2015 Code	IMP w.r.t. 90.2 Ref
1	1.0%	19.9%	59.9%	67.8%	19.9%	59.9%	67.8%
2	21.4%	22.5%	58.2%	67.6%	22.4%	57.9%	67.2%
3	25.8%	22.3%	48.1%	59.7%	21.8%	47.2%	58.5%
4	22.8%	18.9%	41.9%	52.9%	18.9%	41.6%	52.5%
5	21.0%	23.1%	39.1%	53.2%	23.1%	38.5%	52.7%
6	6.8%	21.4%	57.9%	66.9%	21.9%	56.2%	65.8%
7	0.8%	21.5%	54.8%	64.5%	22.0%	53.1%	63.4%
8	0.5%	22.3%	43.9%	56.5%	22.8%	42.9%	55.9%
Average		**21.5%**	**50.5%**	**61.1%**	**21.6%**	**49.7%**	**60.5%**
Wgt'd average		**21.7%**	**47.8%**	**59.2%**	**21.5%**	**47.1%**	**58.4%**

Tables 14 and 15 and Figure 5 show that the 2015 IECC Code results in a national weighted average savings of about 22% with respect to the 90.2 Reference Home (i.e. 2006 IECC). Climate zone 4 exhibits the least savings at about 19% and climate zone 5 shows the greatest savings at about 23%. However, opportunities for energy and cost savings over and above the minimum requirements of the 2015 IECC are significant.

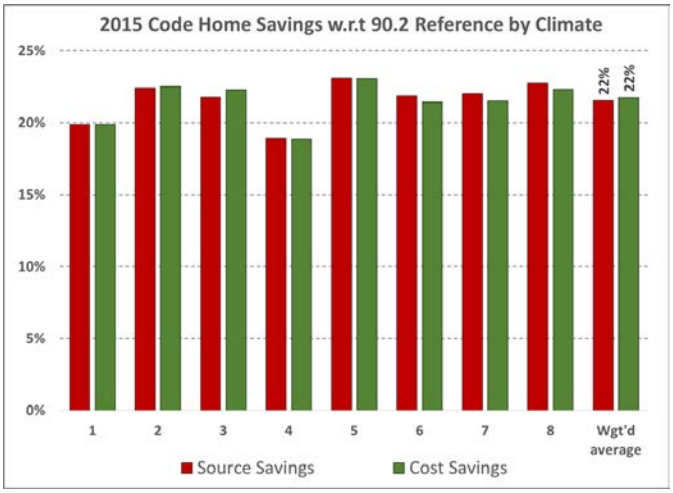

Figure 5: Energy and cost savings of the 2015 IECC with respect to the SSPC 90.2 Reference Home.

Figures 6 and 7 show that when compared with the 2015 Code Homes, the Improved Homes save a national weighted average of 25% to 47%, depending on whether or not they are equipped with renewable energy power production. When compared with the 90.2 Reference Home the national weighted average savings increase to 41% to 59%, again depending on whether or not homes are equipped with renewable energy power production.

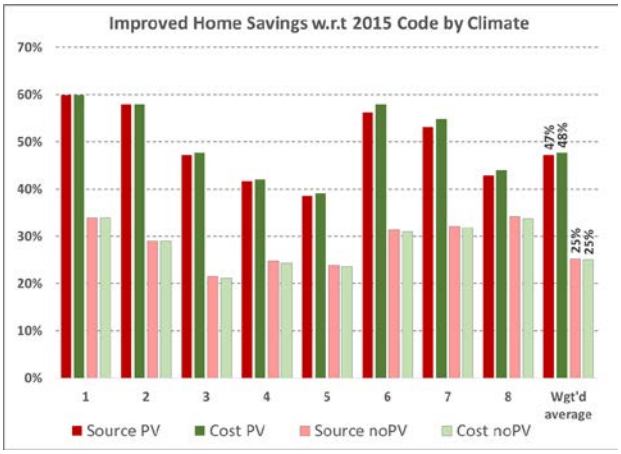

Figure 6: Savings for non-PV-equipped and PV-equipped homes relative to the 2015 IECC Code.

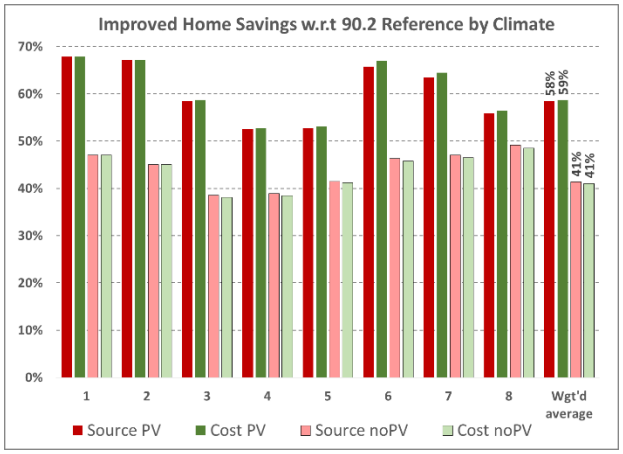

Figure 7: Savings for non-PV-equipped and PV-equipped homes relative to the 90.2 Reference.

It is clear from Figures 6 and 7 that while savings are climate dependent, the incorporation of renewable energy resources in the Improved Homes significantly increases savings in all climates. Appendix C provides detailed energy use, energy cost, improvement costs and economic cost effectiveness results for non-PV-equipped Improved Homes for each of the home configurations in the representative 13 TMY cities and Appendix D provides the same information for the PV-equipped Improved Homes.

Pollution Emission Savings

In addition to energy and cost savings, the pollution emission savings for CO_2, SO_2 and NOx for the Improved Homes with respect to the 2015 Code Homes are computed. The emissions from electricity production are computed using on the national average emissions for electricity from

the EPA 2010 eGrid database.[5] For natural gas devices, the data for National Average Emission Factors for Household Fuels from Table 5.1.2(1), ANSI/RESNET 301-2014 are used to compute emissions.

Emission savings are calculated as the difference in emissions for the 2015 Code Home and the emissions for the Improved Home. As is done for energy and cost savings, the average of the 1-story, 2-story, *Best Case* and *Worst-Case* homes are averaged for each of the 13 representative TMY cities. The TMY city averages are then used to calculate the average climate zone savings, which are then used to calculate the national average and national weighted average pollution emission savings.

Tables 16 and 17 present the climate zone average, national average and the national weighted average pollution emission saving for the non-PV-equipped and PV-equipped Improved Homes, respectively, with respect to the national model energy code standard (i.e. 2015 IECC). The Improved Homes achieve substantive pollution emission savings with respect to this standard.

Table 16: Pollution Emission Savings for non-PV-equipped Improved Homes with respect to 2015 Code Homes

Climate Zone	CZ Wgt.	CO2 lb Saved	SO2 lb Saved	NOx lb Saved	CO2 % Saved	SO2 % Saved	NOx % Saved
1	1.0%	5,501	12	5	33.9%	33.9%	33.9%
2	21.4%	4,821	10	4	29.1%	29.1%	29.1%
3	25.8%	2,812	4	898	21.3%	17.4%	31.7%
4	22.8%	3,750	4	1,578	24.5%	18.5%	34.3%
5	21.0%	4,596	5	1,888	23.7%	19.6%	29.3%
6	6.8%	6,679	7	2,709	31.1%	26.5%	37.3%
7	0.8%	7,315	7	3,232	32.0%	27.3%	36.9%
8	0.5%	9,606	7	5,106	33.9%	26.2%	39.7%
Average		**5,635**	**7**	**1,928**	**28.7%**	**24.8%**	**34.0%**
Wgt'd average		**4,188**	**6**	**1,223**	**25.1%**	**21.5%**	**31.7%**

Table 17: Pollution Emission Savings for PV-equipped Improved Homes with respect to 2015 Code Homes

Climate Zone	CZ Wgt.	CO2 lb Saved	SO2 lb Saved	NOx lb Saved	CO2 % Saved	SO2 % Saved	NOx % Saved
1	1.0%	9,708	21	9	59.9%	59.9%	59.9%
2	21.4%	9,672	21	9	57.9%	57.9%	57.9%
3	25.8%	6,300	11	905	47.4%	52.4%	32.0%
4	22.8%	6,347	10	1,494	41.8%	46.8%	32.7%
5	21.0%	7,525	11	1,816	38.8%	46.4%	28.2%
6	6.8%	12,224	21	1,980	57.0%	79.3%	27.3%
7	0.8%	12,336	20	2,440	53.9%	78.3%	27.9%
8	0.5%	12,282	16	3,708	43.4%	63.1%	28.8%
Average		**9,550**	**16**	**1,545**	**50.0%**	**60.5%**	**36.8%**
Wgt'd average		**7,802**	**14**	**1,129**	**47.4%**	**53.2%**	**36.8%**

Again, we see a marked difference in pollution emission savings between the PV-equipped and the non-PV-equipped Improved Homes. National weighted average CO_2 savings of approximately 1.9 metric tons per home are achieved by the non-PV-equipped Improved Homes while savings of 3.5 metric tons per home are achieved by the PV-equipped Improved Homes.

[5] http://www.epa.gov/cleanenergy/energy-resources/egrid/

Conclusions

Results of the analysis indicate that the maximum level of achievable residential energy efficiency is strongly dependent on whether or not homes are PV-equipped. Without PV, the maximum weighted average cost savings that can be cost effectively achieved by Improved Homes is 41% with respect to the SSPC 90.2 Reference Home (i.e. 2006 IECC). However, when Improved Homes are PV-equipped, the maximum weighted average cost savings increase to 59% with respect to the SSPC 90.2 Reference Home. The overall average savings considering both PV-equipped and non-PV-equipped Improved Homes is 50%. This result supports the Standard 90.2 Standard Advisory Panel's (SAP) recommendation that the 90.2 standard should achieve a 50% savings over the 2006 IECC as well as the ASHRAE Board of Directors objective of moving toward net zero energy buildings.

In addition to energy and cost savings, the Improved Homes shows significant levels of pollution emission savings with respect to the 2015 Code Homes. The emissions savings are also substantively larger for PV-equipped Improved Homes than for non-PV-equipped Improved Homes.

It is also important to point out three additional factors that should inform the decisions of SSPC 90.2 in this matter:

- Section R406 of the 2015 IECC, Energy Rating Index Compliance Alternative, does not exclude renewable energy resources from compliance calculations;
- Section 4.1.2 of ANSI/RESNET 301-2014 explicitly includes credit for on-site power production in the calculation of the HERS Index; and
- Pollution emission savings of the Improved Homes represent a substantive reduction in the societal cost of residential energy use.

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Appendix A
Economic Cost Effectiveness Calculations

If analyses are conducted to evaluate energy saving improvements to the home, indicators of economic cost effectiveness shall use present value life-cycle costs and benefits, which shall be calculated as follows:

LCC_E = P1 * (1st Year Energy Costs) **Eq. [1]**

LCC_I = P2 * (1st Cost of Improvements) **Eq. [2]**

where:
LCC_E = Present Value Life-Cycle Cost of Energy
LCC_I = Present Value Life-Cycle Cost of Improvements
P1 = Ratio of Life-Cycle energy costs to the 1st year energy costs
P2 = Ratio of Life-Cycle Improvement costs to the first cost of improvements

Present value life-cycle energy cost savings shall be calculated as follows:

$LCC_S = LCC_{E,b} – LCC_{E,i}$ **Eq. [3]**
where:
LCC_S = Present Value Life-cycle Energy Cost Savings
$LCC_{E,b}$ = Present Value LCC of energy for **baseline** home configuration
$LCC_{E,i}$ = Present Value LCC of energy for **improved** home configuration

Standard economic cost effectiveness indicators shall be calculated as follows:

SIR = LCC_S / LCC_I **Eq. [4]**

NPV = LCC_S - LCC_I **Eq. [5]**
where:
SIR = Present Value Savings to Investment Ratio
NPV = Net Present Value of Improvements

Calculation of P1 and P2. The ratios represented by P1 and P2 shall be calculated in accordance with the following methodology[6]:

P1 = 1 / (DR - ER) * (1 - ((1 + ER) / (1 + DR))^nAP) **Eq. [6a]**

or if DR = ER then

P1 = nAP / (1+DR) **Eq. [6b]**
where:
P1 = Ratio of Present Value Life-cycle Energy Costs to the 1st year Energy Costs
DR = Discount Rate
ER = Energy Inflation Rate
nAP = number of years in Analysis Period

P2 = DnPmt + $P2_A$ - $P2_B$ + $P2_C$ + $P2_D$ - $P2_E$ + $P2_F$ **Eq. [7]**
where:

[6] Duffie, J.A. and W.A. Beckman, 1980. *Solar Engineering of Thermal Processes*, pp. 398-406, John Wylie & Sons, Inc., New York, NY.

P2 = Ratio of Life-cycle Improvement costs to the first cost of improvements
DnPmt = Mortgage down payment rate
$P2_A$ = Mortgage cost parameter
$P2_B$ = Income Tax cost parameter
$P2_C$ = Operation & Maintenance cost parameter
$P2_D$ = Property tax cost parameter
$P2_E$ = Salvage value cost parameter
$P2_F$ = Replacement cost parameter

$P2_A$ = (1 - DnPmt) * (PWFd / PWFi) **Eq. [8a]**

where:
PWFd = Present Worth Factor for the discount rate = 1/DR*(1-(1/(1+DR)^nAP))
PWFi = Present Worth Factor for the mortgage rate = 1/MR*(1-(1/(1+MR)^nMP))
DR = Discount Rate
MR = Mortgage interest Rate
nAP = number of years of the Analysis Period
nMP = number of years of the Mortgage Period

$P2_B$ = (1 - DnPmt) * iTR * (PWdiff *(MR – 1 / PWFi) + PWFd / PWFi) **Eq. [8b]**

where:
iTR = effective income Tax Rate
PWdiff = ratio of the present worth discount rate to present worth mortgage rate
= 1 / (DR - MR) * (1- (((1 + MR) / (1 + DR))^nMP))

or if DR = MR then
= nMP/(1+MR)

$P2_C$ = MFrac*PWinf **Eq. [8c]**

where:
MFrac = annual O&M costs as a fraction of first cost of improvements
PWinf = ratio of present worth discount rate to present worth general inflation rate
= 1/(DR-GR)*(1-(((1+GR)/(1+DR))^nAP))

or if DR = GR then
= nAP/(1+DR)
GR = General Inflation Rate

$P2_D$ = pTR*AssessRatio*PWinf **Eq. [8d]**

where:
pTR = effective property Tax Rate
AssessRatio = Fraction of assessed property value against which pTR is applied
(typically 0.80)

$P2_E$ = RLF / ((1 + DR)^nAP) **Eq. [8e]**

where:
RLF = Remaining Life Fraction following the end of the analysis period
and
RLF = (nAP/Life) – (Integer (nAP/Life))

or if Life > nAP

RLF = (Life-nAP) / nAP

where:

Life = useful service life of the improvement(s)

$P2_F$ = Sum {1 / ((1 + (DR - GR))^(Life*i))} for i=1, n **Eq. [8f]**

where:

i = the i^{th} replacement of the improvement

Life = the expected service life of the improvement

Appendix B
Determination of HVAC Equipment Costs

NREL maintains a very useful online National Residential Efficiency Measure Database (http://www.nrel.gov/ap/retrofits/index.cfm) containing estimated retrofit costs for HVAC equipment.

The HVAC cost data are cast in terms of only the equipment capacity as Cost = a*CAP. The database provides the value of 'a' for each listed efficiency. Although it would likely be possible to use the listed efficiencies to develop a formulation cast in terms of both efficiency and capacity (e.g. Cost = a*CAP + b*EFF), this likely does not adequately characterize costs. Conventional pricing logic implies that fixed and variable costs are associated with HVAC installation. This can be empirically verified by regressing on collected cost data where fixed and variable cost components are clearly revealed. For example, fixed costs are associated with selling the new equipment, dispatching a vehicle and service personnel to the installation site, removing the old equipment, and hooking up the new equipment that are not tied directly to the efficiency or the size of the new equipment. Thus, the characterization of HVAC costs as stemming solely from equipment efficiency and capacity tends to underestimate costs for small capacity equipment (which will incur a larger percentage of fixed costs relative to total cost) and overstate costs for large capacity equipment (which will incur a smaller percentage of fixed costs relative to total cost).

BA-PIRC attempted to characterize the fixed costs associated with HVAC replacements using an empirical approach. Available online retail costs from available manufacturers were used to determine the, uninstalled retail cost of a variety of HVAC equipment. One clear advantage of this method is that the cost data, unlike those collected from installers are very consistent in their origin with less statistical variation. To these online values were added fixed costs that make up the total price similar to those observed in the NREL database. The resulting total cost data are then regressed in terms of equipment efficiency and capacity for four categories of commonly available HVAC equipment. The four categories are:

- Heat pumps
- Air conditioners (with strip resistance heating)
- Gas furnaces (with no air conditioning)
- Gas furnace-air conditioner combinations

For each equipment category, an 8% tax was applied to the online retail cost plus a fixed "service" cost plus 35% overhead and profit, such that

Total Cost = Retail*1.08 + $750 + Retail*0.35

The fixed "service" cost is calculated based on 4 man-hours of sales time at $28.00 per hour and 16 hours of installation time at $22.50 per hour with a 10% fringe and 30% overhead added to these salary rates. In addition, a daily average truck charge of $100 is added to this total salary charge to arrive at the fixed service charge.

The resulting total cost estimates are then regressed against the equipment capacity and efficiency from online data sources to arrive at generalized equations that can be used to calculate the HVAC costs used in the CostOpt optimizations. The resulting equations are as follows.

Heat Pumps: -5539 + 604*SEER + 699*tons
Air Conditioners (with strip heat): –1409 + 292*SEER + 520*tons
Gas Furnace/air conditioner: –6067 + 568*SEER + 517*tons + 4.04*kBtu + 1468*AFUE
Gas Furnace only: –3936 + 14.95*kBtu + 5865*AFUE

Results from the regressions showing the sample size (n) and correlation coefficient (R^2) for each equipment category are shown in Figure B-1.

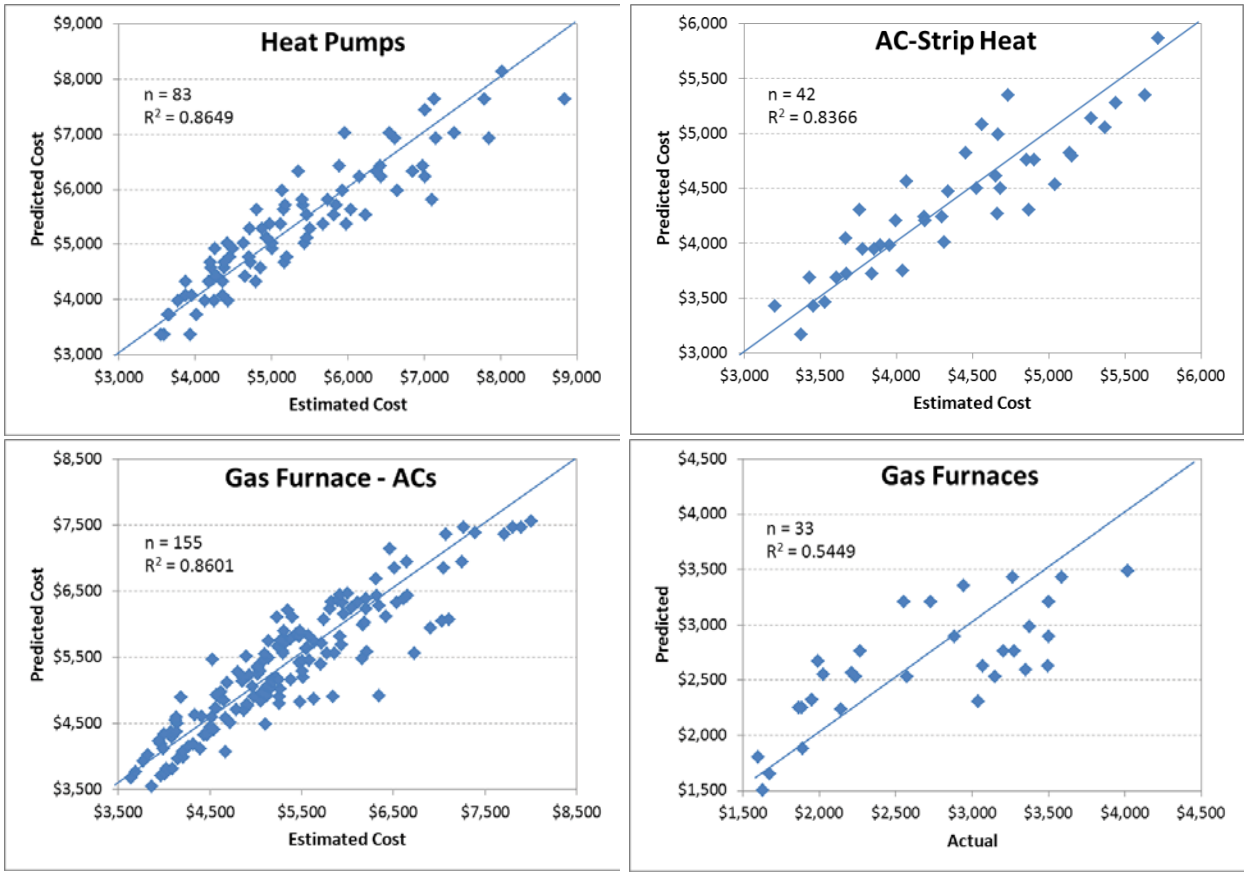

Figure B-1. Results from regression analysis of CostOpt HVAC cost estimates

Considering the variability of the marketplace, the correlation coefficients are reasonable for these regressions. For comparison, Tables B-1 through Table B-3 show the range of costs provided by the NREL database for replacement heat pumps, air conditioners, and gas furnaces.

Table B-1. NREL Cost Estimates for Heat Pumps

NREL Heat Pump Replacement Costs				
SEER	Low $/kBtu	High $/kBtu	Average $/kBtu	± %
13	97	170	140	26%
14	110	180	140	25%
15	110	190	150	27%
16	120	200	160	25%
17	130	210	170	24%
18	140	220	180	22%
19	140	230	180	25%
20	150	230	190	21%
21	160	240	200	20%

Table B-2. NREL Cost Estimates for Air Conditioners

NREL Air Conditioner Replacement Costs				
SEER	Low $/kBtu	High $/kBtu	Average $/kBtu	± %
13	59	190	130	50%
14	66	200	130	52%
15	73	210	140	49%
16	80	210	150	43%
17	87	220	150	44%
18	94	230	160	43%
19	100	230	170	38%
20	110	240	170	38%
21	110	250	180	39%

Table B-3. NREL Cost Estimates for Gas Furnaces

NREL Gas Furnace Replacement Costs				
AFUE	Low $/kBtu	High $/kBtu	Average $/kBtu	± %
78%	8.7	33.3	15	82%
80%	8.7	35.3	18	74%
82%	8.7	38.3	21	70%
90%	14.7	49.3	32	54%
92%	17.7	52.3	35	49%
94%	20.7	55.3	38	46%
96%	23.7	58.3	41	42%

These estimates indicate significant variations in the marketplace with respect to HVAC costs and to a certain degree mirror the variations in costs represented in Figure B-1, with gas furnaces showing the largest variance.

BA-PIRC evaluated the CostOpt estimates against those provided by the NREL database average cost estimates for heat pumps and gas furnaces. Figure B-2 presents the results of this comparison.

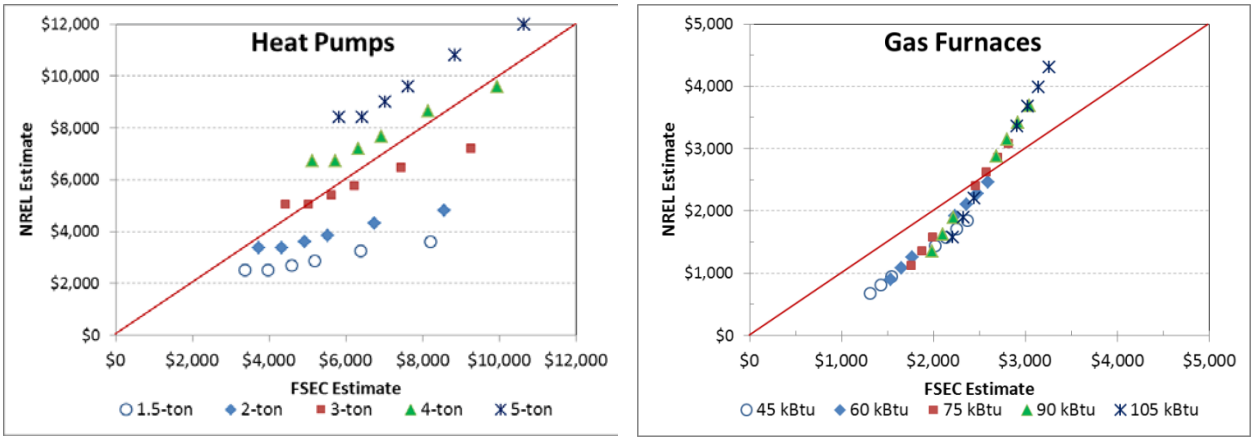

Figure B-2. Comparison of *CostOpt* HVAC cost estimates and NREL HVAC cost estimates

In Figure B-2 the individual plot points represent different efficiencies, with SEERs of 13, 14, 15, 16, 18, and 21 represented on the heat pump chart. The right-hand panel shows data for furnaces: with representative AFUEs of 78%, 80%, 82%, 90%, 92%, 94%, and 96%. Each chart also distinguishes between different capacities, with 1.5-, 2-, 3-, 4-, and 5-ton equipment on the heat pump chart and 45, 60, 75, 90, and 105 kBtu/h equipment on the gas furnace chart.

Both charts show that the CostOpt estimates are larger for the lower capacity and smaller for the larger capacity equipment. The charts also show that, on average, the CostOpt estimates are consistent with the NREL estimates. However, the fact that the CostOpt estimates treat fixed costs more explicitly is evident on both charts. In a practical sense, the CostOpt estimates generally show that monetary savings in the capacity of installed equipment coming from more efficient envelope measures are slightly less important than the original values in the NREL database.

Table C-1: Miami, FL Homes without renewable energy production (noPV)

	2015 Code Homes				Improved Homes - noPV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	12,433	0	$1,463	19.0%	8,268	0	$973	46.2%
1-sty Wrst Case	12,516	0	$1,473	18.5%	8,348	0	$983	45.6%
2-sty Best Case	13,667	0	$1,609	21.1%	8,952	0	$1,054	48.3%
2-sty Wrst Case	13,763	0	$1,620	20.6%	9,045	0	$1,065	47.8%
Averages	**13,095**	**0**	**$1,541**	**19.8%**	**8,653**	**0**	**$1,018**	**47.1%**

	Savings over 2015 Code				Costs Effectiveness			P1 = 20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	4,165	0	$490	33.5%	$5,502	$9,162	$10,092	1.10
1-sty Wrst Case	4,168	0	$491	33.3%	$5,502	$9,162	$10,099	1.10
2-sty Best Case	4,715	0	$555	34.5%	$6,591	$11,135	$11,425	1.03
2-sty Wrst Case	4,718	0	$555	34.3%	$6,591	$11,135	$11,432	1.03
Averages	**4,442**	**0**	**$523**	**33.9%**	**$6,047**	**$10,148**	**$10,762**	**1.06**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,000	$1,000	30		1.059	$1,059
SEER18HP*	$4,280	$6,515	$2,235	15		1.749	$3,910
Capacity (kBtu)	23.4	20.3					
SEER	14	18					
HSPF	8.2	9.2					
HPWH	$300	$1,000	$700	15	2.22%	2.206	$1,544
100%FL	$200	$300	$100	5		4.564	$456
RBS	$0	$542	$542	30		1.059	$574
60% ERV	$100	$750	$650	15		1.749	$1,137
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$5,502**				**$9,162**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER20HP*	$4,525	$7,846	$3,321	15		1.749	$5,810
Capacity (kBtu)	27.6	22.4					
SEER	14	20					
HSPF	8.2	9.4					
HPWH	$300	$1,000	$700	15	2.22%	2.206	$1,544
100%FL	$240	$360	$120	5		4.564	$548
RBS	$0	$325	$325	30		1.059	$344
60% ERV	$100	$750	$650	15		1.749	$1,137
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$6,591**				**$11,135**

* Heat Pump cost calculations based on capacity, SEER and HSPF

Table C-2: Houston, TX Homes without renewable energy production (noPV)

	2015 Code Homes				Improved Homes - noPV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	12,179	0	$1,433	20.0%	8,347	0	$982	45.2%
1-sty Wrst Case	12,289	0	$1,446	19.3%	8,425	0	$992	44.6%
2-sty Best Case	13,493	0	$1,588	21.7%	9,358	0	$1,101	45.7%
2-sty Wrst Case	13,652	0	$1,607	20.8%	9,470	0	$1,115	45.1%
Averages	**12,903**	**0**	**$1,519**	**20.4%**	**8,900**	**0**	**$1,048**	**45.2%**

	Savings over 2015 Code				Costs Effectiveness		P1 =	20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	3,832	0	$451	31.5%	$5,508	$9,172	$9,285	1.01
1-sty Wrst Case	3,864	0	$455	31.4%	$5,508	$9,172	$9,363	1.02
2-sty Best Case	4,135	0	$487	30.6%	$5,749	$9,887	$10,019	1.01
2-sty Wrst Case	4,182	0	$492	30.6%	$5,749	$9,887	$10,133	1.02
Averages	**4,003**	**0**	**$471**	**31.0%**	**$5,629**	**$9,530**	**$9,700**	**1.02**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,000	$1,000	30		1.059	$1,059
SEER18HP*	$4,501	$6,743	$2,241	15		1.749	$3,921
Capacity (kBtu)	27.2	24.2					
SEER	14	18					
HSPF	8.2	9.2					
HPWH	$300	$1,000	$700	15	2.22%	2.206	$1,544
100%FL	$200	$300	$100	5		4.564	$456
RBS	$0	$542	$542	30		1.059	$574
60% ERV	$100	$750	$650	15		1.749	$1,137
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$5,508**				**$9,172**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER19HP*	$4,723	$7,527	$2,804	15		1.749	$4,906
Capacity (kBtu)	31.0	27.3					
SEER	14	19					
HSPF	8.2	9.3					
HPWH	$300	$1,000	$700	15	2.22%	2.206	$1,544
100%FL	$240	$360	$120	5		4.564	$548
60% ERV	$100	$750	$650	15		1.749	$1,137
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$5,749**				**$9,887**

* Heat Pump cost calculations based on capacity, SEER and HSPF

Table C-3: Phoenix, AZ Homes without renewable energy production (noPV)

	2015 Code Homes				Improved Homes - noPV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	13,112	0	$1,543	24.2%	9,583	0	$1,128	44.6%
1-sty Wrst Case	13,307	0	$1,566	23.0%	9,725	0	$1,145	43.8%
2-sty Best Case	14,548	0	$1,712	25.6%	10,567	0	$1,244	45.9%
2-sty Wrst Case	14,782	0	$1,740	24.4%	10,749	0	$1,265	45.0%
Averages	**13,937**	**0**	**$1,640**	**24.3%**	**10,156**	**0**	**$1,195**	**44.9%**

	Savings over 2015 Code				Costs Effectiveness		P1 =	20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	3,529	0	$415	26.9%	$4,828	$7,983	$8,551	1.07
1-sty Wrst Case	3,582	0	$422	26.9%	$4,828	$7,983	$8,679	1.09
2-sty Best Case	3,981	0	$469	27.4%	$5,377	$9,011	$9,646	1.07
2-sty Wrst Case	4,033	0	$475	27.3%	$5,377	$9,011	$9,772	1.08
Averages	**3,781**	**0**	**$445**	**27.1%**	**$5,103**	**$8,497**	**$9,162**	**1.08**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,000	$1,000	30		1.059	$1,059
SEER17HP*	$4,373	$5,935	$1,562	15		1.749	$2,732
Capacity (kBtu)	25.0	20.7					
SEER	14	17					
HSPF	8.2	9.2					
HPWH	$300	$1,000	$700	15	2.22%	2.206	$1,544
100%FL	$200	$300	$100	5		4.564	$456
RBS	$0	$542	$542	30		1.059	$573
60% ERV	$100	$750	$650	15		1.749	$1,137
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$4,828**				**$7,983**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER18HP*	$4,665	$6,772	$2,107	15		1.749	$3,686
Capacity (kBtu)	30.0	24.7					
SEER	14	18					
HSPF	8.2	9.2					
HPWH	$300	$1,000	$700	15	2.22%	2.206	$1,544
100%FL	$240	$360	$120	5		4.564	$548
RBS	$0	$325	$325	30		1.059	$344
60% ERV	$100	$750	$650	15		1.749	$1,137
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$5,377**				**$9,011**

* Heat Pump cost calculations based on capacity, SEER and HSPF

Table C-4: Atlanta, GA Homes without renewable energy production (noPV)

	2015 Code Homes				Improved Homes - noPV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	7,690	386	$1,308	23.4%	6,526	225	$1,003	41.3%
1-sty Wrst Case	7,778	391	$1,324	22.5%	6,628	229	$1,019	40.3%
2-sty Best Case	8,636	397	$1,431	26.0%	7,309	266	$1,138	41.2%
2-sty Wrst Case	8,772	402	$1,453	24.9%	7,422	271	$1,157	40.2%
Averages	**8,219**	**394**	**$1,379**	**24.2%**	**6,971**	**248**	**$1,079**	**40.8%**

	Savings over 2015 Code				Costs Effectiveness			P1 = 20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	1,164	161	$305	23.3%	$3,640	$6,045	$6,284	1.04
1-sty Wrst Case	1,150	162	$305	23.0%	$3,640	$6,045	$6,272	1.04
2-sty Best Case	1,327	131	$293	20.5%	$3,306	$5,752	$6,034	1.05
2-sty Wrst Case	1,350	131	$296	20.4%	$3,306	$5,752	$6,089	1.06
Averages	**1,248**	**146**	**$300**	**21.7%**	**$3,473**	**$5,899**	**$6,170**	**1.05**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,000	$1,000	30		1.059	$1,059
SEER15GF96*	$4,126	$4,799	$674	15		1.749	$1,178
Cooling Cap (kBtu)	21.0	18.0					
SEER	14	15.0					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tankless gas WH	$600	$1,000	$400	15	2.29%	2.900	$1,160
100%FL	$200	$300	$100	5		4.564	$456
RBS	$0	$542	$542	30		1.059	$573
60% ERV	$100	$750	$650	15		1.749	$1,137
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$3,640**				**$6,045**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER15GF96*	$4,212	$4,873	$661	15		1.749	$1,156
Cooling Cap (kBtu)	23.0	19.7					
SEER	14	15.0					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tankless gas WH	$600	$1,000	$400	15	2.29%	2.900	$1,160
100%FL	$240	$360	$120	5		4.564	$548
60% ERV	$100	$750	$650	15		1.749	$1,137
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$3,306**				**$5,752**

* Gas furnace / air conditioner cost calculations based on capacity, SEER and AFUE

Table C-5: El Paso, TX Homes without renewable energy production (noPV)

	2015 Code Homes				Improved Homes - noPV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	7,924	291	$1,237	23.7%	6,359	194	$951	41.3%
1-sty Wrst Case	8,084	297	$1,262	22.2%	6,454	199	$968	40.3%
2-sty Best Case	8,912	291	$1,353	26.6%	7,333	222	$1,095	40.6%
2-sty Wrst Case	9,094	297	$1,381	25.1%	7,500	226	$1,119	39.3%
Averages	**8,504**	**294**	**$1,308**	**24.4%**	**6,912**	**210**	**$1,033**	**40.4%**

	Savings over 2015 Code				Costs Effectiveness			P1 = 20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	1,565	97	$286	23.1%	$3,684	$5,849	$5,879	1.01
1-sty Wrst Case	1,630	98	$294	23.3%	$3,684	$5,849	$6,058	1.04
2-sty Best Case	1,579	69	$258	19.1%	$3,058	$4,823	$5,310	1.10
2-sty Wrst Case	1,594	71	$262	19.0%	$3,058	$4,823	$5,390	1.12
Averages	**1,592**	**84**	**$275**	**21.0%**	**$3,371**	**$5,336**	**$5,659**	**1.06**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,000	$1,000	30		1.059	$1,059
SEER15GF96*	$4,083	$4,799	$717	15		1.749	$1,254
Cooling Cap (kBtu)	20.0	18.0					
SEER	14.0	15.0					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$200	$300	$100	5		4.564	$456
RBS	$0	$542	$542	30		1.059	$574
60% ERV	$100	$750	$650	15		1.749	$1,137
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$3,684**				**$5,849**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER14GF96*	$4,173	$4,262	$88	15		1.749	$155
Cooling Cap (kBtu)	22.1	18.7					
SEER	14.0	14.0					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$240	$360	$120	5		4.564	$548
RBS	$0	$325	$325	30		1.059	$344
60% ERV	$100	$750	$650	15		1.749	$1,137
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$3,058**				**$4,823**

* Gas furnace / air conditioner cost calculations based on capacity, SEER and AFUE

Table C-6: Los Angeles, CA Homes without renewable energy production (noPV)

	2015 Code Homes				Improved Homes - noPV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	6,444	200	$967	14.5%	5,256	141	$766	32.3%
1-sty Wrst Case	6,442	202	$969	14.3%	5,257	143	$768	32.1%
2-sty Best Case	7,016	198	$1,033	17.4%	5,753	139	$822	34.2%
2-sty Wrst Case	7,020	200	$1,035	17.2%	5,759	140	$824	34.1%
Averages	**6,731**	**200**	**$1,001**	**15.8%**	**5,506**	**141**	**$795**	**33.2%**

	Savings over 2015 Code				Costs Effectiveness			P1 = 20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	1,188	59	$201	20.8%	$2,552	$3,869	$4,148	1.07
1-sty Wrst Case	1,185	59	$201	20.7%	$2,552	$3,869	$4,141	1.07
2-sty Best Case	1,263	59	$210	20.4%	$2,624	$4,063	$4,330	1.07
2-sty Wrst Case	1,261	60	$211	20.4%	$2,624	$4,063	$4,346	1.07
Averages	**1,224**	**59**	**$206**	**20.6%**	**$2,588**	**$3,966**	**$4,241**	**1.07**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,000	$1,000	30		1.059	$1,059
SEER14GF96*	$3,997	$4,231	$235	15		1.749	$411
Cooling Cap (kBtu)	18.0	18.0					
SEER	14.0	14.0					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$200	$300	$100	5		4.564	$456
RBS	$0	$542	$542	30		1.059	$574
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$2,552**				**$3,869**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER14GF96*	$3,997	$4,300	$304	15		1.749	$531
Cooling Cap (kBtu)	18.0	19.6					
SEER	14.0	14.0					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$240	$360	$120	5		4.564	$548
RBS	$0	$325	$325	30		1.059	$344
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$2,624**				**$4,063**

* Gas furnace / air conditioner cost calculations based on capacity, SEER and AFUE

Table C-7: Philadelphia, PA Homes without renewable energy production (noPV)

	2015 Code Homes				Improved Homes - noPV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	7,574	549	$1,465	19.6%	6,036	345	$1,071	41.2%
1-sty Wrst Case	7,698	558	$1,489	18.3%	6,118	352	$1,088	40.3%
2-sty Best Case	8,526	584	$1,614	21.5%	6,777	361	$1,175	42.9%
2-sty Wrst Case	8,666	595	$1,642	20.1%	6,898	370	$1,199	41.7%
Averages	**8,116**	**572**	**$1,552**	**19.9%**	**6,457**	**357**	**$1,133**	**41.6%**

	Savings over 2015 Code				Costs Effectiveness			P1 = 20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	1,538	204	$394	26.9%	$5,360	$7,802	$8,115	1.04
1-sty Wrst Case	1,580	206	$401	26.9%	$5,360	$7,802	$8,260	1.06
2-sty Best Case	1,749	223	$439	27.2%	$5,505	$8,405	$9,035	1.08
2-sty Wrst Case	1,768	225	$443	27.0%	$5,505	$8,405	$9,124	1.09
Averages	**1,659**	**215**	**$419**	**27.0%**	**$5,432**	**$8,103**	**$8,634**	**1.07**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,000	$1,000	30		1.059	$1,059
SEER14.5GF96*	$3,601	$4,576	$975	15		1.749	$1,705
Cooling Cap (kBtu)	22.0	19.4					
SEER	13.0	14.5					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$200	$300	$100	5		4.564	$456
Ceiling R (49→60)	$3,430	$4,200	$770	30		1.059	$815
Sheathing R (5→10)	$2,106	$2,754	$648	30		1.059	$686
RBS	$0	$542	$542	30		1.059	$574
60% ERV	$100	$750	$650	15		1.749	$1,137
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$5,360**				**$7,802**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER15GF96*	$3,696	$4,894	$1,199	15		1.749	$2,097
Cooling Cap (kBtu)	24.2	20.2					
SEER	13.0	15.0					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$240	$360	$120	5		4.564	$548
Ceiling R (49→60)	$2,058	$2,520	$462	30		1.059	$489
Sheathing R (5→10)	$2,841	$3,715	$874	30		1.059	$925
RBS	$0	$325	$325	15		1.749	$569
60% ERV	$100	$750	$650	15		1.749	$1,137
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$5,505**				**$8,405**

* Gas furnace / air conditioner cost calculations based on capacity, SEER and AFUE

Table C-8: Albuquerque, NM Homes without renewable energy production (noPV)

	2015 Code Homes				Improved Homes - noPV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	7,224	400	$1,268	19.6%	5,930	265	$975	38.2%
1-sty Wrst Case	7,382	411	$1,298	17.7%	6,036	273	$996	36.9%
2-sty Best Case	8,104	412	$1,384	22.8%	6,645	277	$1,072	40.2%
2-sty Wrst Case	8,322	424	$1,423	20.6%	6,831	285	$1,102	38.5%
Averages	**7,758**	**412**	**$1,343**	**20.2%**	**6,361**	**275**	**$1,036**	**38.5%**

	Savings over 2015 Code				Costs Effectiveness		P1 =	20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	1,294	135	$293	23.1%	$3,464	$5,840	$6,040	1.03
1-sty Wrst Case	1,346	138	$303	23.3%	$3,464	$5,840	$6,230	1.07
2-sty Best Case	1,459	135	$313	22.6%	$3,581	$5,962	$6,440	1.08
2-sty Wrst Case	1,491	139	$321	22.5%	$3,581	$5,962	$6,603	1.11
Averages	**1,398**	**137**	**$307**	**22.9%**	**$3,523**	**$5,901**	**$6,328**	**1.07**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,000	$1,000	30		1.059	$1,059
SEER15.5GF96*	$4,044	$5,083	$1,039	15		1.749	$1,818
Cooling Cap (kBtu)	19.1	18.0					
SEER	14.0	15.5					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$200	$300	$100	5		4.564	$456
60% ERV	$100	$750	$650	15		1.749	$1,137
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$3,464**				**$5,840**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER15.5GF96*	$4,147	$5,083	$936	15		1.749	$1,638
Cooling Cap (kBtu)	21.5	18.0					
SEER	14.0	15.5					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$240	$360	$120	5		4.564	$548
60% ERV	$100	$750	$650	15		1.749	$1,137
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_cWash	$450	$500	$50	15		1.749	$87
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
		Totals	**$3,581**				**$5,962**

* Gas furnace / air conditioner cost calculations based on capacity, SEER and AFUE

Table C-9: Seattle, WA Homes without renewable energy production (noPV)

	2015 Code Homes				Improved Homes - noPV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	6,714	482	$1,294	15.1%	5,564	328	$998	34.5%
1-sty Wrst Case	6,736	490	$1,305	14.4%	5,577	334	$1,005	34.0%
2-sty Best Case	7,326	488	$1,372	17.8%	6,085	330	$1,061	36.4%
2-sty Wrst Case	7,358	497	$1,385	17.0%	6,112	336	$1,071	35.8%
Averages	**7,034**	**489**	**$1,339**	**16.0%**	**5,835**	**332**	**$1,034**	**35.2%**

	Savings over 2015 Code				Costs Effectiveness		P1 =	20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	1,150	154	$296	22.9%	$3,688	$5,857	$6,100	1.04
1-sty Wrst Case	1,159	156	$299	22.9%	$3,688	$5,857	$6,164	1.05
2-sty Best Case	1,241	158	$311	22.7%	$3,691	$5,930	$6,406	1.08
2-sty Wrst Case	1,246	161	$315	22.7%	$3,691	$5,930	$6,483	1.09
Averages	**1,199**	**157**	**$305**	**22.8%**	**$3,689**	**$5,893**	**$6,288**	**1.07**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,000	$1,000	30		1.059	$1,059
SEER15GF96*	$3,429	$4,799	$1,371	15		1.749	$2,398
Cooling Cap (kBtu)	18.0	18.0					
SEER	13	15					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$200	$300	$100	5		4.564	$456
RBS	$0	$542	$542	30		1.059	$574
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
		Totals	**$3,688**				**$5,857**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER15GF96*	$3,429	$4,799	$1,371	15		1.749	$2,398
Cooling Cap (kBtu)	18.0	18.0					
SEER	13	15					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$240	$360	$120	5		4.564	$548
RBS	$0	$325	$325	30		1.059	$344
ES_dWash	$450	$500	$50	15		1.749	$87
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
		Totals	**$3,691**				**$5,930**

* Gas furnace / air conditioner cost calculations based on capacity, SEER and AFUE

Table C-10: Chicago, IL Homes without renewable energy production (noPV)

	2015 Code Homes				Improved Homes - noPV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	8,526	657	$1,690	23.1%	6,859	461	$1,289	41.3%
1-sty Wrst Case	8,647	666	$1,714	22.0%	6,953	467	$1,306	40.5%
2-sty Best Case	9,551	713	$1,869	24.2%	7,664	507	$1,432	41.9%
2-sty Wrst Case	9,679	726	$1,898	23.0%	7,784	516	$1,455	41.0%
Averages	**9,101**	**691**	**$1,793**	**23.1%**	**7,315**	**488**	**$1,371**	**41.2%**

	Savings over 2015 Code				Costs Effectiveness		P1 =	20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	1,667	196	$401	23.7%	$5,134	$8,229	$8,256	1.00
1-sty Wrst Case	1,694	199	$407	23.8%	$5,134	$8,229	$8,386	1.02
2-sty Best Case	1,887	206	$437	23.4%	$4,977	$8,085	$9,004	1.11
2-sty Wrst Case	1,895	210	$442	23.3%	$4,977	$8,085	$9,109	1.13
Averages	**1,786**	**203**	**$422**	**23.5%**	**$5,055**	**$8,157**	**$8,689**	**1.07**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,000	$1,000	30		1.059	$1,059
SEER16GF96*	$3,429	$5,367	$1,939	15		1.749	$3,392
Cooling Cap (kBtu)	18.0	18.0					
SEER	13.0	16.0					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$200	$300	$100	5		4.564	$456
60% ERV	$100	$750	$650	15		1.749	$1,137
Ceiling R (49→60)	$3,430	$4,200	$770	30		1.059	$815
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
		Totals	**$5,134**				**$8,229**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER16GF96*	$3,515	$5,385	$1,870	15		1.749	$3,271
Cooling Cap (kBtu)	20.0	18.4					
SEER	13.0	16.0					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$240	$360	$120	5		4.564	$548
60% ERV	$100	$750	$650	15		1.749	$1,137
Ceiling R (49→60)	$2,058	$2,520	$462	30		1.059	$489
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
		Totals	**$4,977**				**$8,085**

* Gas furnace / air conditioner cost calculations based on capacity, SEER and AFUE

Table C-11: Minneapolis, MN Homes without renewable energy production (noPV)

	2015 Code Homes				Improved Homes – noPV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	9,320	751	$1,882	21.1%	6,832	473	$1,298	45.6%
1-sty Wrst Case	9,420	764	$1,907	20.0%	6,939	482	$1,320	44.6%
2-sty Best Case	10,380	794	$2,051	22.9%	7,608	494	$1,412	46.9%
2-sty Wrst Case	10,536	809	$2,085	21.6%	7,758	505	$1,441	45.8%
Averages	**9,914**	**780**	**$1,981**	**21.4%**	**7,284**	**489**	**$1,368**	**45.8%**

	Savings over 2015 Code				Costs Effectiveness		P1 =	20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	2,488	278	$583	31.0%	$9,139	$11,489	$12,009	1.05
1-sty Wrst Case	2,481	282	$587	30.8%	$9,139	$11,489	$12,078	1.05
2-sty Best Case	2,772	300	$640	31.2%	$9,915	$12,383	$13,171	1.06
2-sty Wrst Case	2,778	304	$645	30.9%	$9,915	$12,383	$13,271	1.07
Averages	**2,630**	**291**	**$614**	**31.0%**	**$9,527**	**$11,936**	**$12,632**	**1.06**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,000	$1,000	30		1.059	$1,059
SEER13.5GF96*	$3,429	$3,947	$519	15		1.749	$908
Cooling Cap (kBtu)	18.0	18.0					
SEER	13.0	13.5					
Heating Cap (kBtu)	40.0	40.0					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$200	$300	$100	5		4.564	$456
60% ERV	$100	$750	$650	15		1.749	$1,137
Wall Cavity R (13→21)	$9,266	$10,660	$1,393	30		1.059	$1,475
Floor R (30→38)	$2,700	$3,420	$720	30		1.059	$762
Ceiling R (49→60)	$3,430	$4,200	$770	30		1.059	$815
Window U (0.32→0.25)	$6,409	$9,720	$3,312	30		1.059	$3,507
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
		Totals	**$9,139**				**$11,489**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER13.5GF96*	$3,475	$3,947	$472	15		1.749	$826
Cooling Cap (kBtu)	18.8	18.0					
SEER	13.0	13.5					
Heating Cap (kBtu)	43.0	40.0					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$240	$360	$120	5		4.564	$548
60% ERV	$100	$750	$650	15		1.749	$1,137
Wall Cavity R (13→21)	$12,498	$14,377	$1,879	30		1.059	$1,990
Floor R (30→38)	$1,620	$2,052	$432	30		1.059	$457
Ceiling R (49→60)	$2,058	$2,520	$462	30		1.059	$489
Window U (0.32→0.25)	$7,690	$11,665	$3,974	30		1.059	$4,208
ES_Fridge	$1,200	$1,300	$100	15		1.749	$175
ES_dWash	$400	$475	$75	15		1.749	$131
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
		Totals	**$9,915**				**$12,383**

* Gas furnace / air conditioner cost calculations based on capacity, SEER and AFUE

Table C-12: Duluth, MN Homes without renewable energy production (noPV)

	2015 Code Homes				Improved Homes - noPV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	9,070	910	$2,018	20.4%	6,598	574	$1,376	45.8%
1-sty Wrst Case	9,100	918	$2,030	20.0%	6,621	581	$1,386	45.4%
2-sty Best Case	9,998	960	$2,180	23.0%	7,264	603	$1,485	47.5%
2-sty Wrst Case	10,042	971	$2,197	22.4%	7,290	612	$1,498	47.1%
Averages	**9,553**	**940**	**$2,106**	**21.4%**	**6,943**	**593**	**$1,436**	**46.5%**

	Savings over 2015 Code				Costs Effectiveness			P1 = 20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	2,472	336	$642	31.8%	$9,609	$12,666	$13,218	1.04
1-sty Wrst Case	2,479	337	$644	31.7%	$9,609	$12,666	$13,257	1.05
2-sty Best Case	2,734	357	$695	31.9%	$10,107	$13,258	$14,305	1.08
2-sty Wrst Case	2,752	359	$699	31.8%	$10,107	$13,258	$14,392	1.09
Averages	**2,609**	**347**	**$670**	**31.8%**	**$9,858**	**$12,962**	**$13,793**	**1.06**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,000	$1,000	30		1.059	$1,059
SEER14GF96*	$3,429	$4,931	$1,503	15		1.749	$2,629
Cooling Cap (kBtu)	18.0	18.0					
SEER	13.0	14.0					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$200	$300	$100	5		4.564	$456
Wall Cavity R (13→20)	$9,266	$10,660	$1,393	30		1.059	$1,475
Floor R (38→49)	$3,420	$4,410	$990	30		1.059	$1,048
Ceiling R (49→60)	$3,430	$4,200	$770	30		1.059	$815
Window U (0.32→0.26)	$6,409	$8,936	$2,528	30		1.059	$2,676
60% ERV	$100	$750	$650	15		1.749	$1,137
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$9,609**				**$12,666**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER14GF96*	$3,445	$4,939	$1,494	15		1.749	$2,613
Cooling Cap (kBtu)	18.0	18.0					
SEER	13.0	14.0					
Heating Cap (kBtu)	44	41.8					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$240	$360	$120	5		4.564	$548
Wall Cavity R (13→20)	$12,498	$14,377	$1,879	30		1.059	$1,990
Floor R (38→49)	$2,052	$2,646	$594	30		1.059	$629
Ceiling R (49→60)	$2,058	$2,520	$462	30		1.059	$489
Window U (0.32→0.26)	$7,690	$10,723	$3,033	30		1.059	$3,212
60% ERV	$100	$750	$650	15		1.749	$1,137
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$10,107**				**$13,258**

* Gas furnace / air conditioner cost calculations based on capacity, SEER and AFUE

Table C-13: Fairbanks, AK Homes without renewable energy production (noPV)

	2015 Code Homes				Improved Homes - noPV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	9,260	1,327	$2,477	21.5%	6,851	808	$1,651	47.7%
1-sty Wrst Case	9,266	1,337	$2,488	21.1%	6,857	816	$1,660	47.4%
2-sty Best Case	10,192	1,428	$2,692	23.4%	7,508	852	$1,774	49.5%
2-sty Wrst Case	10,198	1,439	$2,704	23.0%	7,518	860	$1,784	49.2%
Averages	**9,729**	**1,383**	**$2,590**	**22.3%**	**7,184**	**834**	**$1,717**	**48.5%**

	Savings over 2015 Code				Costs Effectiveness		P1 =	20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	2,409	519	$826	33.3%	$13,312	$16,184	$17,003	1.05
1-sty Wrst Case	2,409	521	$828	33.3%	$13,312	$16,184	$17,046	1.05
2-sty Best Case	2,684	576	$918	34.1%	$14,498	$17,385	$18,895	1.09
2-sty Wrst Case	2,680	579	$920	34.0%	$14,498	$17,385	$18,950	1.09
Averages	**2,546**	**549**	**$873**	**33.7%**	**$13,905**	**$16,785**	**$17,973**	**1.07**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,000	$1,000	30		1.059	$1,059
SEER13GF96*	$3,445	$4,363	$919	15		1.749	$1,607
Cooling Cap (kBtu)	18.0	18.0					
SEER	13.0	13.0					
Heating Cap (kBtu)	44.0	40.0					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$200	$300	$100	5		4.564	$456
Wall Cavity R (13→21)	$9,266	$10,660	$1,393	30		1.059	$1,475
Floor R (38→49)	$3,420	$4,410	$990	30		1.059	$1,048
Ceiling R (49→60)	$3,430	$4,200	$770	30		1.059	$815
Window U (0.32→0.22)	$6,409	$13,224	$6,815	30		1.059	$7,217
60% ERV	$100	$750	$650	15		1.749	$1,137
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$13,312**				**$16,184**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER13GF96*	$3,632	$4,371	$739	15		1.749	$1,293
Cooling Cap (kBtu)	21.7	18.0					
SEER	13.0	13.0					
Heating Cap (kBtu)	51	42					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$240	$360	$120	5		4.564	$548
Wall Cavity R (13→21)	$12,498	$14,377	$1,879	30		1.059	$1,990
Floor R (38→49)	$2,052	$2,646	$594	30		1.059	$629
Ceiling R (49→60)	$2,058	$2,520	$462	30		1.059	$489
Window U (0.32→0.22)	$7,690	$15,869	$8,179	30		1.059	$8,660
60% ERV	$100	$750	$650	15		1.749	$1,137
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$14,498**				**$17,385**

* Gas furnace / air conditioner cost calculations based on capacity, SEER and AFUE

Table D-1: Miami, FL Homes with renewable energy production (PV)

	2015 Code Homes				Improved Homes - PV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	12,433	0	$1,463	19.0%	4,811	0	$566	68.7%
1-sty Wrst Case	12,516	0	$1,473	18.5%	4,901	0	$577	68.1%
2-sty Best Case	13,667	0	$1,609	21.1%	5,603	0	$659	67.7%
2-sty Wrst Case	13,763	0	$1,620	20.6%	5,709	0	$672	67.1%
Averages	**13,095**	**0**	**$1,541**	**19.8%**	**5,256**	**0**	**$619**	**67.8%**

	Savings over 2015 Code				Costs Effectiveness			P1 = 20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	7,622	0	$897	61.3%	$11,294	$17,263	$18,469	1.07
1-sty Wrst Case	7,615	0	$896	60.8%	$11,294	$17,263	$18,452	1.07
2-sty Best Case	8,064	0	$949	59.0%	$11,779	$18,179	$19,540	1.07
2-sty Wrst Case	8,054	0	$948	58.5%	$11,779	$18,179	$19,515	1.07
Averages	**7,839**	**0**	**$923**	**59.9%**	**$11,537**	**$17,721**	**$18,994**	**1.07**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,000	$1,000	30		1.059	$1,059
SEER16HP*	$4,280	$5,307	$1,027	15		1.749	$1,797
Capacity (kBtu)	23.4	20.3					
SEER	14	16					
HSPF	8.2	9.0					
HPWH	$300	$1,000	$700	15	2.22%	2.206	$1,544
100%FL	$200	$300	$100	5		4.564	$456
RBS	$0	$542	$542	30		1.059	$574
60% ERV	$100	$750	$650	15		1.749	$1,137
2.5 kWp PV system**	$0	$7,000	$7,000	30	1.94%	1.459	$10,214
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$11,294**				**$17,263**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER17HP*	$4,525	$6,034	$1,509	15		1.749	$2,640
Capacity (kBtu)	27.6	22.4					
SEER	14	17					
HSPF	8.2	9.1					
HPWH	$300	$1,000	$700	15	2.22%	2.206	$1,544
100%FL	$240	$360	$120	5		4.564	$548
RBS	$0	$325	$325	30		1.059	$344
60% ERV	$100	$750	$650	15		1.749	$1,137
2.5 kWp PV system**	$0	$7,000	$7,000	30	1.94%	1.459	$10,214
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$11,779**				**$18,179**

* Heat Pump cost calculations based on capacity, SEER and HSPF

** $4.00/Wp - 30% ITC = $2.80/Wp

Table D-2: Houston, TX Homes with renewable energy production (PV)

	2015 Code Homes				Improved Homes - PV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	12,179	0	$1,433	20.0%	5,778	0	$680	62.0%
1-sty Wrst Case	12,289	0	$1,446	19.3%	5,863	0	$690	61.5%
2-sty Best Case	13,493	0	$1,588	21.7%	6,920	0	$814	59.9%
2-sty Wrst Case	13,652	0	$1,607	20.8%	7,049	0	$830	59.1%
Averages	**12,903**	**0**	**$1,519**	**20.4%**	**6,403**	**0**	**$754**	**60.5%**

	Savings over 2015 Code				Costs Effectiveness			P1 = 20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	6,401	0	$753	52.6%	$9,900	$15,230	$15,510	1.02
1-sty Wrst Case	6,426	0	$756	52.3%	$9,900	$15,230	$15,571	1.02
2-sty Best Case	6,573	0	$774	48.7%	$9,537	$14,888	$15,927	1.07
2-sty Wrst Case	6,603	0	$777	48.4%	$9,537	$14,888	$16,000	1.07
Averages	**6,501**	**0**	**$765**	**50.4%**	**$9,719**	**$15,059**	**$15,752**	**1.05**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,000	$1,000	30		1.059	$1,059
SEER16HP*	$4,501	$5,535	$1,033	15		1.749	$1,807
Capacity (kBtu)	27.2	24.2					
SEER	14	16					
HSPF	8.2	9.0					
HPWH	$300	$1,000	$700	15	2.22%	2.206	$1,544
100%FL	$200	$300	$100	5		4.564	$456
RBS	$0	$542	$542	30		1.059	$574
60% ERV	$100	$750	$650	15		1.749	$1,137
2.0 kWp PV system**	$0	$5,600	$5,600	30	1.94%	1.459	$8,171
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$9,900**				**$15,230**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER16HP*	$4,723	$5,715	$992	15		1.749	$1,736
Capacity (kBtu)	31.0	27.3					
SEER	14	16					
HSPF	8.2	9.0					
HPWH	$300	$1,000	$700	15	2.22%	2.206	$1,544
100%FL	$240	$360	$120	5		4.564	$548
60% ERV	$100	$750	$650	15		1.749	$1,137
2.0 kWp PV system**	$0	$5,600	$5,600	30	1.94%	1.459	$8,171
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$9,537**				**$14,888**

* Heat Pump cost calculations based on capacity, SEER and HSPF

** $4.00/Wp - 30% ITC = $2.80/Wp

Table D-3: Phoenix, AZ Homes with renewable energy production (PV)

	2015 Code Homes				Improved Homes - PV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	13,112	0	$1,543	24.2%	4,257	0	$501	75.4%
1-sty Wrst Case	13,307	0	$1,566	23.0%	4,399	0	$518	74.6%
2-sty Best Case	14,548	0	$1,712	25.6%	5,215	0	$614	73.3%
2-sty Wrst Case	14,782	0	$1,740	24.4%	5,404	0	$636	72.4%
Averages	**13,937**	**0**	**$1,640**	**24.3%**	**4,819**	**0**	**$567**	**73.8%**

	Savings over 2015 Code				Costs Effectiveness			P1 = 20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	8,855	0	$1,042	67.5%	$13,228	$20,240	$21,456	1.06
1-sty Wrst Case	8,908	0	$1,048	66.9%	$13,228	$20,240	$21,585	1.07
2-sty Best Case	9,333	0	$1,098	64.2%	$13,173	$20,212	$22,614	1.12
2-sty Wrst Case	9,378	0	$1,104	63.4%	$13,173	$20,212	$22,724	1.12
Averages	**9,119**	**0**	**$1,073**	**65.4%**	**$13,201**	**$20,226**	**$22,095**	**1.09**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER17HP*	$4,665	$6,168	$1,503	15		1.749	$2,630
Capacity (kBtu)	30.0	24.7					
SEER	14	17					
HSPF	8.2	9.1					
HPWH	$300	$1,000	$700	15	2.22%	2.206	$1,544
100%FL	$240	$360	$120	5		4.564	$548
RBS	$0	$325	$325	15		1.749	$569
60% ERV	$100	$750	$650	15		1.749	$1,137
3.0 kWp PV system**	$0	$8,400	$8,400	30	1.94%	1.459	$12,257
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$13,228**				**$20,240**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER17HP*	$4,665	$6,168	$1,503	15		1.749	$2,630
Capacity (kBtu)	30.0	24.7					
SEER	14	17					
HSPF	8.2	9.1					
HPWH	$300	$1,000	$700	15	2.22%	2.206	$1,544
100%FL	$240	$360	$120	5		4.564	$548
RBS	$0	$325	$325	30		1.059	$344
60% ERV	$100	$750	$650	15		1.749	$1,137
3.0 kWp PV system**	$0	$8,400	$8,400	30	1.94%	1.459	$12,257
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$13,173**				**$20,212**

* Heat Pump cost calculations based on capacity, SEER and HSPF

** $4.00/Wp - 30% ITC = $2.80/Wp

Table D-4: Atlanta, GA Homes with renewable energy production (PV)

	2015 Code Homes				Improved Homes - PV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	7,690	386	$1,308	23.4%	4,430	225	$757	55.7%
1-sty Wrst Case	7,778	391	$1,324	22.5%	4,539	229	$774	54.7%
2-sty Best Case	8,636	397	$1,431	26.0%	5,215	266	$892	53.9%
2-sty Wrst Case	8,772	402	$1,453	24.9%	5,332	270	$910	53.0%
Averages	**8,219**	**394**	**$1,379**	**24.2%**	**4,879**	**248**	**$833**	**54.3%**

	Savings over 2015 Code				Costs Effectiveness			P1 = 20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	3,260	161	$552	42.2%	$7,272	$11,180	$11,363	1.02
1-sty Wrst Case	3,239	162	$551	41.6%	$7,272	$11,180	$11,333	1.01
2-sty Best Case	3,421	131	$540	37.7%	$6,938	$10,887	$11,108	1.02
2-sty Wrst Case	3,440	132	$543	37.4%	$6,938	$10,887	$11,175	1.03
Averages	**3,340**	**147**	**$546**	**39.6%**	**$7,105**	**$11,033**	**$11,245**	**1.02**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,000	$1,000	30		1.059	$1,059
SEER14GF96*	$4,126	$4,231	$106	15		1.749	$185
Cooling Cap (kBtu)	21.0	18.0					
SEER	14	14					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tankless gas WH	$600	$1,000	$400	15	2.29%	2.900	$1,160
100%FL	$200	$300	$100	5		4.564	$456
RBS	$0	$542	$542	30		1.059	$573
60% ERV	$100	$750	$650	15		1.749	$1,137
1.5 kWp PV system**	$0	$4,200	$4,200	30	1.94%	1.459	$6,128
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$7,272**				**$11,180**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER14GF96*	$4,212	$4,305	$93	15		1.749	$162
Cooling Cap (kBtu)	23.0	19.7					
SEER	14	14					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tankless gas WH	$600	$1,000	$400	15	2.29%	2.900	$1,160
100%FL	$240	$360	$120	5		4.564	$548
60% ERV	$100	$750	$650	15		1.749	$1,137
1.5 kWp PV system**	$0	$4,200	$4,200	30	1.94%	1.459	$6,128
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$6,938**				**$10,887**

* Gas furnace / air conditioner cost calculations based on capacity, SEER and AFUE

** $4.00/Wp - 30% ITC = $2.80/Wp

Table D-5: El Paso, TX Homes with renewable energy production (PV)

	2015 Code Homes				Improved Homes - PV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	7,924	291	$1,237	23.7%	1,727	194	$406	75.0%
1-sty Wrst Case	8,084	297	$1,262	22.2%	1,816	199	$422	74.0%
2-sty Best Case	8,912	291	$1,353	26.6%	2,589	222	$537	70.9%
2-sty Wrst Case	9,094	297	$1,381	25.1%	2,754	226	$560	69.6%
Averages	**8,504**	**294**	**$1,308**	**24.4%**	**2,222**	**210**	**$481**	**72.2%**

	Savings over 2015 Code				Costs Effectiveness			P1 = 20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	6,197	97	$831	67.2%	$11,252	$17,057	$17,103	1.00
1-sty Wrst Case	6,268	98	$840	66.6%	$11,252	$17,057	$17,296	1.01
2-sty Best Case	6,323	69	$816	60.3%	$9,794	$14,982	$16,805	1.12
2-sty Wrst Case	6,340	71	$820	59.4%	$9,794	$14,982	$16,890	1.13
Averages	**6,282**	**84**	**$827**	**63.2%**	**$10,523**	**$16,019**	**$17,023**	**1.06**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,000	$1,000	30		1.059	$1,059
SEER16GF96*	$4,083	$5,367	$1,285	15		1.749	$2,247
Cooling Cap (kBtu)	20.0	18.0					
SEER	14.0	16.0					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$200	$300	$100	5		4.564	$456
RBS	$0	$542	$542	30		1.059	$574
60% ERV	$100	$750	$650	15		1.749	$1,137
2.5 kWp PV system**	$0	$7,000	$7,000	30	1.94%	1.459	$10,214
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$11,252**				**$17,057**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER16GF96*	$4,173	$5,398	$1,224	15		1.749	$2,142
Cooling Cap (kBtu)	22.1	18.7					
SEER	14.0	16.0					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$240	$360	$120	5		4.564	$548
RBS	$0	$325	$325	30		1.059	$344
60% ERV	$100	$750	$650	15		1.749	$1,137
2.0 kWp PV system**	$0	$5,600	$5,600	30	1.94%	1.459	$8,171
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$9,794**				**$14,982**

* Gas furnace / air conditioner cost calculations based on capacity, SEER and AFUE

** $4.00/Wp - 30% ITC = $2.80/Wp

Table D-6: Los Angeles, CA Homes with renewable energy production (PV)

	2015 Code Homes				Improved Homes - PV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	6,444	200	$967	14.5%	3,603	141	$571	49.5%
1-sty Wrst Case	6,442	202	$969	14.3%	3,604	143	$574	49.3%
2-sty Best Case	7,016	198	$1,033	17.4%	4,094	137	$625	50.0%
2-sty Wrst Case	7,020	200	$1,035	17.2%	4,099	138	$627	49.9%
Averages	**6,731**	**200**	**$1,001**	**15.8%**	**3,850**	**140**	**$599**	**49.7%**

	Savings over 2015 Code				Costs Effectiveness			P1 = 20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	2,841	59	$396	40.9%	$5,352	$7,955	$8,153	1.02
1-sty Wrst Case	2,838	59	$396	40.8%	$5,352	$7,955	$8,146	1.02
2-sty Best Case	2,922	61	$408	39.5%	$5,424	$8,149	$8,393	1.03
2-sty Wrst Case	2,921	62	$409	39.5%	$5,424	$8,149	$8,412	1.03
Averages	**2,881**	**60**	**$402**	**40.2%**	**$5,388**	**$8,052**	**$8,276**	**1.03**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,000	$1,000	30		1.059	$1,059
SEER14GF96*	$3,997	$4,231	$235	15		1.749	$411
Cooling Cap (kBtu)	18.0	18.0					
SEER	14.0	14.0					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$200	$300	$100	5		4.564	$456
RBS	$0	$542	$542	30		1.059	$574
1.0 kWp PV system**	$0	$2,800	$2,800	30	1.94%	1.459	$4,086
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$5,352**				**$7,955**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER14GF96*	$3,997	$4,300	$304	15		1.749	$531
Cooling Cap (kBtu)	18.0	19.6					
SEER	14.0	14.0					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$240	$360	$120	5		4.564	$548
RBS	$0	$325	$325	30		1.059	$344
1.0 kWp PV system**	$0	$2,800	$2,800	30	1.94%	1.459	$4,086
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$5,424**				**$8,149**

* Gas furnace / air conditioner cost calculations based on capacity, SEER and AFUE

** $4.00/Wp - 30% ITC = $2.80/Wp

Table D-7: Philadelphia, PA Homes with renewable energy production (PV)

	2015 Code Homes				Improved Homes - PV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	7,574	549	$1,465	19.6%	4,205	368	$879	51.7%
1-sty Wrst Case	7,698	558	$1,489	18.3%	4,281	375	$896	50.9%
2-sty Best Case	8,526	584	$1,614	21.5%	4,925	391	$988	51.9%
2-sty Wrst Case	8,666	595	$1,642	20.1%	5,017	400	$1,009	50.9%
Averages	**8,116**	**572**	**$1,552**	**19.9%**	**4,607**	**384**	**$943**	**51.4%**

	Savings over 2015 Code				Costs Effectiveness			P1 = 20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	3,369	181	$586	40.0%	$7,884	$11,978	$12,057	1.01
1-sty Wrst Case	3,417	183	$593	39.8%	$7,884	$11,978	$12,217	1.02
2-sty Best Case	3,601	193	$626	38.8%	$7,921	$12,111	$12,878	1.06
2-sty Wrst Case	3,649	195	$633	38.6%	$7,921	$12,111	$13,037	1.08
Averages	**3,509**	**188**	**$609**	**39.3%**	**$7,902**	**$12,045**	**$12,547**	**1.04**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,000	$1,000	30		1.059	$1,059
SEER14GF96*	$3,601	$4,318	$717	15		1.749	$1,254
Cooling Cap (kBtu)	22.0	20.0					
SEER	13	14					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$200	$300	$100	5		4.564	$456
RBS	$0	$542	$542	30		1.059	$574
60% ERV	$100	$750	$650	15		1.749	$1,137
1.5 kWp PV system**	$0	$4,200	$4,200	30	1.94%	1.459	$6,128
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$7,884**				**$11,978**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER14GF96*	$3,696	$4,447	$751	15		1.749	$1,314
Cooling Cap (kBtu)	24.2	23.0					
SEER	13	14					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$240	$360	$120	5		4.564	$548
RBS	$0	$325	$325	30		1.059	$344
60% ERV	$100	$750	$650	15		1.749	$1,137
1.5 kWp PV system**	$0	$4,200	$4,200	30	1.94%	1.459	$6,128
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$7,921**				**$12,111**

* Gas furnace / air conditioner cost calculations based on capacity, SEER and AFUE

** $4.00/Wp - 30% ITC = $2.80/Wp

Table D-8: Albuquerque, NM Homes with renewable energy production (PV)

	2015 Code Homes				Improved Homes - PV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	7,224	400	$1,268	19.6%	2,342	265	$553	65.0%
1-sty Wrst Case	7,382	411	$1,298	17.7%	2,445	273	$573	63.7%
2-sty Best Case	8,104	412	$1,384	22.8%	3,051	277	$649	63.8%
2-sty Wrst Case	8,322	424	$1,423	20.6%	3,232	285	$678	62.2%
Averages	**7,758**	**412**	**$1,343**	**20.2%**	**2,768**	**275**	**$613**	**63.6%**

	Savings over 2015 Code				Costs Effectiveness			P1 = 20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	4,882	135	$716	56.4%	$9,348	$14,508	$14,734	1.02
1-sty Wrst Case	4,937	138	$725	55.9%	$9,348	$14,508	$14,932	1.03
2-sty Best Case	5,053	135	$736	53.2%	$9,465	$14,630	$15,148	1.04
2-sty Wrst Case	5,090	139	$744	52.3%	$9,465	$14,630	$15,324	1.05
Averages	**4,991**	**137**	**$730**	**54.4%**	**$9,407**	**$14,569**	**$15,034**	**1.03**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,000	$1,000	30		1.059	$1,059
SEER16GF96*	$4,044	$5,367	$1,323	15		1.749	$2,315
Cooling Cap (kBtu)	19.1	18.0					
SEER	14	16					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$200	$300	$100	5		4.564	$456
60% ERV	$100	$750	$650	15		1.749	$1,137
2 kWp PV system**	$0	$5,600	$5,600	30	1.94%	1.459	$8,171
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$9,348**				**$14,508**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER16GF96*	$4,147	$5,367	$1,220	15		1.749	$2,134
Cooling Cap (kBtu)	21.5	18.0					
SEER	14	16					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$240	$360	$120	5		4.564	$548
60% ERV	$100	$750	$650	15		1.749	$1,137
2 kWp PV system**	$0	$5,600	$5,600	30	1.94%	1.459	$8,171
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_cWash	$450	$500	$50	15		1.749	$87
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
		Totals	**$9,465**				**$14,630**

* Gas furnace / air conditioner cost calculations based on capacity, SEER and AFUE

** $4.00/Wp - 30% ITC = $2.80/Wp

Table D-9: Seattle, WA Homes with renewable energy production (PV)

	2015 Code Homes				Improved Homes - PV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	6,714	482	$1,294	15.1%	4,449	330	$868	43.0%
1-sty Wrst Case	6,736	490	$1,305	14.4%	4,465	336	$877	42.5%
2-sty Best Case	7,326	488	$1,372	17.8%	4,969	331	$931	44.2%
2-sty Wrst Case	7,358	497	$1,385	17.0%	4,998	337	$940	43.6%
Averages	**7,034**	**489**	**$1,339**	**16.0%**	**4,720**	**334**	**$904**	**43.4%**

	Savings over 2015 Code				Costs Effectiveness			P1 = 20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	2,265	152	$425	32.9%	$5,378	$8,375	$8,758	1.05
1-sty Wrst Case	2,271	154	$428	32.8%	$5,378	$8,375	$8,816	1.05
2-sty Best Case	2,357	157	$441	32.2%	$5,598	$8,678	$9,089	1.05
2-sty Wrst Case	2,360	160	$445	32.1%	$5,598	$8,678	$9,161	1.06
Averages	**2,313**	**156**	**$435**	**32.5%**	**$5,488**	**$8,526**	**$8,956**	**1.05**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,000	$1,000	30		1.059	$1,059
SEER14GF96*	$3,429	$4,231	$803	15		1.749	$1,404
Cooling Cap (kBtu)	18.0	18.0					
SEER	13	14					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$200	$300	$100	5		4.564	$456
1.0 kWp PV system**	$0	$2,800	$2,800	30	1.94%	1.459	$4,086
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
		Totals	**$5,378**				**$8,375**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER14GF96*	$3,429	$4,231	$803	15		1.749	$1,404
Cooling Cap (kBtu)	18.0	18.0					
SEER	13	14					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$240	$360	$120	5		4.564	$548
1 kWp PV system**	$0	$2,800	$2,800	30	1.94%	1.459	$4,086
ES_dWash	$450	$500	$50	15		1.749	$87
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
		Totals	**$5,598**				**$8,678**

* Gas furnace / air conditioner cost calculations based on capacity, SEER and AFUE

** $4.00/Wp - 30% ITC = $2.80/Wp

Table D-10: Chicago, IL Homes with renewable energy production (PV)

	2015 Code Homes				Improved Homes - PV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	8,526	657	$1,690	23.1%	4,409	471	$1,011	54.0%
1-sty Wrst Case	8,647	666	$1,714	22.0%	4,510	477	$1,029	53.1%
2-sty Best Case	9,551	713	$1,869	24.2%	5,224	513	$1,151	53.3%
2-sty Wrst Case	9,679	726	$1,898	23.0%	5,352	522	$1,175	52.3%
Averages	**9,101**	**691**	**$1,793**	**23.1%**	**4,874**	**496**	**$1,092**	**53.2%**

	Savings over 2015 Code				Costs Effectiveness			P1 = 20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	4,117	186	$679	40.2%	$8,828	$13,597	$13,977	1.03
1-sty Wrst Case	4,137	189	$684	39.9%	$8,828	$13,597	$14,090	1.04
2-sty Best Case	4,327	200	$718	38.4%	$8,979	$13,780	$14,787	1.07
2-sty Wrst Case	4,327	204	$722	38.1%	$8,979	$13,780	$14,873	1.08
Averages	**4,227**	**195**	**$701**	**39.1%**	**$8,903**	**$13,689**	**$14,432**	**1.05**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,000	$1,000	30		1.059	$1,059
SEER14GF96*	$3,429	$4,231	$803	15		1.749	$1,404
Cooling Cap (kBtu)	18.0	18.0					
SEER	13.0	14.0					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$200	$300	$100	5		4.564	$456
60% ERV	$100	$750	$650	15		1.749	$1,137
2.0 kWp PV system**	$0	$5,600	$5,600	30	1.94%	1.459	$8,171
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
		Totals	**$8,828**				**$13,597**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER14GF96*	$3,515	$4,249	$734	15		1.749	$1,284
Cooling Cap (kBtu)	20.0	18.4					
SEER	13.0	14.0					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$240	$360	$120	5		4.564	$548
60% ERV	$100	$750	$650	15		1.749	$1,137
2.0 kWp PV system**	$0	$5,600	$5,600	30	1.94%	1.459	$8,171
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
		Totals	**$8,979**				**$13,780**

* Gas furnace / air conditioner cost calculations based on capacity, SEER and AFUE

** $4.00/Wp - 30% ITC = $2.80/Wp

Table D-11: Minneapolis, MN Homes with renewable energy production (PV)

	2015 Code Homes				Improved Homes - PV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	9,320	751	$1,882	21.1%	1,607	547	$761	68.1%
1-sty Wrst Case	9,420	764	$1,907	20.0%	1,702	556	$781	67.2%
2-sty Best Case	10,380	794	$2,051	22.9%	2,399	578	$886	66.7%
2-sty Wrst Case	10,536	809	$2,085	21.6%	2,519	589	$912	65.7%
Averages	**9,914**	**780**	**$1,981**	**21.4%**	**2,057**	**568**	**$835**	**66.9%**

	Savings over 2015 Code				Costs Effectiveness			P1 = 20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	7,713	204	$1,121	59.6%	$14,428	$21,769	$23,078	1.06
1-sty Wrst Case	7,718	208	$1,126	59.0%	$14,428	$21,769	$23,176	1.06
2-sty Best Case	7,981	216	$1,165	56.8%	$14,651	$22,078	$23,985	1.09
2-sty Wrst Case	8,017	220	$1,174	56.3%	$14,651	$22,078	$24,159	1.09
Averages	**7,857**	**212**	**$1,146**	**57.9%**	**$14,540**	**$21,923**	**$23,599**	**1.08**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,000	$1,000	30		1.059	$1,059
SEER14GF96*	$3,429	$4,231	$803	15		1.749	$1,404
Cooling Cap (kBtu)	18.0	18.0					
SEER	13	14					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$200	$300	$100	5		4.564	$456
60% ERV	$100	$750	$650	15		1.749	$1,137
4.0 kWp PV system**	$0	$11,200	$11,200	30	1.94%	1.459	$16,342
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
		Totals	**$14,428**				**$21,769**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER14GF96*	$3,475	$4,231	$756	15		1.749	$1,323
Cooling Cap (kBtu)	18.8	18.0					
SEER	13	14					
Heating Cap (kBtu)	43	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$240	$360	$120	5		4.564	$548
60% ERV	$100	$750	$650	15		1.749	$1,137
4.0 kWp PV system**	$0	$11,200	$11,200	30	1.94%	1.459	$16,342
ES_Fridge	$1,200	$1,300	$100	15		1.749	$175
ES_dWash	$400	$475	$75	15		1.749	$131
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
		Totals	**$14,651**				**$22,078**

* Gas furnace / air conditioner cost calculations based on capacity, SEER and AFUE

** $4.00/Wp - 30% ITC = $2.80/Wp

Table D-12: Duluth, MN Homes with renewable energy production (PV)

	2015 Code Homes				Improved Homes - PV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	9,070	910	$2,018	20.4%	1,720	655	$887	65.0%
1-sty Wrst Case	9,100	918	$2,030	20.0%	1,744	661	$896	64.7%
2-sty Best Case	9,998	960	$2,180	23.0%	2,403	695	$1,009	64.3%
2-sty Wrst Case	10,042	971	$2,197	22.4%	2,435	702	$1,020	63.9%
Averages	**9,553**	**940**	**$2,106**	**21.4%**	**2,076**	**678**	**$953**	**64.5%**

	Savings over 2015 Code				Costs Effectiveness			P1 = 20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	7,350	255	$1,132	56.1%	$14,560	$22,000	$23,295	1.06
1-sty Wrst Case	7,356	257	$1,134	55.9%	$14,560	$22,000	$23,353	1.06
2-sty Best Case	7,595	265	$1,171	53.7%	$14,771	$22,287	$24,104	1.08
2-sty Wrst Case	7,607	269	$1,176	53.6%	$14,771	$22,287	$24,219	1.09
Averages	**7,477**	**262**	**$1,153**	**54.8%**	**$14,665**	**$22,143**	**$23,743**	**1.07**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,000	$1,000	30		1.059	$1,059
SEER13GF96*	$3,429	$4,363	$935	15		1.749	$1,635
Cooling Cap (kBtu)	18.0	18.0					
SEER	13.0	13.0					
Heating Cap (kBtu)	40	40					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$200	$300	$100	5		4.564	$456
60% ERV	$100	$750	$650	15		1.749	$1,137
4.0 kWp PV system**	$0	$11,200	$11,200	30	1.94%	1.459	$16,342
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$14,560**				**$22,000**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER13GF96*	$3,445	$4,371	$926	15		1.749	$1,620
Cooling Cap (kBtu)	18.0	18.0					
SEER	13.0	13.0					
Heating Cap (kBtu)	44	41.8					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$240	$360	$120	5		4.564	$548
60% ERV	$100	$750	$650	15		1.749	$1,137
3.0 kWp PV system**	$0	$11,200	$11,200	30	1.94%	1.459	$16,342
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$14,771**				**$22,287**

* Gas furnace / air conditioner cost calculations based on capacity, SEER and AFUE

** $4.00/Wp - 30% ITC = $2.80/Wp

Table D-13: Fairbanks, AK Homes with renewable energy production (PV)

	2015 Code Homes				Improved Homes - PV			
Case	**kWh/y**	**Th/y**	**$/y**	**$save '06**	**kWh/y**	**Th/y**	**$/y**	**$save '06**
1-sty Best Case	9,260	1,327	$2,477	21.5%	3,249	948	$1,373	56.5%
1-sty Wrst Case	9,266	1,337	$2,488	21.1%	3,254	955	$1,381	56.2%
2-sty Best Case	10,192	1,428	$2,692	23.4%	3,926	1,014	$1,522	56.7%
2-sty Wrst Case	10,198	1,439	$2,704	23.0%	3,936	1,022	$1,531	56.4%
Averages	**9,729**	**1,383**	**$2,590**	**22.3%**	**3,591**	**985**	**$1,452**	**56.5%**

	Savings over 2015 Code				Costs Effectiveness		P1 =	20.587
Case	**Δ kWh/y**	**Δ Th/y**	**Δ $/y**	**$save '15**	**1stCost**	**LC Cost**	**LC Save**	**SIR**
1-sty Best Case	6,011	379	$1,104	44.6%	$14,544	$21,971	$22,719	1.03
1-sty Wrst Case	6,012	382	$1,107	44.5%	$14,544	$21,971	$22,786	1.04
2-sty Best Case	6,266	414	$1,170	43.5%	$14,604	$21,995	$24,089	1.10
2-sty Wrst Case	6,262	417	$1,173	43.4%	$14,604	$21,995	$24,144	1.10
Averages	**6,138**	**398**	**$1,138**	**43.9%**	**$14,574**	**$21,983**	**$23,434**	**1.07**

1sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,000	$1,000	30		1.059	$1,059
SEER13GF96*	$3,445	$4,363	$919	15		1.749	$1,607
Cooling Cap (kBtu)	18.0	18.0					
SEER	13.0	13.0					
Heating Cap (kBtu)	44.0	40.0					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$200	$300	$100	5		4.564	$456
60% ERV	$100	$750	$650	15		1.749	$1,137
4.0 kWp PV system**	$0	$11,200	$11,200	30	1.94%	1.459	$16,342
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$14,544**				**$21,971**

2sty Improved home incremental costs

Measure	**Base$**	**Improv$**	**Incr$**	**svc life**	**Maint**	**P2**	**LC Cost**
Interior Ducts	$0	$1,200	$1,200	30		1.059	$1,271
SEER13GF96*	$3,632	$4,392	$759	15		1.749	$1,328
Cooling Cap (kBtu)	21.7	18.0					
SEER	13.0	13.0					
Heating Cap (kBtu)	51	47					
AFUE	80%	96%					
Tnkless gasWH	$600	$1,000	$400	15	2.29%	2.221	$888
100%FL	$240	$360	$120	5		4.564	$548
60% ERV	$100	$750	$650	15		1.749	$1,137
4.0 kWp PV system**	$0	$11,200	$11,200	30	1.94%	1.459	$16,342
ES_cWash/dry	$1,200	$1,350	$150	15		1.749	$262
ES_Fridge	$1,200	$1,275	$75	15		1.749	$131
ES_dWash	$450	$500	$50	15		1.749	$87
		Totals	**$14,604**				**$21,995**

* Gas furnace / air conditioner cost calculations based on capacity, SEER and AFUE

** $4.00/Wp - 30% ITC = $2.80/Wp