Review and Economic Analysis of Increased Wall Insulation Required by the 2004 IECC Supplement

Prepared for

The North American Insulation Manufacturers Association and

The Polyisocyanurate Insulation Manufacturers Association

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Executive Summary

The 2004 IECC supplement contains fundamental changes designed to improve its usability and enforceability. One of the key changes decouples the envelope efficiency requirements from the window efficiency and window area requirements for the home. To compensate for a potential decrease in overall efficiency of the homes built to this code, amendments were made during the code development hearings, in accordance with the ICC code development process, to increase the required wall insulation in many parts of the country. Since the adoption of the 2004 IECC supplement, questions have arisen about the cost effectiveness of this increase in wall insulation requirements.

At the request of the North American Insulation Manufacturers Association (NAIMA) and the Polyisocyanurate Insulation Manufacturers Association (PIMA), ICF Consulting conducted an independent analysis to assess the cost effectiveness associated with the increased wall insulation requirements. For its analysis, ICF Consulting simulated the annual energy consumption of single-family homes that were configured with one of four wall insulation scenarios that meet or exceed the code requirements and compared this to homes configured to meet the code prior to the increase in wall insulation. Cost effectiveness was then calculated by translating the energy savings into utility bill savings and comparing these to the material and labor costs of each wall insulation scenario. To increase accuracy, ICF Consulting modeled multiple housing configurations in multiple locations and accounted for regional variations in utility costs, material and labor costs, housing starts, and housing characteristics. In all, over 1.23 million simulations were completed using the DOE2.1E simulation program.

This study assessed the impacts of achieving the 2004 IECC wall insulation requirements through the use of specific wall insulation products. However, the energy savings results of this analysis are generally equivalent to other insulation products which meet the R-value requirements of the wall insulation scenarios analyzed. For example, wall cavity insulation R-values can be achieved through the use of spray foams (e.g., Icynene) and cellulose insulation products, in addition to the medium and high-density fiberglass batt insulation used in this study. Likewise, exterior insulated wall sheathing can be met by the available array of rigid foam insulation products, including extruded polystyrene (XEPS), expanded polystyrene (EPS), and polyurethane (PUR), in addition to the polyisocyanurate (polyiso) assessed in this study.

ICF Consulting also reviewed a report on the same topic written by the Pacific Northwest National Laboratory (PNNL) to assess how the analytical approach and assumptions differed from ICF Consulting.

Key findings of these two analyses include the following:

- ICF Consulting found that in every climate zone impacted by the increased wall insulation requirements, there is at least one insulation scenario that meets the code, saves energy, and costs less to install than the lower insulation requirements originally proposed for the 2004 IECC (the RICC).

- When evaluating cost effectiveness in terms of simple payback period, ICF Consulting found that in all climate zones, including 4 Marine, at least one of the wall insulation scenarios analyzed had a payback of zero years. Alternatively, when ICF Consulting calculated cost effectiveness in terms of annual cash flow, it found that a homeowner's monthly cash flow would fall between a cost of $1.00 and a credit of $3.75 per month. ICF Consulting also found that certain insulation scenarios, such as using ¾” polyisocyanurate (polyiso) rigid insulation with let-in bracing, can offer homeowners a positive cash flow up to $89 per year.

- Energy savings derived from increased insulation levels are particularly significant because of their permanence. Unlike energy savings from equipment upgrades, which may decrease over time or be eliminated when equipment is replaced, energy savings from insulation upgrades should continue to accrue throughout the life of the structure. There are a number of benefits associated with this, including creating more affordable homes for both current and future home buyers through potentially lower first costs and a positive cash flow every year. For example, this analysis found that construction costs of a new home can be reduced by as much as $490 when using insulated sheathing products with corner bracing in place of full structural sheathing.

- Among the wall insulation scenarios analyzed, using rigid insulated sheathing products in combination with medium-density fiberglass batt insulation is the most effective, while upgrading from medium-density fiberglass batt insulation to high-density fiberglass batt insulation is least cost effective. (According to a 1996 NAHB study[1], approximately 30% of all single family homes constructed in the United States used insulated sheathing products, nearly as popular in use as oriented strand board (OSB) sheathing.)

- The differences between ICF Consulting’s results and PNNL’s results are due primarily to ICF Consulting’s accounting for regional variations, for its use of less widely bracketed cost estimates, and for its inclusion of additional insulation scenarios beyond high-density fiberglass insulation. PNNL’s analysis was based on a single house configuration, national average upgrade costs, a single wall insulation upgrade scenario, and four distinct climate zones (i.e., 3, 4, 5, & 6). In contrast, ICF Consulting’s analysis was based on 324 house configurations, regional factors, four wall insulation upgrade scenarios, and five distinct climate zones (i.e., 3, 4, 4 Marine, 5, & 6).

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[1] “Factory and Site-Built Housing a Comparison for the 21st Century,” prepared by the NAHB Research Center, October 1998. Table 12: Use of Wall Sheathing Materials in New Conventional Single-Family Housing and Manufactured Housing, 1996. Retrieved from http://www.mfghome.org/developer_resources/factory_vs_sitebuilt/index.asp#_Ref421410668 on June 3, 2005.

Introduction and Background

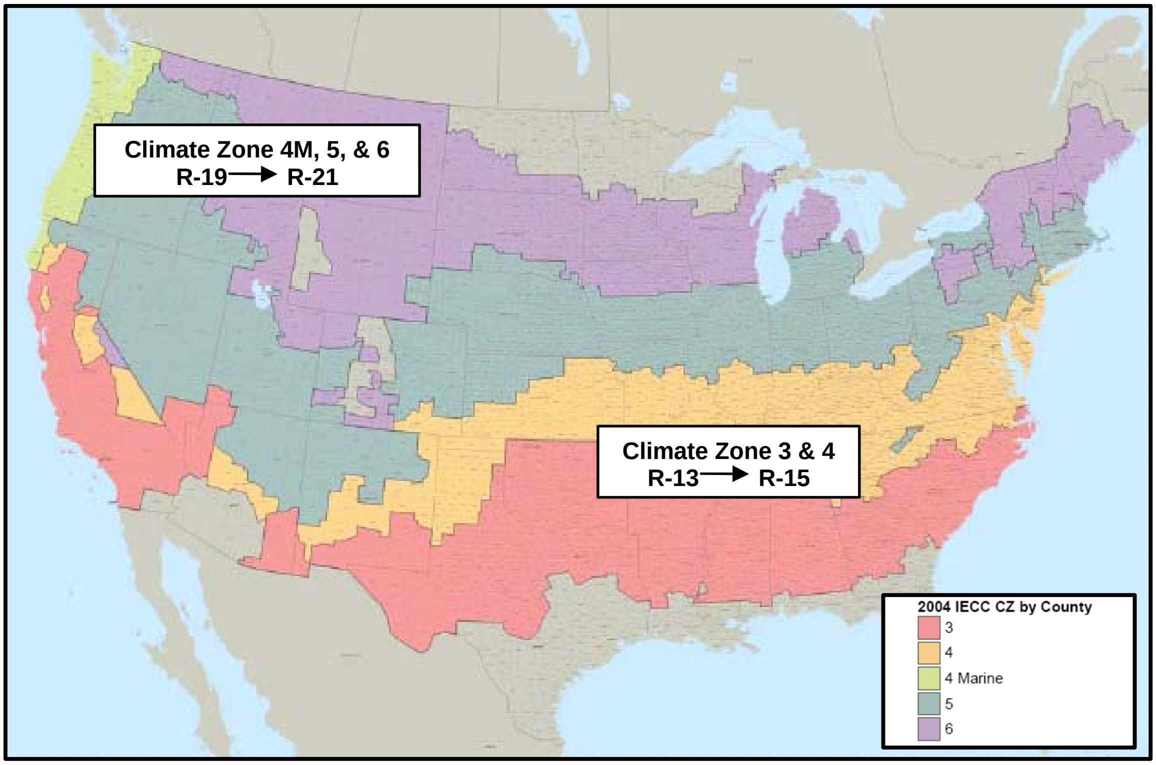
Fundamental changes designed to improve the usability and enforceability of the 2003 IECC were proposed in Department of Energy’s (DOE) Residential IECC Code-Change (RICC) proposal (EC48-03/04). The requirements for wall insulation in the RICC were proposed to be increased by an amendment at the September 2003 Code Development Hearings of the International Code Council (ICC). As illustrated in Exhibit 1, the amendment increased the wall insulation from R-13 to R-15 in climate zones 3 and 4, and from R-19 to R-21 in climate zones 4 Marine through 6. This proposal was subsequently accepted by the IECC development committee and the increased wall insulation levels became the basis of the 2004 IECC supplement.

DOE felt that the changes in wall insulation requirements were substantial enough to warrant an analysis of their potential impacts. This analysis was conducted by PNNL and is summarized in a report titled “An Analysis of Floor Modifications to IECC Code Change EC48-03/04[2],” dated February 23, 3005. In addition, the American Council for an Energy Efficient Economy (ACEEE) conducted a study on the energy impact of the code changes. The results of this study are in the February 2005 ACEEE report titled “Impact Assessment of 2004 IECC Wall Criteria Changes.”

Objective

The North American Insulation Manufacturers Association (NAIMA) and the Polyisocyanurate Insulation Manufacturers Association (PIMA) wanted to independently assess the energy savings and incremental costs associated with the increased wall insulation requirements in the 2004 IECC supplement. They asked ICF Consulting to conduct this independent analysis and to review and assess the analysis conducted by PNNL. The results of these two efforts are presented in this report.

Exhibit 1: 2004 IECC Climate Zones 3 - 6



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[2] An Analysis of Floor Modifications to IECC Code Change EC48-03/04. February 23, 2005. Retrieved May 16, 2005 from http://www.energycodes.gov/ec48_floor_mods_analysis.pdf.

Energy Savings and Cost-Effective Analysis

ICF Consulting conducted a comprehensive analysis on the cost-effectiveness of the increased wall insulation requirements in the 2004 IECC supplement. The analysis assessed five insulation scenarios (a baseline and four wall insulation upgrade scenarios) applied to a broad range of housing characteristics and locations. To increase the accuracy of the results, estimates of regional variations in utility rates, construction costs, and housing characteristics were applied.

The three major steps of this analysis are listed below and described in detail in the following sections:

1) Conduct energy modeling;
2) Determine regional economic factors; and
3) Calculate cost-effectiveness.

Energy Modeling

In order to conduct the energy modeling, the variations in housing characteristics and wall insulation scenarios to be assessed were first identified.

Housing Characteristics

The energy consumption of a house is affected by several major housing characteristics, including: architectural features, such as window area, floor area, and orientation, as well as energy related features, such as insulation levels, infiltration levels, and equipment efficiencies. For this study, a range of architectural features was selected that represents a large majority of the new single-family detached construction occurring today (see Exhibit 2). All energy related features other than wall insulation (which varies based on the five insulation scenarios), were defined by the requirements of the 2004 IECC.

Exhibit 2 – Major architectural features and locations of simulated homes

House Characteristics	Variations Modeled
Orientation	North, East, South, & West
Number of Stories & Conditioned Floor Area	1-Story with 1000, 2000, & 3000 ft^2 of total conditioned floor area
	2-Story with 1600, 2000, 2400 ft^2 of total conditioned floor area
Window Area to Conditioned Floor Area Ratio	15%, 18%, & 21%
Window Distribution (% of Total Window Area on Front, Back, Left, Right)	(50%, 25%, 12.5%, 12.5%), (25%, 25%, 25%, 25%), & (37.5%, 37.5%, 12.5%, 12.5%)
Foundation Type	Slab-on-grade, Basement, & Crawlspace
Foundation Aspect Ratio	2:1
Number of Bedrooms	3
Location	All 36 available TMY2 weather files in CZ 3, All 43 available TMY2 weather files in CZ 4, All 8 available TMY2 weather files in CZ 4 Marine, All 52 available TMY2 weather files in CZ 5, All 52 available TMY2 weather files in CZ 6,
Heating Fuel & Equiprment Type	Electric Heatpump & Natural Gas Furnace

Wall Insulation Scenarios

There are many wall construction practices and insulation products that can be used to meet the increased wall insulation levels specified in the 2004 IECC supplement. Four different wall insulation upgrade scenarios were assessed in this analysis, along with a baseline wall insulation scenario that meets the requirements in the RICC. The five wall insulation scenarios assessed are as follows:

1. Medium-Density Insulation (Baseline) – Housing configurations modeled with OSB sheathing that covers 100% of exterior opaque wall surfaces and medium-density fiberglass batt insulation in wall cavities. Configurations meet the requirements of the RICC;
2. High-Density Insulation – Housing configurations modeled with OSB sheathing that covers 100% of exterior opaque wall surfaces and high-density fiberglass batt insulation in wall cavities. Configurations meet the requirements of the 2004 IECC;
3. 25% OSB Corner Bracing & 75% ½ Inch Rigid Foam Insulation – Housing configurations modeled with OSB sheathing that covers 25% of the exterior opaque wall surfaces, ½” rigid foam insulation (see below) that covers the remaining 75% of exterior opaque wall surfaces, and medium-density fiberglass batt insulation in wall cavities.
    a. Insulation meets requirements of the 2004 IECC through ½” R-2 rigid foam insulation;
    b. Insulation exceeds requirements of the 2004 IECC through ½” R-3.5 polyiso rigid foam insulation;
4. Full OSB Bracing & ½ Inch Rigid Foam Insulation - Housing configurations modeled with OSB sheathing that covers 100% of exterior opaque wall surfaces, ½” rigid foam insulation (see below) that also covers 100% of exterior opaque wall surfaces, and medium-density fiberglass batt insulation in wall cavities.
    a. Insulation slightly exceeds requirements of the 2004 IECC through 100% OSB sheathing with100% R-2 rigid foam insulation;
    b. Insulation exceeds requirements of the 2004 IECC through 100% OSB sheathing with100% R-3.5 polyiso rigid foam insulation; and
5. Let-in Bracing & ¾ Inch Rigid Foam Insulation - Housing configurations modeled with 16 gauge steel let-in bracing, ¾” polyiso rigid sheathing (R-4.9, nominal 6.5 per inch) that covers 100% of exterior opaque wall surfaces, and medium-density fiberglass batt insulation in wall cavities. Configurations exceed the requirements of the 2004 IECC.

While this analysis did not explicitly assess the multitude of wall insulation products available, the energy savings results are generally equivalent to other insulation products which meet the R-value requirements of the wall insulation scenarios analyzed. For example, the wall cavity insulation R-values can also be achieved through the use of spray foams (e.g., Icynene) and cellulose insulation products. Likewise, exterior insulated wall sheathing can be met by the available array of rigid foam insulation products, including extruded polystyrene (XEPS), expanded polystyrene (EPS), and polyurethane (PUR).

The major characteristics of these five insulation scenarios are summarized in Exhibit 3.

Exhibit 3: Major Characteristics That Vary Between Insulation Scenarios

Climate Zone	Scenario Name	Sheathing Layer			Wall Cavity Layer		Wall Insulation R-Value
		Material	Nominal Insulating Value	% of Exterior Wall Surface Covered	Framing Material	Nominal Insulating Value	
3 & 4	1. Baseline Scenario	OSB	n/a	100%	2x4	R-13	R-13
	2. High-Density Insulation Scenario	OSB	n/a	100%	2x4	R-15	R-15
	3. Corner-bracing & ½" Rigid Sheathing	OSB	n/a	25%			
	a. Minimum R-2 Insulation	½" Minimum R-2	R-2	75%	2x4	R-13	R-15
	b. Polyisocyanurate	½" Polyisocyanurate	R-3.3	75%	2x4	R-13	R-16.3
	4. Full-bracing & ½" Rigid Sheathing	OSB	n/a	100%			
	a. Minimum R-2 Insulation	½" Minimum R-2	R-2	100%	2x4	R-13	R-15
	b. Polyisocyanurate	½" Polyisocyanurate	R-3.3	100%	2x4	R-13	R-16.3
	5. Let-in Bracing & ¾" Rigid Sheathing	¾" Polyisocyanurate	R-4.9	100%	2x4	R-13	R-17.9
4 Marine, 5, & 6	A. Baseline Scenario	OSB	n/a	100%	2x6	R-19	R-19
	B. High-Density Insulation Scenario	OSB	n/a	100%	2x6	R-21	R-21
	C. Corner-bracing & ½" Rigid Sheathing	OSB	n/a	25%			
	a. Minimum R-2 Insulation	½" Minimum R-2	R-2	75%	2x6	R-19	R-21
	b. Polyisocyanurate	½" Polyisocyanurate	R-3.3	75%	2x6	R-19	R-22.3
	D. Full-bracing & ½" Rigid Sheathing	OSB	n/a	100%			
	a. Minimum R-2 Insulation	½" Minimum R-2	R-2	100%	2x6	R-19	R-21
	b. Polyisocyanurate	½" Polyisocyanurate	R-3.3	100%	2x6	R-19	R-22.3
	E. Let-in Bracing & ¾" Rigid Sheathing	¾" Polyisocyanurate	R-4.9	100%	2x6	R-19	R-23.9

Energy Modeling

Each unique housing configuration was modeled five times – one time each using wall insulation scenario 1, 2, 3a, 4a, and 5. A subset of housing configurations was additionally modeled using wall insulation scenario 3b and 4b. All scenarios were modeled with 23% framing fraction, 16" o.c. stud spacing[3], and faced fiberglass batt insulation in the wall cavity. The energy modeling was conducted using the DOE-2.1E[4] energy simulation program with ICF Consulting's proprietary front-end. This implementation of DOE 2.1E meets the BESTEST[5] and has been used to provide technical and policy support to EPA's ENERGY STAR Labeled Homes program[6] since its inception. 247,536 DOE-2 simulations were performed for each of the five insulation scenarios. In all, more than 1.23 million energy simulations were conducted across the 191 relevant TMY2 weather files.

Economic Factors

The cost effectiveness of the increased wall insulation requirements in the 2004 IECC were assessed for each climate zone, as that is how the code requirements are specified and will be applied. However, each climate zone will be most accurately assessed if regional variations are accounted for, rather than relying on national or climate zone averages. For this reason, ICF

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[3] Although advanced framing wall construction with 24" o.c. spacing is possible with 2x6 studs, it was not assessed in this analysis.

[4] Gates, S.D. & Hirsch, J.J. (1996). *DOE-2.1E-110 Enhancements.*

[5] Judkoff, R. & Neymark, J. (February 1995). *International Energy Agency Building Energy Simulation Test (BESTEST) and Diagnostic Method.* NREL/TP-472-6231. Retrieved on June 3, 2005 from http://www.nrel.gov/docs/legosti/old/6231.pdf.

[6] http://www.energystar.gov/homes.

Consulting used the most region-specific inputs available, including state-level utility rates and housing characteristics as well as metropolitan-level housing starts and material costs.

Utility Rates

Estimated state-level utility rates were used to calculate annual energy costs savings using the results from the energy modeling. To estimate utility rates for each state, ICF Consulting referenced the Energy Information Administration's (EIA) State Energy Price and Expenditure Report[7]. This report was selected primarily because it is cited as an acceptable source of energy prices within the 2004 IECC. In addition, it contains the most recent historical data available from a single source, assuring that consistent methodologies were used to assess both natural gas and electricity prices. However, this report only provides utility rates through 2001; therefore ICF Consulting adjusted the rates to estimates for 2005 using the following procedure.

To account for the escalation of fuel prices between 2001 and 2005 ICF Consulting calculated a five-year historical national average using EIA's most current data[8]. Prior to calculating the average, each of the annual values was adjusted to 2005 dollars. An inflation rate of 2.6% per year was used to be consistent with PNNL's analysis. This five-year average was then compared to the 2001 national utility rate, and the percent change between these two values was applied to the 2001 state utility rates. The net result is that the state utility rates used in this analysis are 2% higher for natural gas and 8% higher for electricity. This is summarized in Exhibit 4.

Exhibit 4: Historical and Adjusted Fuel Prices

	Natural Gas Prices ($/MCF)		**Electricity Prices (¢/kWh)**	
Year	**Historical Price**	**In 2005 $**	**Historical Price**	**In 2005 ¢**
2000	7.8	8.8	8.2	9.4
2001	9.6	10.7	8.6	9.6
2002	7.9	8.5	8.5	9.1
2003	9.5	10.0	8.7	9.2
2004	10.7	11.0	8.9	9.2
Average		**9.8**		**9.3**
% Change From 2001		**2%**		**8%**

It is important to note that these rates do not account for any increase or decrease in utility rates beyond 2005 (i.e., the fuel escalation rate is assumed to be zero). While it would have been ideal to estimate average utility rates that extend over the life of the insulation, accurate long-term forecasts of fuel prices are difficult to produce. EIA's Annual Energy Outlook 2005 contains projections of energy prices by sector and source through 2025[9], yet even the near-term projections for 2002-2004 have not matched historical values. For example, the outlook forecasted a 2004 natural gas national average at $0.99 per therm instead of an actual national average of $1.09 per therm. Because of these difficulties, ICF Consulting assumed that its estimate of five year average utility rates in 2005 dollars would remain constant throughout the terms of all financial analyses. Any future increase in utility rates would improve the cost-effectiveness of increased wall insulation.

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[7] Energy Information Administration. (2001). *State Energy Data 2001 Price and Expenditure Data.* Retrieved on June 3, 2005 from http://www.eia.doe.gov/emeu/states/sep_sum/html/pdf/sum_pr_all.pdf.

[8] Energy Information Administration. (2000-2004). *US Natural Gas Prices.* Retrieved on June 3, 2005 from http://tonto.eia.doe.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm. *U.S. Electric Utility Average Retail Price (Revenue per Kilowatthour) Data.* Retrieved on June 3, 2005 from http://www.eia.doe.gov/cneaf/electricity/page/sales_revenue.xls.

[9] Energy Information Administration. (2004). *Annual Energy Outlook 2005 – Table 3. Energy Prices by Sector and Source.* Retrieved on June 3, 2005 at http://www.eia.doe.gov/oiaf/aeo/excel/aeotab_3.xls.

The estimated cost effectiveness of the insulation requirements can be substantially impacted by the assumed utility rates. As noted above, ICF Consulting chose to use state-level utility rates to account for regional variations. To illustrate how state-level rates can vary from national average utility rates, ICF Consulting calculated average utility rates for each climate zone and compared them to the national average rates. The climate zone utility rates were estimated by weighting the state-level rates by the number of housing starts in each state. These and the national average utility rates are presented in Exhibit 5. It is interesting to note that regional price estimates vary significantly from national averages. For example, climate zone 4 Marine has the lowest electric rates in the country, while climate zone 3 has the highest rates.

Exhibit 5: Utility Costs Weighted by Location and Housing Starts

Climate Zone	National	3	4	4 Marine	5	6
Natural Gas ($/therm)	$0.99	$1.02	$1.09	$0.96	$0.93	$0.88
Electricity ($/kWh)	$0.093	$0.118	$0.117	$0.080	$0.114	$0.112

Regional-Based Weighting Factors

To more precisely estimate the economic impacts on a regional basis, weighting factors reflecting the characteristics of those regions were applied in this analysis. These factors include housing starts, number of stories, and location cost factors. The weighting factors were applied to the results of the energy modeling for each weather file location. These weighted results were then summarized by climate zone. An explanation of why these factors were used, how they were derived and where they were used in the analysis is provided below.

- Housing Starts

  The impacts of the increased wall insulation levels in the 2004 IECC supplement are dependent on the actual number of homes constructed to this code. Thus weighting the results of the energy modeling by the relative number of housing starts is critical to more realistically assessing the impacts of the wall insulation level changes. Data available for major metropolitan areas in the 2003 U.S. Census Annual Housing Permits report[10] were used to approximate housing starts for each weather file location. Weighting factors were then calculated as the percentage of housing starts for each TMY2 weather file location relative to all starts within a climate zone.

- Number of Stories

  Single and double story homes have different wall to conditioned floor area ratios. A varying ratio means that the impact of the wall area on the homes overall energy use will also vary. Thus, the prevalence of single versus double story homes will affect the impacts of the insulation changes in a given location. Metropolitan data from the 2003 American Housing Survey[11] was used to estimate the percent of single versus double story homes on a state by state basis. Exhibit 6 shows an estimate of this percentage across each of the climate zones assessed in this analysis. This data shows that most homes in the northern regions are double story homes, while the southern regions have a more equal mix of single and double story homes.

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[10] Table 3au. New Privately Owned Housing Units Authorized, Unadjusted Units by Metropolitan Area, Annual 2003. Retrieved from http://www.census.gov/const/C40/Table3/tb3u2003.txt on June 3, 2005.

[11] http://www.huduser.org/datasets/ahs.html.

Exhibit 6: Weighting by Percent Single vs. Double Story Home for Each Climate Zone

Climate Zone	3	4	4 Marine	5	6
1-Story	45%	20%	22%	11%	7%
2-Story	55%	80%	78%	89%	93%

In addition to understanding the percentage of homes which are single versus double story, it is important to assess the variation in wall area in relationship to the size of the conditioned floor area. This relationship not only impacts energy use, but it also directly impacts the upgrade costs. Exhibit 7 summarizes the wall areas modeled in this analysis for the various housing configurations.

Exhibit 7: Calculated Net Wall Area for Each House Type

House Type	Conditioned Floor Area (Sq. Ft.)	Wall Surface Area (Sq. Ft.)	Average Wall Area per House Type (Sq. Ft.)
1-Story Single Family	1000	893	1123
	2000	1158	
	3000	1319	
2-Story Single Family	1600	1752	1913
	2000	1921	
	2400	2066	

- Location Cost Factors

  To further regionalize the results from the energy modeling, ICF Consulting assigned RS Means[12] location factors to each TMY2 weather file location. These factors impact the material, labor, and overhead costs associated with each wall insulation scenario. To illustrate the relative importance of these factors Exhibit 8 shows the location cost factors weighted by the number of housing starts for each climate zone.

Exhibit 8: RS Means Location Factors Summarized by Climate Zone

Climate Zone	3	4	4 Marine	5	6
Location Factor	89%	99%	101%	103%	102%

Material Costs – Incremental Installed Unit Costs

ICF Consulting was able to find multiple sources of data for the cost of high-density insulation, but was only able to obtain one reliable source for each of the three insulated sheathing scenarios. These incremental installed unit costs are listed in the following five exhibits.

The incremental installed unit costs listed for the 2005 RS Means high-density fiberglass batt insulation were provided by Owens Corning[13]. Owens Corning developed these values by interpolating between available costs and assuming approximately constant material cost per unit weight of insulation.

ICF Consulting utilized the lowest cost structural sheathing available in 2005 RS Means to estimate the cost of OSB. This provided the most conservative estimate of cost-effectiveness when structural sheathing is replaced with insulated sheathing.

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[12] RS Means Residential Cost Data, 23rd Annual Edition, 2004.

[13] High density fiberglass batt insulation pricing provided by Owens Corning in excel format for the purpose of having accurate pricing this report: MEANS 2005 Insulation Prices (5-24-05).xls.

In the following exhibits, positive costs indicate that a wall insulation scenario is more expensive than the baseline approach, while negative costs indicate that a wall insulation scenario is less expensive than the baseline approach. This can occur when the cost of increasing insulation is outweighed by the savings of using less structural sheathing.

Exhibit 9: Incremental Installed Unit Cost for R-13 to R-15 Batt Insulation ($\$/ft^2$ of wall area)

Source	Notes	PNNL Value	ICF Value
CA 2001 DEER	Assumes no change in labor, overhead or profit.	0.42	0.26
CA 2005 DEER	Assumes no change in labor, overhead or profit.	n/a	0.13
2005 RS MEANS		n/a	0.28

Exhibit 10: Incremental Installed Unit Cost for R-19 to R-21 Batt Insulation ($\$/ft^2$ of wall area)

Source	Notes	PNNL Value	ICF Value
Oregon 1993 Study	Recalculated to account for wall area, instead of floor area	$0.10	$0.15
CA 2001 DEER	Assumes no change in labor, overhead or profit.	$0.44	$0.20
CA 2005 DEER	Assumes no change in labor, overhead or profit.	n/a	$0.20
2005 RS MEANS		n/a	$0.25

Exhibit 11: Incremental Installed Unit Cost for Full Structural Sheathing Changed to 25% Structural Sheathing + 75% ½" Insulating Sheathing ($\$/ft^2$ of wall area)

Source	Notes	Wood	Insulation	Upgrade Cost
2005 RS MEANS	Plywood to 1/2" Minimum Insulating Sheathing	$0.88	$0.54	-$0.26 *
2005 RS MEANS	OSB to 1/2" Minimum Insulating Sheathing	$0.82	$0.54	-$0.21 *
2005 RS MEANS	Plywood to 1/2" PolyIso Insulating Sheathing	$0.88	$0.73	-$0.11 *
2005 RS MEANS	OSB to 1/2" PolyIso Insulating Sheathing	$0.82	$0.73	-$0.07 *

* A negative number indicates savings compared to the baseline on a per square foot basis.

Exhibit 12: Incremental Installed Unit Cost for Addition of Full Wall ½" Insulating Sheathing ($\$/ft^2$ of wall area)

Source	Notes	Wood	Insulation	Upgrade Cost
2005 RS MEANS	+ 1/2" Minimum Insulating Sheathing	$0.00	$0.54	$0.54
2005 RS MEANS	+ 1/2" PolyIso Insulating Sheathing	$0.00	$0.73	$0.73

Exhibit 13: Incremental Installed Unit Cost for Plywood to ¾" Polyiso Insulating Sheathing ($\$/ft^2$ of wall area)

Source	Notes	Wood	Bracing (/LF)	Insulation	Upgrade Cost
2005 RS MEANS	Plywood to 3/4" PolyIso Insulating Sheathing 1 Story	$0.88	$1.22	$0.67	-$0.11 *
2005 RS MEANS	Plywood to 3/4" PolyIso Insulating Sheathing 2 Story	$0.88	$1.22	$0.67	-$0.15 *
2005 RS MEANS	OSB to 3/4" PolyIso Insulating Sheathing 1 Story	$0.82	$1.22	$0.67	-$0.05 *
2005 RS MEANS	OSB to 3/4" PolyIso Insulating Sheathing 2 Story	$0.82	$1.22	$0.67	-$0.09 *

* A negative number indicates savings compared to the baseline on a per square foot basis.

Material Costs – Total Incremental Installed Costs

The lowest and highest incremental installed unit costs from the above tables are summarized by climate zone in Exhibits 14 and 15. For wall insulation scenarios that have only one estimate, “N/A” is indicated in the highest cost table.

Exhibit 14: Lowest Incremental Installed Cost per Sq. Ft. for Each Climate Zone and Scenario

#	Climate Zone	3	4	4 Marine	5	6
2	High-Density Insulation	$0.13	$0.13	$0.15	$0.15	$0.15
3a	25% Wood+ 75% ½" Min. Insulating Sheathing	-$0.26*	-$0.26*	-$0.26*	-$0.26*	-$0.26*
3b	25% Wood+ 75% ½" PolyIso Insulating Sheathing	-$0.11*	-$0.11*	-$0.11*	-$0.11*	-$0.11*
4a	Plus ½" Minimum Insulating Sheathing	$0.54	$0.54	$0.54	$0.54	$0.54
4b	Plus ½" PolyIso Insulating Sheathing	$0.73	$0.73	$0.73	$0.73	$0.73
5	¾" PolyIso Insulating Sheathing w/ Let-In Bracing	-$0.13*	-$0.14*	-$0.14*	-$0.15*	-$0.15*

* A negative number indicates savings compared to the baseline on a per square foot basis.

Exhibit 15: Highest Incremental Installed Cost per Sq. Ft. for Each Climate Zone and Scenario

#	Climate Zone	3	4	4 Marine	5	6
2	High-Density Insulation	$0.28	$0.28	$0.25	$0.25	$0.25
3a	25% Wood+ 75% ½" Min. Insulating Sheathing	-$0.21*	-$0.21*	-$0.21*	-$0.21*	-$0.21*
3b	25% Wood+ 75% ½" PolyIso Insulating Sheathing	-$0.07*	-$0.07*	-$0.07*	-$0.07*	-$0.07*
4a	Plus ½" Minimum Insulating Sheathing	N/A	N/A	N/A	N/A	N/A
4b	Plus ½" PolyIso Insulating Sheathing	N/A	N/A	N/A	N/A	N/A
5	¾" PolyIso Insulating Sheathing w/ Let-In Bracing	-$0.07*	-$0.08*	-$0.08*	-$0.09*	-$0.09*

* A negative number indicates savings compared to the baseline on a per square foot basis.

To determine the total incremental installed cost of each wall insulation scenario, the unit costs were multiplied by the wall areas for each climate zone. These wall areas were determined by multiplying the wall areas from Exhibit 7 by the single and double story weighting factors in Exhibit 6. The resulting lowest and highest incremental installed costs for each wall insulation scenario are shown in Exhibits 16 and 17.

Exhibit 16: Lowest Estimated Incremental Installed Cost by Wall Insulation Scenario

#	Climate Zone	3	4	4 Marine	5	6
2	High-Density Insulation	$181	$226	$264	$281	$285
3a	25% Wood+ 75% ½" Min. Insulating Sheathing	-$362*	-$452*	-$458*	-$487*	-$493*
3b	25% Wood+ 75% ½" PolyIso Insulating Sheathing	-$153*	-$191*	-$194*	-$206*	-$209*
4a	Plus ½" Minimum Insulating Sheathing	$752	$938	$952	$1,011	$1,024
4b	Plus ½" PolyIso Insulating Sheathing	$1,016	$1,268	$1,287	$1,367	$1,385
5	¾" PolyIso Insulating Sheathing w/ Let-In Bracing	-$111*	-$154*	-$162*	-$172*	-$172*

* A negative number indicates first cost savings compared to the baseline. For example, a value of -$362 means the scenario's first cost is $362 cheaper than the base case scenario.

Exhibit 17: Highest Estimated Incremental Installed Cost by Wall Insulation Scenario

#	Climate Zone	3	4	4 Marine	5	6
2	High-Density Insulation	$390	$487	$441	$468	$474
3a	25% Wood+ 75% ½" Min. Insulating Sheathing	-$292*	-$365*	-$370*	-$393*	-$398*
3b	25% Wood+ 75% ½" PolyIso Insulating Sheathing	-$97 *	-$122*	-$123*	-$131*	-$133*
4a	Plus ½" Minimum Insulating Sheathing	N/A	N/A	N/A	N/A	N/A
4b	Plus ½" PolyIso Insulating Sheathing	N/A	N/A	N/A	N/A	N/A
5	¾" PolyIso Insulating Sheathing w/ Let-In Bracing	-$27 *	-$49 *	-$56 *	-$60 *	-$58 *

* A negative number indicates first cost savings compared to the baseline. For example, a value of -$292 means the scenario's first cost is $292 cheaper than the base case scenario.

These exhibits indicate that construction costs of a new home can be reduced by $493 when using insulated sheathing products with corner bracing in place of full structural sheathing. When constructing homes with full structural and insulated sheathings, the costs can increase by as much as $1,385. However, this scenario also exceeds the required wall insulation levels in the 2004 IECC supplement.

Economic Results

Having selected and modeled the various housing configurations and wall insulation scenarios and estimated incremental installed costs for each wall insulation scenario, ICF Consulting was able to proceed with a series of economic viability analyses.

As there is no single standard measure of cost effectiveness that is universally accepted to assess the increase in insulation[14], ICF Consulting presented the economic results of this analysis in terms of annual energy cost savings, low and high payback periods, annual cash flow and energy saved.

Annual Energy Cost Savings

The estimated decrease in annual utility bills for each wall insulation scenario is presented below.

Exhibit 18: Estimated Annual Energy Cost Savings ($) for the Wall Insulation Scenarios

#	Climate Zone	3	4	4 Marine	5	6
2	High-Density Insulation	$10	$19	$7	$11	$13
3a	25% Wood+ 75% ½" Min. Insulating Sheathing	$12	$24	$10	$19	$24
3b	25% Wood+ 75% ½" PolyIso Insulating Sheathing	$17	$35	$17	$31	$38
4a	Plus ½" Minimum Insulating Sheathing	$23	$44	$17	$31	$38
4b	Plus ½" PolyIso Insulating Sheathing	$28	$54	$25	$43	$52
5	¾" PolyIso Insulating Sheathing w/ Let-In Bracing	$38	$83	$30	$50	$57

Payback Periods

The payback periods are calculated by dividing the lowest and highest incremental installed costs in Exhibits 16 and 17 by the annual energy cost savings in Exhibit 18. The results are shown in Exhibits 19 and 20. While payback periods are not routinely expressed in values lower than zero, negative values were included in these exhibits. A negative payback period indicates that the insulation scenario actually costs less than the baseline scenario, and in addition saves money every year compared to the baseline scenario. The lower the number, the more favorable the payback period is for the insulation scenario, e.g., the -46 is the best simple payback scenario.

Exhibit 19: Lowest Estimated Simple Payback (Years) for the Wall Insulation Scenarios

#	Climate Zone	3	4	4 Marine	5	6
2	High-Density Insulation	18	12	40	25	22
3a	25% Wood+ 75% ½" Min. Insulating Sheathing	-30*	-19*	-46*	-25*	-21 *
3b	25% Wood+ 75% ½" PolyIso Insulating Sheathing	-9 *	-5 *	-11 *	-7 *	-6 *
4a	Plus ½" Minimum Insulating Sheathing	32	21	55	32	27
4b	Plus ½" PolyIso Insulating Sheathing	36	23	52	32	27
5	¾" PolyIso Insulating Sheathing w/ Let-In Bracing	-3 *	-2 *	-5 *	-3 *	-3 *

* A negative payback period indicates the insulation scenario costs less than the baseline scenario.

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[14] The ICC development committee is not required to justify code changes using an economic analysis.

Exhibit 20: Highest Estimated Simple Payback (Years) for the Wall Insulation Scenarios

#	Climate Zone	3	4	4 Marine	5	6
2	High-Density Insulation	39	26	67	42	37
3a	25% Wood+ 75% ½" Min. Insulating Sheathing	-24 *	-15 *	-37 *	-20 *	-17 *
3b	25% Wood+ 75% ½" PolyIso Insulating Sheathing	-6 *	-3 *	-7 *	-4 *	-4 *
4a	Plus ½" Minimum Insulating Sheathing	N/A	N/A	N/A	N/A	N/A
4b	Plus ½" PolyIso Insulating Sheathing	N/A	N/A	N/A	N/A	N/A
5	¾" PolyIso Insulating Sheathing w/ Let-In Bracing	-1 *	-1 *	-2 *	-1 *	-1 *

* A negative payback period indicates the insulation scenario costs less than the baseline scenario.

Annual Cash Flow

A payback period is an easily recognized measure of cost-effectiveness. However, there are disadvantages to using payback periods to illustrate the financial viability of energy efficiency upgrades in residential new construction. One primary disadvantage is that payback periods do not reflect the way in which a homeowner would finance an upgrade (e.g., through an increased mortgage) or financially benefit from an upgrade (e.g., through reduced utility bills). This disadvantage can be addressed by using annual cash flow as an economic indicator.

Annual cash flow represents the annual energy cost savings of an upgrade scenario minus its annual costs. The annual upgrade costs are determined by financing the incremental installed costs over a 30 year period at an assumed interest rate. This provides the actual economic impact of an upgrade over the life of a 30 year mortgage; the most conservative option when financing the purchase of a home. The resulting cash flow occurs each and every year regardless of how long an owner stays in their home.

The following tables show the annual cash flow of each wall insulation scenario across each of the climate zones. Exhibit 21 contains values that were calculated using the lowest estimated incremental installed cost. Exhibit 22 contains values that were calculated using the highest estimated incremental installed cost. These values were calculated assuming that the entire upgrade cost is financed at an interest rate of 6% over 30 years, and assumes that the insulation has a 50 year life.

Exhibit 21: Annual Cash Flow for the Lowest Estimated Incremental Installed Costs
for Each Wall Insulation Scenario

#	Climate Zone	3	4	4 Marine	5	6
2	High-Density Insulation	$2	$9	-$5 *	-$1 *	$1
3a	25% Wood+ 75% ½" Min. Insulating Sheathing	$28	$44	$30	$40	$45
3b	25% Wood+ 75% ½" PolyIso Insulating Sheathing	$24	$43	$26	$40	$47
4a	Plus ½" Minimum Insulating Sheathing	-$9 *	$3	-$24 *	-$12 *	-$6 *
4b	Plus ½" PolyIso Insulating Sheathing	-$16 *	-$1 *	-$31 *	-$16 *	-$8 *
5	¾" PolyIso Insulating Sheathing w/ Let-In Bracing	$43	$89	$37	$57	$65

* A negative number indicates a negative annual cash flow. For example, -$9 means that the scenario costs $9 more a year than the base case scenario.

Exhibit 22: Annual Cash Flow for the Highest Estimated Incremental Installed Costs for Each Wall Insulation Scenarios

#	Climate Zone	3	4	4 Marine	5	6
2	High-Density Insulation	-$7 *	-$2 *	-$12 *	-$9 *	-$8 *
3a	25% Wood+ 75% ½" Min. Insulating Sheathing	$25	$40	$26	$36	$41
3b	25% Wood+ 75% ½" PolyIso Insulating Sheathing	$21	$40	$23	$37	$44
4a	Plus ½" Minimum Insulating Sheathing	N/A	N/A	N/A	N/A	N/A
4b	Plus ½" PolyIso Insulating Sheathing	N/A	N/A	N/A	N/A	N/A
5	¾" PolyIso Insulating Sheathing w/ Let-In Bracing	$40	$85	$33	$52	$60

* A negative number indicates a negative annual cash flow. For example, -$7 means that the scenario costs $7 more a year than the base case scenario.

These exhibits illustrate that many of the wall insulation scenarios result in positive cash flow for the homeowner. Furthermore, within every climate zone, there are at least three wall insulation scenarios that result in positive cash flow, which is significant in some cases. Finally, for homes using high-density fiberglass insulation, homeowners would save money in many climate zones and would never pay more than about $1 per month for the increased wall insulation.

Energy Saved

A third measure of the cost effectiveness is national potential energy savings. This measure presumes that the United States would benefit from a reduced rate of growth in residential energy consumption with the potential for reduced emissions, avoided construction of new power supplies, reduced dependence on imported fuels, etc. This is the same general measure evaluated in ACEEE's[15] analysis of the increased wall insulation levels.

ICF Consulting agrees with the ACEEE finding that significant energy savings will occur from the minimal increase in insulation requirements in the 2004 IECC supplement. Energy savings derived from increased insulation levels are particularly significant because of their permanence. Unlike energy savings from equipment upgrades, which may decrease over time or be eliminated when equipment is replaced, energy savings from insulation upgrades should continue to accrue throughout the life of the structure.

ICF Consulting calculated national potential energy savings for the next 30 years assuming that the 2004 IECC supplement was adopted in climate zones 3 through 6 in 2005, such that all new homes were constructed with the increased wall insulation. ICF also conservatively assumed that housing starts would remain constant over the next 30 years and that each home will save a consistent amount of energy from the time of its construction until the time period ends. Thus a home built this year will save energy for 30 years and a home built 29 years from now will only save energy for 1 year. This is an accurate assessment of a 30 year life of a home, but is a conservative estimate of the life of the actual home and insulation.

Using these assumptions, ICF Consulting estimates that 750 to 1,000 trillion BTU's would be saved in the first 30 years of utilizing the 2004 IECC supplement These energy savings are equivalent to reducing the number of "Very Large Crude Carrier" super tankers that import fuel to the United States from foreign sources by 118[16] over the first 30 years. In other terms, it is the equivalent of

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[15] Impact Assessment of 2004 IECC Wall Criteria Changes, February 2005, William R. Prindle, ACEEE & Bion D. Howard, Building Environmental Science and Technology.

[16] Energy Information Administration, Annual Energy Review 2003, Appendix A, Thermal Conversion Factors http://www.eia.doe.gov/emeu/aer/pdf/pages/sec13_1.pdf.

reducing the crude oil imports by 241 million gallons per year. Additionally, this is equivalent to removing the 330,000 cars from the road through reduced emissions of 3.9 million tons of carbon dioxide released in the air per year. Further savings of approximately 3,000 trillion BTU's can cost effectively be achieved if all housing starts were to utilize the ¾" polyiso insulation option, or other insulation products with an equivalent property of R-4.9.

Exhibit 23: Billion BTU's Equivalent of Energy Saved within First 30 years of Enacted Code

#	Climate Zone	3	4	4 Marine	5	6	Total Bbtu
2	High-Density Insulation	238,358	279,814	15,940	161,232	63,265	758,610
3a	25% Wood+ 75% ½" Min. Insulating Sheathing	290,827	358,060	24,256	280,762	116,355	1,070,260
3b	25% Wood+ 75% ½" PolyIso Insulating Sheathing	407,036	511,367	42,224	453,771	185,852	1,600,251
4a	Plus ½" Minimum Insulating Sheathing	556,768	646,647	42,115	458,534	188,066	1,892,129
4b	Plus ½" PolyIso Insulating Sheathing	670,451	796,162	59,713	629,076	256,657	2,412,059
5	¾" PolyIso Insulating Sheathing w/ Let-In Bracing	914,483	1,217,420	73,865	728,666	281,074	3,215,507

Review of PNNL's Analysis

ICF Consulting was also tasked with reviewing PNNL's analysis on the cost-effectiveness of the 2004 IECC supplement wall insulation requirements "An Analysis of Floor Modifications to IECC Code Change EC48-03/03". ICF Consulting found that PNNL's analysis could be improved upon in two general ways – first by refining the utility rates and insulation cost assumptions and, second, by expanding the scope of the analysis to include additional wall insulation scenarios, foundation types, house sizes, and other major housing characteristics. A summary of the key areas of PNNL's analysis that ICF Consulting felt could have been more robust are presented below.

Utility Rates

The utility rates used in PNNL's analysis were assumed using two different sources. For natural gas, the EIA's national average long-term "reference case" residential rate for 2005 to 2025[17] was used, with rates adjusted from 2003 to 2005 dollars. For electricity, the EIA's reported residential average rate for August 2004[18] was used, unadjusted to 2005 dollars. There are two areas of concern with using these assumptions:

- The gas and electric utility rates were derived from two different EIA sources that represented different values – one representing a long-term forecasted value adjusted to current dollars and the other representing the actual rate for the month of August 2004. This approach does not provide consistency between the two utility rates.
- The utility rates used represent a national average. Two drawbacks of this approach are that it includes utility rates for areas that are not within the scope of the analysis, e.g., Hawaii and Alaska, and at the same time it does not allow for variations in regional utility rates to be assessed.

Insulation Costs

The high and low bracketed wall insulation costs used in PNNL's analysis were estimated using two sources: California's 2001 Database for Energy Efficient Resources (DEER)[19] and a 1994 article from Energy Source Builder[20]. There are three areas of concern with the assumed wall insulation costs:

- PNNL cited difficulties in estimating the cost of meeting the 2004 IECC supplement wall insulation requirements using methods other than high-density insulation, such as rigid foam board sheathing. While such difficulties do exist due to the difference in installation procedures, it is possible to assess the material and labor costs associated with these construction methods.
- For assessing the cost of increasing wall insulation from R-19 to R-21 using high-density fiberglass batt insulation, PNNL assumed a low end incremental cost that may be too low. PNNL cited a low end incremental cost of \$0.10 / ft^2 from a 1993 Oregon study published in Energy Source Builder. However, the value cited in the study represents a cost of \$0.10 per square foot of conditioned floor area, rather than square feet of insulation which was used in the PNNL analysis. Using housing characteristics provided in the study and

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[17] Annual Energy Outlook 2005 with Projections to 2025. January 2005. Report number DOE/EIA-0383(2005). Retrieved May 20, 2005 from http://www.eia.doe.gov/oiaf/aeo/aeoref_tab.html.

[18] Electric Power Monthly. November 2004. Report number DOE/EIA-0226 (2004/11). Retrieved May 20, 2005 from http://tonto.eia.doe.gov/ftproot/electricity/epm/02260411.pdf.

[19] 2001 DEER Update Study. August 2001. Retrieved May 20, 2005 from http://www.energy.ca.gov/deer/.

[20] Oregon Study Estimates Costs of Energy Code. August 1994. Energy Source Builder, #35. Retrieved May 20, 2005 from http://oikos.com/esb/34/oregoncode.html.

assuming a single story home, 18% window area to conditioned floor area ratio, and an aspect ratio for the foundation of 2 to 1, the incremental costs would actually fall between \$0.13 and \$0.17 / ft^2 of insulation.

- For assessing the cost of increasing wall insulation from R-19 to R-21 using high-density fiberglass batt insulation, PNNL assumed a high end incremental cost that may be too high. PNNL cited a high end cost of \$0.44 / ft^2 based upon the California 2001 Database for Energy Efficient Resources (DEER). Interestingly, in reviewing this source, it was discovered that cost estimates were available both in terms of incremental installed costs and in terms of absolute material costs. The \$0.44 / ft^2 used in PNNL's analysis is based on the incremental installed cost of R-19 to R-21 using high-density fiberglass batt insulation. However, the database estimates that the incremental material cost is only \$0.20 / ft^2 – less than half the installed cost contained in the database. It is unlikely that labor costs would double when installing high-density insulation. While CEC was unable to explain the high installed cost at the time of this report's publication, equivalent or cheaper incremental material costs were found in a draft version of the California 2005 DEER.

Housing Characteristics

PNNL used the DOE-2 energy simulation program to conduct annual energy simulations of a 2000 ft^2 two story house on a crawlspace foundation. Wall insulation was first modeled per the requirements contained in the RICC and then modeled using high-density insulation to meet the requirements of the 2004 IECC supplement. All climate zone 3 - 6 TMY2 weather files were used. There are two areas of concern with the housing configurations modeled:

- The housing configurations modeled by PNNL were limited to a two story, 2000 ft^2 home on a crawlspace foundation. Estimated annual energy cost savings, however, can be impacted by a number of major variables including foundation type, number of stories, the ratio of window area to conditioned floor area, orientation of the home, distribution of windows among the elevations of the home, and heating fuel type (i.e., gas furnace versus electric heat pump). The impacts of these variations were not assessed in PNNL's analysis.
- Additional methods of complying with the 2004 IECC wall insulation requirements were not analyzed (i.e., rigid board insulation). Omitting an analysis of rigid insulated sheathing is of particular concern as it accounted for approximately 30% of the sheathing used in 1996[21], (see Exhibit 24).

Exhibit 24: Prevalence of Sheathing Materials in New Construction

Sheathing Type	**Percent of New Conventional Single-Family Housing Utilizing Sheathing Type (1996)**
All OSB Materials	32.3%
All Plywood Materials	18.8%
All Foam Insulating Materials	29.3%
Other or None	19.7%
Total	100.0%

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[21] "Factory and Site-Built Housing a Comparison for the 21st Century," prepared by the NAHB Research Center, October 1998. Table 12: Use of Wall Sheathing Materials in New Conventional Single-Family Housing and Manufactured Housing, 1996. Retrieved from http://www.mfghome.org/developer_resources/factory_vs_sitebuilt/index.asp#_Ref421410668 on June 3, 2005.

Reassessment of PNNL Predicted Payback Periods

As noted above, ICF Consulting found that refinements could be made in the utility rate and material cost assumptions used in PNNL's report. In order to assess the relative impact of these refinements, ICF Consulting applied PNNL's approach but with revised assumptions for the utility rates and material costs. This analysis involved estimating the annual energy savings predicted by PNNL's report and applying the revised economic assumptions.

In order to determine the annual energy savings used in PNNL's report, ICF Consulting multiplied the reported material costs by the wall area and then divided this by the reported payback periods. Using this information, ICF Consulting was able to estimate the annual energy savings for each of the climate zones in PNNL's report. PNNL did not provide estimates for climate zone 4 Marine; therefore, ICF Consulting assumed these values to be the same as climate zone 4 for this step. The resulting annual energy savings include both electric and gas savings. In order to estimate the savings attributed to each fuel type, the ratio of gas to electric consumption from ICF Consulting's energy simulations was applied as shown in Exhibit 25.

Exhibit 25: Average Predicted Ratio of Gas Heating Consumption to Electric Cooling Consumption

Climate Zone	3	4	4 Marine	5	6
Gas Heating to Electric Cooling Ratio	1.6 : 1	3.6 : 1	17.4 : 1	7.8 : 1	13.2 : 1

Once the annual energy savings were determined, ICF Consulting applied revised assumptions for the utility rates and material costs in order to estimate revised payback periods. The assumptions for the revised utility costs and material costs are explained in the section titled Economic Factors of the Cost-Effective Analysis. The original PNNL payback periods are presented along with ICF Consulting's revised payback periods in Exhibit 26.

Exhibit 26: Original & Revised PNNL Payback Periods for High-Density Wall Insulation Scenario

Climate Zone	3	4	4 Marine	5	6
PNNL Predicted Low Payback	21	12	n/a	11	9
Revised PNNL Predicted Low Payback	19	13	15	15	12
PNNL Predicted High Payback	89	52	n/a	49	40
Revised PNNL Predicted High Payback	42	30	27	26	21

The revised economic assumptions result in payback periods that are reduced by as much as 50%, from 89 to 42 years. However, the payback period also increases by 25%, from 9 to 12 years, when the low insulation cost is corrected to be based on the square feet of conditioned floor area.

Conclusions

ICF Consulting completed two broad analyses for NAIMA and PIMA: conducting an analysis to assess the energy savings and incremental costs associated with the increased wall insulation requirements in the 2004 IECC supplement, and reviewing a PNNL report which assessed these impacts.

This study assessed the impacts of achieving the 2004 IECC wall insulation requirements through the use of specific wall insulation products. However, the energy savings results of this analysis are generally equivalent to other insulation products which meet the R-value requirements of the wall insulation scenarios analyzed. For example, wall cavity insulation R-values can be achieved through the use of spray foams (e.g., Icynene) and cellulose insulation products, in addition to the medium and high-density fiberglass batt insulation used in this study. Likewise, exterior insulated wall sheathing can be met by the available array of rigid foam insulation products, including extruded polystyrene (XEPS), expanded polystyrene (EPS), and polyurethane (PUR), in addition to the polyiso assessed in this study.

Findings of these two analyses include the following:

- In all climate zones, including 4 Marine, at least one of the wall insulation scenarios analyzed had a simple payback period of zero years. This signifies that in every climate zone impacted by the increased wall insulation requirements, there is at least one insulation scenario that meets the code, saves energy, and costs less to install than the lower insulation requirements originally proposed for the 2004 IECC (the RICC).

- ICF Consulting examined various metrics for evaluating the cost effectiveness of the increased wall insulation requirements and generally found that there were cost effective options for each metric. However, as indicated in ACEEE's[22] evaluation of these code changes, the ICC development committee is not required to justify code changes using an economic analysis. As a result, there is no single standard measure of cost effectiveness that is universally accepted to assess the increase in insulation. For example, ACEEE chose to evaluate cost effectiveness in part by assessing total potential energy savings for the country as a whole – versus other metrics such as payback period, life cycle cost analysis, etc. It is also interesting to note that the state of Oregon has maintained wall insulation levels equivalent to the 2004 IECC Supplement in its state code since 1992[23].

- When ICF Consulting calculated cost effectiveness in terms of annual cash flow for the homeowner, accounting for reduced utility bills and an increased mortgage to finance the insulation upgrades, it found values between -$12 and $45 for the insulation scenarios that meet code. This signifies that the impact of the increased insulation on a homeowner's monthly cash flow would fall between a cost of $1.00 and a credit of $3.75 per month. ICF Consulting also found that certain insulation scenarios, such as using ¾" polyisocyanurate (polyiso) rigid insulation with let-in bracing, can offer homeowners a positive cash flow up to $89 per year. These financial savings are based on an assumption that fuel costs are fixed for the period of analysis. Hence, they would be conservative if fuel prices increase.

- The cash flow resulting from the 2004 IECC insulation level improvements occurs each and every year, regardless of how long an owner stays in their home. There are a number of

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[22] http://www.osti.gov/energycitations/product.biblio.jsp?osti_id=10140941.

[23] Changes to Code in 1992, Oregon Department of Energy, www.obrt.state.or.us/ENERGY/CONS/Codes/cdres.shtml.

benefits associated with this, including creating the possibility for more affordable homes for both current and future home buyers through potentially lower first costs and a positive cash flow every year. For example, this analysis found that construction costs of a new home can be reduced by as much as $490 when using insulated sheathing products with corner bracing in place of full structural sheathing. In addition, any positive cash flow is a long term benefit since the increased insulation levels will physically last in the home significantly longer than the heating and air conditioning equipment. Thus, there will not be any replacement costs associated with the increased insulation levels.

- There are multiple wall insulation scenarios that can be used to meet or exceed the code requirements. However, estimates of cost effectiveness vary significantly between the scenarios. Among the scenarios analyzed, using rigid insulated sheathing products in combination with medium-density fiberglass batt insulation is the most effective, while upgrading from medium-density fiberglass batt insulation to high-density fiberglass batt insulation is least cost effective. (According to a 1996 NAHB study[24], approximately 30% of all single family homes constructed in the United States used insulated sheathing products, nearly as popular in use as oriented strand board (OSB) sheathing.)

- When ICF Consulting calculated cost effectiveness in terms of simple payback period, the same metric used by PNNL, it found values between 0 and 42 years in the major 4 climate zones assessed by PNNL. This is in contrast to a range of 11 to 89 years predicted by PNNL. For climate zone 4 Marine, a small sub-climate not assessed separately by PNNL, ICF Consulting found values between 0 and 67 years. Ranges were predicted, rather than single values, due to variations in climate zones, insulation scenarios, and estimated financial values. The differences between ICF Consulting's results and PNNL's results are due primarily to ICF Consulting's accounting for regional variations, for its use of less widely bracketed cost estimates, and for its inclusion of additional insulation scenarios beyond high-density fiberglass insulation.

- PNNL's analysis of the increased insulation levels in the 2004 IECC was more limited in scope, and hence does not provide as comprehensive of an assessment as was requested by NAIMA and PIMA. PNNL's analysis was based on a single house configuration, national average upgrade costs, a single wall insulation scenario (i.e., medium versus high-density fiberglass batt insulation), and climate zone 4 Marine was combined with climate zone 4. In contrast, ICF Consulting's analysis was based on 324 house configurations, regional factors applied to estimated local upgrade costs, four upgrade wall insulation scenarios, including rigid insulated sheathing options; and climate zone 4 Marine was analyzed separately from the rest of climate zone 4.

Conducting an economic analysis of any energy efficiency improvement can be challenging. These challenges include determining reasonable estimates for upgrade costs, utility rates, fuel escalation rates and the impact of increasing product demand on upgrade costs. In addition, it is difficult to assess less-tangible impacts such as builder acceptance and impacts on occupant comfort. Where possible, estimates should be made for these factors in future analyses to provide an even more complete impact assessment of the increased wall insulation requirements in the 2004 IECC supplement.

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[24] "Factory and Site-Built Housing a Comparison for the 21st Century," prepared by the NAHB Research Center, October 1998. Table 12: Use of Wall Sheathing Materials in New Conventional Single-Family Housing and Manufactured Housing, 1996. Retrieved from http://www.mfghome.org/developer_resources/factory_vs_sitebuilt/index.asp#_Ref421410668 on June 3, 2005.