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Analysis of 2009 International Energy Conservation Code Requirements for Residential Buildings in Mesa, Arizona

R Lucas

March 2011



Pacific Northwest
NATIONAL LABORATORY

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Richland, Washington 99352

Summary

The 2009 International Energy Conservation Code (IECC) contains several major improvements in energy efficiency over the 2006 IECC and the 2003 IECC. The notable changes are

- Improved duct sealing verified by testing the duct system
- Increased duct insulation
- Improvement of window U-factors from 0.40 to 0.35
- Efficient lighting requirements.

An analysis of these changes resulted in estimated annual energy cost savings of \$145 a year for an average new house compared to the 2003 IECC. This energy cost saving decreases to \$125 a year for the 2009 IECC compared to the 2006 IECC. Construction cost increases (per home) for complying with the 2009 IECC are estimated at \$1256 relative to the 2003 IECC and \$800 for 2006 IECC. Home owners will experience an annual cost savings of about \$80 a year by complying with the 2009 IECC because reduction to energy bills will more than compensate for increased mortgage payments and other costs.

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Overview of the 2009 IECC

The IECC scope includes residential single-family housing and multifamily housing three stories or less above-grade, intended for permanent living (hotel/motel is not “residential”). The code applies to new buildings and additions/alterations/renovations/repairs. Key envelope requirements are shown in Table 1.

Table 1 Envelope Requirements in the 2009 IECC

Ceiling	R-30
Skylight U-factor	U-0.75
Window U-factor	U-0.65
Wood Frame Wall	R-13
Fenestration Solar Heat Gain Coefficient (SHGC)	0.30
Mass Wall	R-4/6 ⁽¹⁾
Floor	R-13
Basement Wall	No insulation
Slab	No insulation
Crawlspace Wall	No insulation

⁽¹⁾ The second R-value applies if more than one-half the insulation is on the interior of the mass wall.

Additional requirements in the 2009 IECC:

- Building envelope must be caulked and sealed.
- Supply ducts in attics must be insulated to R-8. Return ducts in attics and all ducts in crawlspaces, unheated basements, garages, or otherwise outside the building envelope must be insulated to R-6.
- All ducts must be sealed and either:
 - *verified by pressure testing* – the duct system has to be tested and the air leakage out of ducts must be kept to an acceptable maximum level.
 - *installed entirely within the building thermal envelope* – testing is not required if all ducts are inside the building thermal envelope (for example in heated basements), although the ducts still have to be sealed.
- Piping for hydronic (boiler) heating systems must be insulated to R-3.

- Less insulation is allowed for mass walls and more insulation is required for steel framing.
- 50% of the lighting “lamps” (bulbs, tubes, etc.) in a building must be high efficacy. Compact fluorescents qualify; standard incandescent bulbs do not.
- Standard I-code administrative requirements (inspections, documentation) apply.
- A certificate must be posted near the electrical panel listing insulation levels and other energy-efficiency measures.

Exemptions/allowances from prescriptive measures:

- One door and 15 ft² of window area are exempt.

Mandatory requirements:

Windows can never exceed an area-weighted average solar heat gain coefficient (SHGC) of 0.50. The 2009 IECC also identifies a set of other requirements that are strictly “mandatory” that must be done in all buildings, such as building envelope and duct sealing.

Compliance paths:

The 2003, 2006, and 2009 IECC all effectively contains three alternative compliance paths.

- 1) Prescriptive measures. This is considered the simplest path. These requirements do not vary by building size, shape, window area, or other features. The 2009 IECC has a single table of requirements for insulation R-values and window and door U-factors and SHGC. There is a corresponding U-factor table that permits compliance of less common component types (e.g., structural insulated panels), albeit without any cross-component trade-offs.
- 2) Total building envelope UA (U-factor multiplied by area). This is the path predominantly used by the REScheckTM software. Based on the prescriptive U-factor table, it allows trade-offs whereby some energy-efficiency measures can fall below code requirements if balanced by other measures that exceed code requirements.
- 3) Simulated performance (requires software programs). This path allows compliance if the home has a calculated annual energy consumption (or energy cost) equal to or less than that of a standard reference design that just meets the code’s prescriptive requirements. This path allows for crediting energy-efficiency measures not accounted for in the other paths, such as renewable energy measures. The 2009 performance path differs from previous editions of the IECC in that it allows no trade-off credit for the use of high-efficiency space heating, space cooling, or water heating equipment.

Main Difference between the 2006 IECC and the 2009 IECC

The 2006 IECC has the same format (including the same climate zones) and many of the same requirements as the 2009 IECC. The 2006 IECC differs from the 2009 IECC resulting from the four amendments described above. In addition to this, other major differences between the 2006 IECC and the 2009 IECC are listed below

- The 2006 IECC requires ducts to be sealed but not to a specific leakage rate verified by testing, as is required in the 2009 IECC (if any ducts are outside the building envelope).
- 50% of the lighting “lamps” (bulbs, tubes, etc.) in a building have to be high efficacy in the 2009 IECC; the 2006 IECC has no lighting requirement. Compact fluorescents qualify; standard incandescent bulbs do not.
- Trade-off credit can no longer be obtained for high-efficiency heating, ventilation, and air conditioning (HVAC) equipment in the 2009 IECC. For example, if a high-efficiency furnace is used, no reduction in wall insulation is allowed. (This will have a substantial impact on the flexibility allowed by the REScheck™ software and other energy performance analysis tools.)
- A number of thermal envelope requirements have improved in the 2009 IECC. These are highlighted in Table 2.

Table 2 Comparison of Envelope Requirements

	2003 IECC (15% or lower window area)	2006 IECC	2009 IECC
Ceiling	19	30	30
Skylight U-factor	0.75	0.75	0.75
Fenestration U-factor	0.75	0.75	0.65
Fenestration SHGC	0.40	0.40	0.30
Wood Frame Wall	11	13	13
Mass Wall	Varies	4/6 ⁽¹⁾	4/6 ⁽¹⁾
Floor	11	13	13
Basement Wall	No Requirement	No Requirement	No Requirement
Slab	No Requirement	No Requirement	No Requirement
Crawlspace Wall	R-5	No Requirement	No Requirement

⁽¹⁾ The second R-value applies if more than one-half the insulation is on the interior of the mass wall.

Other changes in the 2009 IECC compared to the 2006 IECC:

- R-3 pipe insulation on hydronic distribution systems (increased from R-2)
- Stricter area limits on door exemptions
- Improved (more detailed) air-sealing language
- Pool covers are required for heated pools.

Main Difference between the 2003 IECC and the 2006 IECC

The 2003 IECC has a different format and different climate zones from the 2006 IECC (and 2009 IECC). The prescriptive envelope requirements vary by the window area percentage of the residence. Table 2 shows the 2003 IECC prescriptive requirements for a home with 12 to 15% window area (as a percent of total wall area), which is typical for many starter or mid-level homes. For homes with a high window area of 20 to 25%, the 2003 IECC requirements become more stringent, with a maximum allowable glazing-factor of only U-0.55 and ceiling insulation of R-30. In contrast, the 2006 and 2009 IECC requirements shown in Table 2 apply to all homes regardless of the window area percentage.

Other than this difference in format, the 2003 IECC has generally consistent requirements with the 2006 IECC, and the differences listed above between the 2006 and 2009 IECC also apply to the 2003 IECC compared to the 2009 IECC.

Energy Analysis

A brief energy analysis was conducted comparing the energy use resulting from compliance with the different versions of the IECC. The EnergyGauge™ software (Florida Solar Energy Center 1999) was used to determine the energy impacts of changes in envelope requirements. EnergyGauge™ utilizes the DOE-2 energy simulation software developed by the U.S. Department of Energy (DOE). (Use of specific brands or trade names is for research purposes only and does not constitute an endorsement of these items.)

Three sets of buildings were simulated: one with energy-efficiency levels set to the prescriptive requirements of the 2003 IECC, 2006 IECC, and the 2009 IECC. All inputs other than the changes in energy-efficiency levels were identical in the three sets of simulations.

The analysis assumed a two-story, single-family house with a conditioned floor area of 2,400 ft² with a slab-on-grade foundation. It was assumed that the house had 9-ft high ceilings, a ceiling area (bordering the unconditioned attic) of 1,200 ft², a gross exterior wall area of 2,380 ft², and a window area of 360 ft² equally oriented north, south, east, and west. This window area corresponds to 15% of the wall area, which impacts the requirements of the 2003 IECC, as discussed above.

Heating with a 78% annual fuel utilization efficiency (AFUE) natural gas furnace (\$1.42/therm) and cooling with a 13 seasonal energy efficiency ratio (SEER) central electric air conditioning (\$0.116/kWh) were assumed. All fuel prices were obtained from the DOE Energy Information Administration and are residential prices specific for Arizona. Natural gas costs are for the heating season; and therefore, the January 2010 cost was used.^a Electricity for air conditioning is the August 2010 state average cost.^b

Table 3 shows the estimated annual energy usage for a home built to the requirements of the 2003 IECC, 2006 IECC and the 2009 IECC. For heating energy use with a natural gas furnace, the first value is natural gas energy use; the second value is fan electricity use for distributing the heated air. Tables 4 and 5 show these impacts in terms of energy cost, including the savings per house that results from meeting the improved requirements in the 2009 IECC. Total savings and percent savings includes space heating and cooling (air conditioning) only. Tons of CO₂ savings per home per year are also shown in these tables.

^a <http://www.eia.gov/dnav/ng/hist/n3010mo3m.htm>

^b http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html

Table 3 Annual Energy Use

<i>2003 IECC</i>		<i>2006 IECC</i>		<i>2009 IECC</i>	
Heating	Cooling (kWh)	Heating	Cooling (kWh)	Heating	Cooling (kWh)
9.3 MBtu + 54 kWh	7754	8.5 MBtu + 49 kWh	7668	8.2 MBtu + 47 kWh	7372

Table 4 Annual Energy Costs and Percentage Savings Vs. 2006 IECC

<i>Annual Energy Cost (\$)</i>				<i>Total savings 2009 IECC vs. 2006 IECC</i>		
<i>2006 IECC</i>		<i>2009 IECC</i>		Savings (\$/yr)	Percent Savings	Tons of CO ₂ Saved
Heating	Cooling	Heating	Cooling			
\$127	\$805	\$110	\$697	\$125	13.4%	0.21

Table 5 Annual Energy Costs and Percentage Savings Vs. 2003 IECC

<i>Annual Energy Cost (\$)</i>				<i>Total savings 2009 IECC vs. 2003 IECC</i>		
<i>2003 IECC</i>		<i>2009 IECC</i>		Savings (\$/yr)	Percent Savings	Tons of CO ₂ Saved
Heating	Cooling	Heating	Cooling			
\$138	\$814	\$110	\$697	\$145	15.2%	0.31

Improved duct sealing was assumed to save 10% of the heating and cooling costs. This impact was not included in the simulation analysis, but rather was applied directly to the simulation results. The 10% savings was assumed in the state analysis report (Lucas and Cole 2009). However, it is important to emphasize actual savings will vary depending on many factors, including how well ducts are currently sealed in the absence of any testing requirements.

High-efficacy lighting requirements were not included in Tables 3, 4, and 5 because savings attributable to the lighting requirements in the IECC will become less relevant because Federal law requires improved light bulbs in 2012 to 2014. However, if efficient lighting is assumed to increase from 10% to 50% of all lighting within the home, lighting energy use decreases by 26%.

Also, wall insulation is assumed to be R-13 for 2003 IECC compliance, even though that code allows R-11 because R-13 fiberglass batts are the most commonly used product for insulating wood frame walls regardless of the code requirement.

Purchase Price Impacts

The more stringent requirements in the 2009 IECC will increase the cost of new homes. The construction cost impacts assumed in this analysis are documented below.

Window U-factor and SHGC Improvement

It is difficult to accurately assign a cost to the U-factor improvement to U-0.65 and the SHGC improvement to 0.30 for the 2009 IECC. A cost of \$1 per square foot of window area is estimated for this improvement (EPA and DOE 2009).

Improved Duct Sealing Verified by Testing

The IECC duct sealing requirement has two cost components. First is the cost of testing the installed ducts using duct pressurization equipment. Hammon and Modera (1999) estimate a cost of \$131 to \$163 for testing, and suggest costs will be even lower in a mature market. The Journal of Light Construction (Uniacke 2003) quotes a cost of \$220 for testing. The Appalachian State study (2010) reports a cost of \$175 to \$250. It is important to note that the 2009 IECC allows the ducts to be tested by the HVAC contractor immediately after the ducts are installed. This should help keep both costs and construction timeline impacts to a minimum. A cost of \$200 for duct testing was assumed for this analysis.

There is a one-time cost of purchasing a “duct blaster” and related equipment for pressurizing the duct system and testing the air leakage. Frank Spevak of the Energy Conservatory (a manufacturer of blower doors) verbally reported a price of \$1800 for this equipment. Another source reports a cost of \$1500-2000 (Wray et al. 2003). This cost was not included in the economic analysis results below because the cost per home should be minimal because the equipment can be used many times.

Hammon and Modera (1999) estimate a cost of \$214 for materials and labor for improved duct sealing. Research for the 2011 Energy Star Home estimates a cost of \$0.10/ft² of home floor area for improved sealing (EPA 2009). For the 2400 ft² home analyzed here, this is a cost of \$240, which was the value assumed in this analysis.

Ceiling Insulation

The 2003 IECC requires R-19 insulation; the 2006 and 2009 IECC requires R-30 cavity insulation. A cost increase of \$0.38/ft² or \$456 for the entire ceiling based on 2011 RS Means published cost data (includes overhead and profit) (RS Means 2011) is assumed in this analysis.

Cost Effectiveness of the 2009 IECC requirements

Total construction cost increases from the 2009 IECC assumed in this report are \$1256 relative to the 2003 IECC and \$800 relative to the 2006 IECC.

Because most houses are financed, consumers will be very interested in the financial impacts of buying a home that complies with the 2009 IECC requirements. Mortgages spread the payment for the cost of a house over a long period of time. In this analysis, a 30-year fixed-rate mortgage was assumed. It was also assumed that homebuyers will deduct the interest portion of the payments from their income taxes.

The financial and economic parameters required for input to this analysis are summarized below. These parameters are used to calculate the costs and benefits of increased energy efficiency from the homeowner's perspective.

- New-home mortgage parameters:
 - 5.0% mortgage interest rate (fixed rate)
 - points and loan fees equal to 1% of the mortgage amount
 - 30-year loan term
 - 20% down payment

- Other rates and economic parameters:
 - 28% marginal Federal income tax
 - 4% state income tax
 - 1% property tax.

Table 6 shows the impacts to consumers' cash flow resulting from the improvements in the 2009 IECC. The upfront costs include the down payment, points, and loan fees. The savings from income tax deductions for the mortgage interest will slowly decrease over time. The annual values shown in the table are for the first year. Table 6 also includes increases in annual property taxes because of the higher assessed house values. The net annual cash flow includes energy costs, mortgage payments, mortgage tax deductions, and property taxes but not the upfront costs. The time to positive cash flow is under 4 years for the improvements in the 2009 IECC compared to the 2003 IECC and 2 years compared to the 2006 IECC. This includes all costs and benefits, including the down payment and other upfront costs.

Table 6 Impacts to Consumers' Cash Flow from Compliance with 2009 IECC

	Cost Impact	
	2003 to 2009 IECC	2006 to 2009 IECC
Down payment and other upfront costs	\$265	\$169
Annual energy savings	\$145	\$125
Annual mortgage increase	\$76	\$48
Net annual cash flow savings	\$78	\$85

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