U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

BUILDING ENERGY CODES PROGRAM

Impacts of the 2009 IECC for Residential Buildings at State Level

September 2009

Prepared by Pacific Northwest National Laboratory
for the U.S. Department of Energy Building Energy Codes Program

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Executive Summary

The Building Energy Codes Program (BECP) recently conducted a nationwide residential energy code analysis for the U.S. Department of Energy (DOE). The analysis compares the requirements of the 2009 International Energy Conservation Code® (IECC) with the residential code—or typical construction practice in the absence of a code—in most states as of June 2009. The results, which include estimated typical energy savings of updating each state's code to the 2009 IECC, are provided in this report in chapters specific to each state.

An overview of the 2009 IECC and its major chapters, as well as a brief comparison to previous versions, is provided as introductory information. The IECC is then briefly compared to the International Residential Code, which contains a chapter with energy efficiency requirements that are very similar to the IECC.

Several states have either not adopted a mandatory energy code or developed their own codes which have minimal or no connection to the IECC. The latter—including California, Florida, Oregon, and Washington—were not included in this analysis as the codes in these states would be difficult to appropriately compare to the 2009 IECC and most of these states have energy offices that have already assessed the IECC on their own.

Chapter 2 is dedicated to outlining some of the major code differences in the 2009 IECC that are not contained in any previous version of the code, and to which much of the energy savings of the 2009 IECC compared to previous versions is attributable. These energy saving differences are described in further detail in the report, and include:

- Mandatory duct pressure testing coupled with maximum allowable duct leakage rates. These requirements are applicable when any portion of the ducts are outside the conditioned space.
- A requirement that 50% of lamps in a residence must be energy efficient
- Several improvements in basic envelope requirements
- Elimination of trade-off credits for high efficiency heating, cooling, or water heating equipment.

The full results of each state specific analysis are provided in the following report.[1]

[1] DISCLAIMER: The results contained in this report are complete and accurate to the best of BECP's knowledge, based on information available at the time it was written.

1.0 Chapter 1 Overview of the 2009 IECC

1.1 Introduction

This report examines the requirements of the 2009 International Energy Conservation Code® (IECC) on residential buildings on a state-by-state basis with a separate, stand-alone chapter for each state. A summary of the requirements of the code is given for each state. The 2009 IECC is then compared to the current state code for most states[2] or typical current construction practice for the states that do not have a residential energy efficiency code. Estimated typical energy savings of updating each state's code to the 2009 IECC are reported.

1.2 Overview of the 2009 IECC

The International Energy Conservation Code sets requirements for the "effective use of energy" in all buildings. Certain buildings that use very low energy use (such as buildings with no heating or cooling) are exempt. The code applies to new buildings and to remodels, renovations, and additions to buildings.

Table 1 shows the organization of the 2009 IECC. The IECC has two separate categories of buildings: residential and commercial. The code requirements are almost entirely different for these two categories. Residential buildings are essentially defined as low-rise buildings (3 stories or less above grade) intended for long-term living (hotels/motels are classified as commercial buildings). The requirements for residential buildings are in Chapter 4; the requirements for commercial buildings are in Chapter 5. Chapters 1 though 3 and Chapter 6 apply to all buildings. This report only addresses the residential portion of the IECC, a separate report addresses commercial buildings[3].

The only chapters of the IECC with specific requirements for residential buildings are Chapter 4 and, to a lesser extent, Chapter 1 and Chapter 3. Chapter 4 does reference certain commercial building requirements in Chapter 5 (for example, HVAC systems serving multiple dwelling units). Chapters 2 and 6 only provide supporting information.

Chapter 1 primarily addresses when the code applies and provides instruction to help confirm compliance with the code.

Table 2 below summarizes the sections in Chapter 1.

Chapter 2 defines terms used in the code.

Chapter 3 provides a U.S. map and tables of the climate zones used in the IECC. Climate zones in the code are set on county boundaries. These zones are shown in Figure 1. Section 303 specifies information required at the building site to verify insulation level and specifies National Fenestration Rating Council (NFRC) standards for

[2] States with their own home-developed codes are not compared to the IECC in this report. This includes California, Oregon, Washington, and Florida. This is done for two reasons. First, these states generally have codes that have little resemblance to the IECC, making a thorough comparison beyond the scope of this study. Second, these states generally have highly capable energy offices that are capable of assessing the IECC on their own (and often have). Alaska, Hawaii and Vermont also do not have an energy analysis here because of difficulties in assessing construction practice particular to those states. No energy analysis was conducted for states that have already adopted the 2009 IECC.

[3] Many states adopt the ANSI/ASHRAE/IESNA Standard 90.1 for commercial buildings rather than the IECC and therefore 90.1-2007 is examined for commercial buildings in the separate report. The 2009 IECC permits compliance with Standard 90.1-2007 as one option for complying with the IECC for commercial buildings.

rating fenestration performance. Chapter 3 contains only one element that directly contains a specific construction requirement: protective covering for insulation on the exterior of foundations (Section 303.2.1).

Table 1. IECC Table of Contents

CHAPTER 1 ADMINISTRATION
101 Scope and General Requirements 102 Alternate Materials—Method of Construction, Design or Insulating Systems 103 Construction Documents 104 Inspections 105 Validity 106 Reference Standards 107 Fees 108 Stop Work Order 109 Board of Appeals
CHAPTER 2 DEFINITIONS
201 General 202 General Definitions
CHAPTER 3 CLIMATE ZONES
301 Climate Zones 302 Design Conditions 303 Materials, Systems and Equipment
CHAPTER 4 RESIDENTIAL ENERGY EFFICIENCY
401 General 402 Building Thermal Envelope 403 Systems 404 Electrical Power and Lighting Systems 405 Simulated Performance Alternative
CHAPTER 5 COMMERCIAL ENERGY EFFICIENCY
501 General 502 Building Envelope Requirements 503 Building Mechanical Systems 504 Service Water Heating 505 Electrical Power and Lighting Systems 506 Total Building Performance
CHAPTER 6 REFERENCED STANDARDS

Table 2. Overview of IECC Chapter 1

Section	Overview/summary
101 Scope and General Requirements	Defines how code applies to additions, alterations, renovations, and repairs. Exempts certain low energy buildings.
102 Alternate Materials—Method of Construction, Design or Insulating Systems	Provides code official leeway in interpreting requirements.
103 Construction Documents	Construction documents as required by the code official must be provided.
104 Inspections	Inspections must be permitted and code officials must give approval before allowing further construction or occupancy.
105 Validity	Instructs that remainder of code applies even if a portion is found to be illegal or void.
106 Referenced Standards	Referenced standards must be complied with; the IECC takes precedence if there are any conflicts.
107 Fees	Fees for permits.
108 Stop Work Order	Authority and conditions for stop work orders
109 Board of Appeals	For hearing and deciding appeals.

1.3 Residential Building Requirements – Chapter 4 of the IECC

The 2009 IECC sets construction requirements related to energy efficiency for four energy end-uses:

1) Space heating
2) Space cooling (air conditioning)
3) Water heating
4) Lighting[4]

Table 3 shows the organization of the IECC requirements in Chapter 4.

Most of the requirements in the IECC are contained in Section 402 for the building envelope (ceilings, walls, windows, floor/foundation). Figure 1 shows the prescriptive requirements for most envelope measures (there are also separate requirements for skylights, high mass walls, and steel-framed ceilings, walls, and floors).

[4] Lighting is new to the scope of the IECC for residential buildings in 2009. Previous editions of the IECC only had requirements for space heating, space cooling, and water heating.

Table 3. Overview of IECC Chapter 4

Section	Overview/summary
401 General	Identifies the two compliance paths: prescriptive and performance. Requires a certificate to be posted on the building listing R-values and other energy efficiency information.
402 Building Thermal Envelope	This section contains most of the prescriptive requirements in the code. Insulation and fenestration requirements are given by climate zone. Air sealing requirements.
403 Systems	Contains requirements for heat pump controls, duct testing and sealing, piping insulation, and equipment sizing.
404 Electrical Power and Lighting Systems	Contains requirements for efficient lighting.
405 Simulated Performance Alternative	The performance approach. This utilizes the requirements of Sections 401 through 404 as a starting point and allows trade-offs. Unlike previous versions of the IECC this does not give extra credit for high efficiency heating, cooling, and water heating equipment. Compliance is determined using computer software. Allows more flexibility in meeting the code.

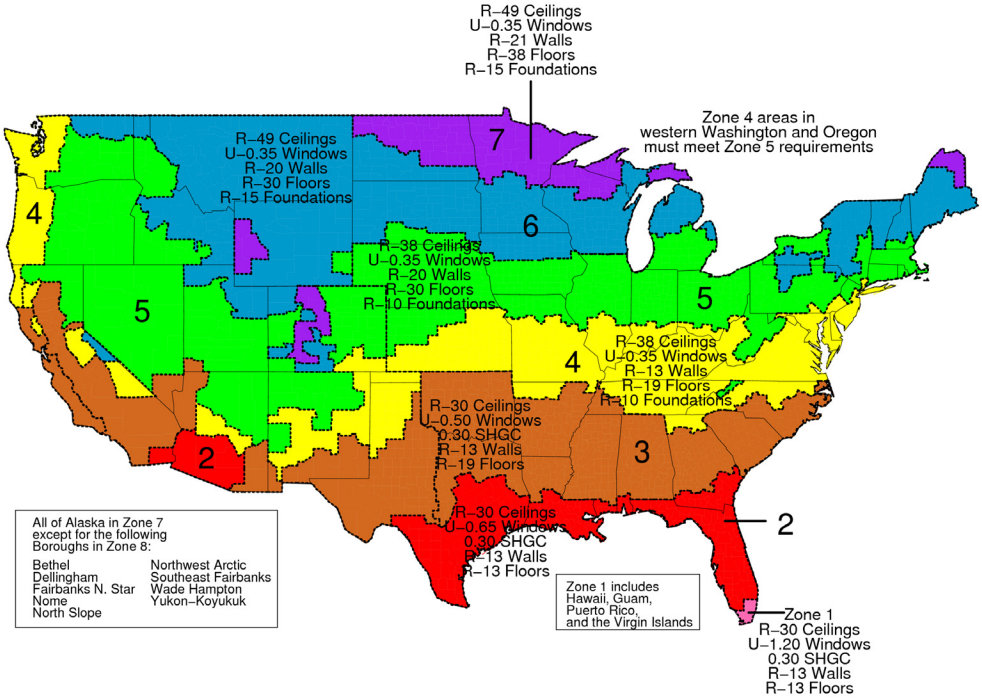

Figure 1. Prescriptive Envelope requirements

1.4 Comparison to Previous Versions of the IECC

The IECC is typically published every three years, though there are some exceptions. In the last two decades, full editions of the MEC came out in 1989, 1992, 1993, and 1995, and full editions of the IECC came out in 1998, 2000, 2003, 2006, and 2009[5].

Though there were changes in each edition of the IECC from the previous one, the IECC can be categorized into two general eras: 2003 and before, and 2004 and after. This is because the residential portion of the IECC was heavily revised in 2004. The climate zones were completely revised (reduced from 17 zones to 8 primary zones in 2004) and the building envelope requirements were restructured into a different format. The code became much more concise and much simpler to use. These changes complicate comparisons of state codes based on pre-2004 versions of the IECC to the 2009 IECC.

The IECC also had substantial revisions from 2006 to 2009. These revisions were not to the code format, but rather were changes to specific requirements to improve energy efficiency and make the code more stringent. The 2009 has some important new requirements:

- The duct system now has to be tested and the air leakage out of ducts must be kept to an acceptable maximum level. Testing is not required if all ducts are inside the building envelope (for example in heated basements), though the ducts still have to be sealed.
- 50% of the lighting "lamps" (bulbs, tubes, etc.) in a building have to be energy efficient. Compact fluorescents qualify, standard incandescent bulbs do not.
- Trade-off credit can no longer be obtained for high efficiency HVAC equipment. For example, if a high efficiency furnace is used, no reduction in wall insulation is allowed. This will have a great impact on reducing the flexibility allowed by the RES*check*™ software. No energy impact is assigned to this code change in the analysis of updating state codes to the 2009 IECC in this report.
- Vertical fenestration U-factor requirements are reduced from 0.75 to 0.65 in Climate Zone 2, 0.65 to 0.5 in Climate Zone 3, and 0.4 to 0.35 in Climate Zone 4.
- The maximum allowable solar heat gain coefficient is reduced from 0.40 to 0.30 in Climate Zones 1, 2, and 3.
- R-20 walls in climate zones 5 and 6 (increased from R-19)
- Modest basement wall and floor insulation improvements
- R-3 pipe insulation on hydronic distribution systems (increased from R-2)
- Limitation on opaque door exemption both size and style (side hinged)
- Improved air-sealing language
- Controls for driveway/sidewalk snow melting systems
- Pool covers are required for heated pools.

1.5 The IECC Compared to the International Residential Code (IRC)

Chapter 11 of the IRC contains energy efficiency requirements that are very similar to the IECC. This Chapter allows compliance with the IECC as an option for IRC compliance. The scope of the IRC is limited to one- and two-family dwellings and to townhouses, whereas the IECC includes other low-rise multifamily buildings such

[5] There was also a published version of the IECC in 2004, but that version is referred to as a "supplement" edition.

as apartments. States can adopt the IRC, the IECC, or both. While nearly all the requirements in the IRC are identical to those in the IECC, there are a few differences between the 2009 IECC and 2009 IRC. Most notably:

- The IRC requires 0.35 solar heat gain coefficient (SHGC) glazing in Climate Zones 1-3, the IECC requires 0.30 SHGC. Impact resistant fenestration in Climate Zones 2 and 3 is allowed to have an SHGC of up to 0.40 in the IRC only.
- The IECC has higher basement wall and floor insulation levels in colder zones.
- The IRC has no "mandatory" (cannot be traded off) requirements related to fenestration U-factor or SHGC, the IECC does.
- Compliance with the IECC is allowed as an alternative to Chapter 11 of the IRC. The IRC does not directly contain a simulated performance alternative; the IECC must be used instead for this compliance alternative.

Because of these changes, the 2009 IRC does not achieve equivalent energy savings to the 2009 IECC.

1.6 Current State Codes

This report addresses each state code individually, but a brief summary of state codes is presented here. Almost 40 states have adopted the IECC or its predecessor, the Model Energy Code (MEC), as their mandatory state code. Many of these states have made some modifications or amendments to the IECC or MEC. These modifications can vary from a few minor changes to extensive revisions.

Some states have no mandatory codes. As of the date of this report, these states are:

- Alabama
- Hawaii
- Kansas
- Mississippi
- Missouri
- North Dakota
- South Dakota
- Wyoming

Four states have developed their own codes that have minimal or no connection to the IECC:

- California
- Florida
- Oregon
- Washington

In certain cases, cities or counties within a state have a different code from the rest of the state. For example, Austin and Houston have adopted progressive energy codes that exceed the minimum Texas statewide code.

2.0 Chapter 2 – Energy Analysis of Major Improvement in 2009 IECC

The 2009 IECC contains major differences that are not contained in any previous version of the IECC. These changes account for much of the energy savings attributable to the 2009 IECC compared to any of the older versions of the IECC.

2.1 Duct Testing

Section 403.2.2 of the 2009 IECC requires air ducts systems, where any of the ducts pass outside of the conditioned space (into attics, garages, etc.), to be pressure tested for leakage with maximum leakage rates specified. The duct system now has to be tested to prove that the air leakage out of ducts is kept to an acceptable level. Testing is not required if all ducts are inside the building envelope (for example in heated basements), though all ducts are required to be sealed.

The IECC has always required ducts to be sealed. However, multiple studies have shown that visual inspection of ducts is not adequate. Ducts are often located in difficult to access areas such as attics and crawl spaces. Cracks and other leakage points in ducts may not be visible because they are covered by insulation, hidden from view, or simply too small to be readily apparent to the human eye. Testing of completed homes in Washington state, where prescriptive code requirements for duct sealing apply, "showed no significant improvement" over non-code homes (Washington State University 2001). Another study from Washington state concluded: "Comparisons to air leakage rates reported elsewhere for homes built before the implementation of the 1991 WSEC show no significant improvement by the general population" despite years of training emphasizing duct sealing (Hales et al. 2003). The requirement to meet a specific leakage limit will result in improving the buildings that would have had the leakiest ducts. Figure 2 illustrates this effect.

Numerous other studies around the nation show substantial duct leakage in new homes, including those in states with codes requiring duct sealing. For example, a 2001 study of 186 houses built under the MEC in Massachusetts reported "serious problems were found in the quality of duct sealing in about 80% of these houses" (Xenergy 2001). Pressurization tests in 22 of these houses found an average leakage to the outside of the house of 183 cfm, or 21.6% of the system flow, at a pressure of 25 Pascals.

The IECC allows a variety of compliance methods. Notably, the testing can be done at rough-in stage immediately after the ducts are installed. This allows potentially costly call backs to be avoided if the tested leakage rate exceeds code requirements.

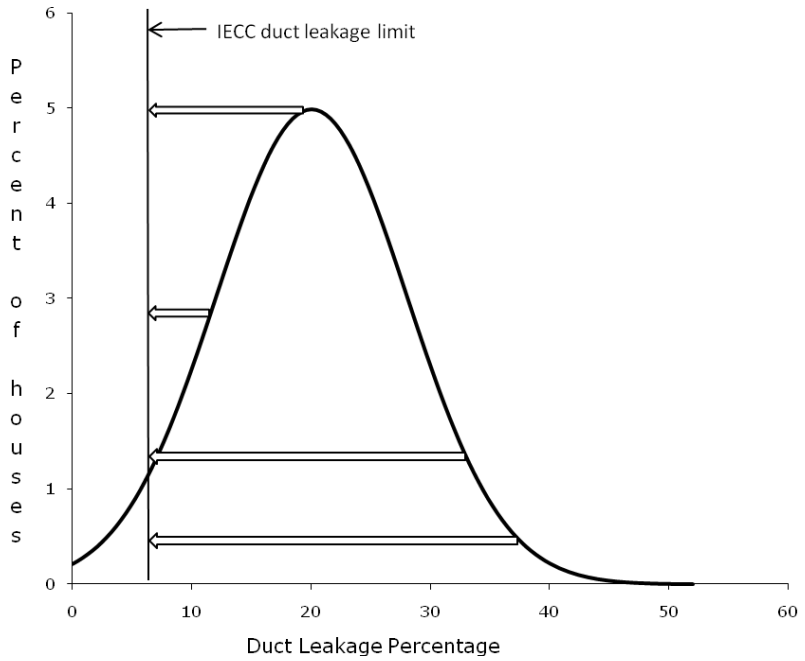

Figure 2. Impact of improved duct sealing. The curve illustrates the approximate distribution of leakage rate in new homes. The arrows show the reduction in duct leakage necessary to meet the code requirement.

2.2 Lighting

The 2009 IECC requires 50% of lamps (bulbs, tubes) within a residence to be energy efficient. There were no requirements for lighting in single-family homes in previous versions of the IECC. This includes but is not limited to CFLs. Standard incandescent bulbs do not qualify. Savings attributable to the lighting requirements in the IECC will decrease as Federal law requires improved light bulbs in 2012 to 2014.

2.3 Envelope Improvements

The 2009 IECC has a number of improvements in basic envelope requirements over the 2006 IECC. Allowable glazed fenestration (windows and skylights) SHGC has been reduced to a maximum of 0.30, meaning that no more than 30% of the sun's heat can pass through the window into the home. Fenestration U-factor requirements have improved in Climate Zones 2, 3, and 4. Wall insulation for wood frame walls has been bumped up from R-19 to R-20 in Climate Zones 5 and 6. Floor insulation and basement wall insulation have increased in the very coldest zones.

2.4 Elimination of Equipment Trade-offs

Previous versions of the IECC allow reductions in envelope measures to below-code levels if heating and cooling equipment efficiency is improved to above-code levels. For example, a popular trade-off in colder climates is to use a high efficiency gas furnace allowing a reduction of wall insulation. The 2009 IECC eliminates these types of trade-offs. Since these trade-offs are by definition energy neutral, their eliminiation in theory would not impact energy use. However, building envelope measures often have longer lifetimes than heating and cooling equipment so there can be long-term impacts. Additionally, there is expected to be some "free rider" effect where high efficiency equipment will be used regardless of the IECC requirements and the trade-offs, so the older IECC allowed envelope reductions as an unintended side effect.

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Analysis of 2009 International Energy Conservation Code Requirements for Residential Buildings in Arkansas

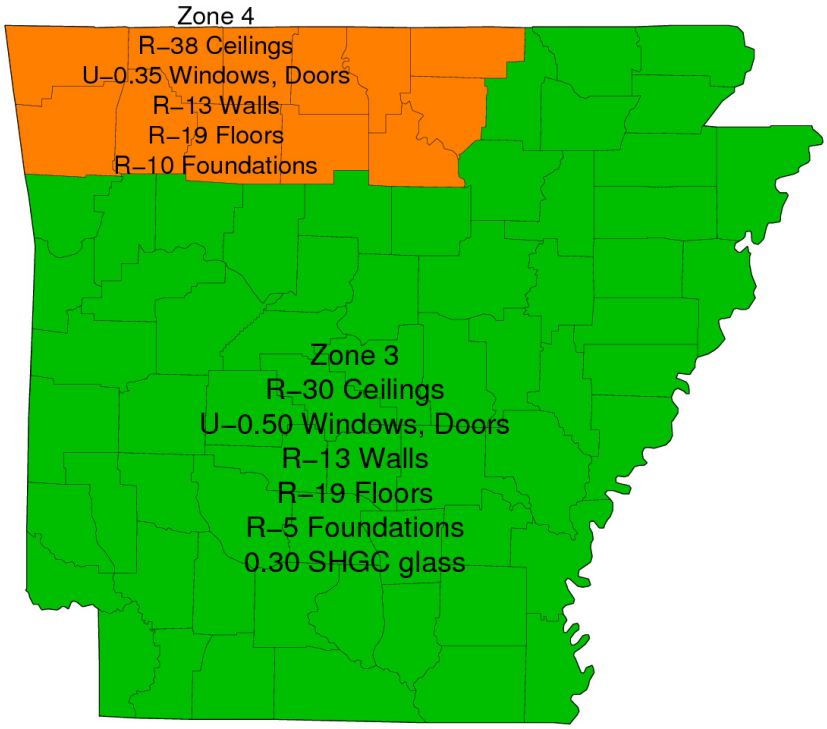
Summary

The 2009 International Energy Conservation Code (IECC) contains several major improvements in energy efficiency over the current state code, the 2003 IECC with amendments. The most notable changes are improved duct sealing and efficient lighting requirements. A limited analysis of these changes resulted in estimated savings of $242 to $245 a year for an average new house at recent fuel prices.

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.

The map below shows the primary building envelope requirements for all residential buildings in the 2009 IECC.



Notable requirements in the 2009 IECC:

- Building envelope must be caulked and sealed.
- Slab-on-grade insulation is R-10 to a depth of 2 feet in Zone 4. Insulation is <u>not</u> required for slab-on-grade foundations in Zone 3.
- 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 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), though the ducts still have to be sealed.
- Piping for hydronic (boiler) heating systems must be insulated to R-3.
- Although vapor retarders are not required by the IECC, the I-codes do set wall vapor retarder requirements in Section R601.3 of the 2009 IRC. However, vapor retarders are not required in Arkansas.
- 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 ft^2 of window area are exempt
- Skylight U-factors are allowed to be U-0.65 in Zone 3 and U-0.60 in Zone 4
- 500 ft^2 or 20% of ceiling area of cathedral ceiling, whichever is less, is allowed to have R-30 insulation

Mandatory Requirements:

Windows can never exceed an area-weighted U-factor of 0.48 in Zone 4 and cannot exceed an area-weighted SHGC of 0.50 in Zone 3. 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 IECC 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 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 RES*check*™ 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 <u>no tradeoff credit</u> for the use of high efficiency space heating, space cooling, or water heating equipment.

Main Difference between the Current Arkansas Code and the 2009 IECC

Arkansas has adopted the 2003 IECC with amendments, including:

- No glazed fenestration SHGC requirement. The 2003 IECC requires a maximum SHGC of 0.40 in south and central Arkansas.
- Duct insulation is set to R-5.6. The 2003 IECC duct insulation values vary from R-2 to R-8.

Major differences between the 2009 IECC and the Arkansas code are listed below:

- The current state code 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 2003 IECC has no lighting requirement. Compact fluorescents qualify, standard incandescent bulbs do not.
- Trade-off credit can no longer be obtained for high efficiency 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 RES*check*™ software and other energy performance analysis tools.)
- The format of the 2003 IECC and 2009 IECC are substantially different. The 2009 IECC has new climate zones that cover larger geographic regions than the zones in the 2003 IECC. The envelope insulation and window requirements in the 2003 IECC vary by window-to-wall area percentage, but not in the 2009 IECC. This change in format makes a simple comparison of the envelope requirements in the two codes impossible.

Energy Analysis

A brief energy analysis was conducted comparing the current state code to the 2009 IECC. The EnergyGauge™ software was used to determine the energy impacts of changes in envelope requirements. EnergyGauge™ is based on the DOE-2 energy simulation software developed by DOE (Lawrence Berkeley National Laboratory 1981).

Two sets of buildings were simulated: one with energy efficiency levels set to the prescriptive requirements of the current state code, and one with energy efficiency levels set to the prescriptive requirements of the 2009 IECC. All inputs other than the changes in energy efficiency levels were identical in the two sets of simulations.

The analysis assumed a two-story, single-family house with a conditioned floor area of 2,400 ft^2. It was assumed that the house had 8.5-ft high ceilings, a ceiling area (bordering the unconditioned attic) of 1,200 ft^2, a gross exterior wall area of 2,380 ft^2, and a window area of 357 ft^2 (15% of the wall area) equally oriented north, south, east, and west. Heating with a natural gas furnace ($1.20/therm) and central electric air conditioning ($.12/kWh) were assumed.

High-efficacy lighting was assumed to increase from 10% to 50% of all lighting within the building, reducing lighting energy use by 26%, or $74 a year. Savings attributable to the lighting requirements in the IECC will decrease as Federal law requires improved light bulbs in 2012 to 2014. Improved duct sealing was assumed to save 10% of the heating and cooling costs. Actual savings will vary depending on many factors, including how well ducts are currently sealed in the absence of any testing requirements.

Table 1 shows the estimated annual energy savings per house that result from meeting the improved requirements in the 2009 IECC. Total savings includes heating, cooling, and lighting and is shown as a percentage of the end-uses covered by the 2009 IECC (heating, cooling and water heating).

Table 1. Energy End Use and Percentage Savings

Climate Zone	*Annual Energy Cost ($)*				*Savings 2009 IECC vs. Arkansas Code*	
	Arkansas Code		*2009 IECC*			
	Heating	Cooling	Heating	Cooling	Savings ($/yr)	Percent Savings
Little Rock (CZ 3A)	965	300	853	244	242	15
Springfield MO (CZ 4A)	1185	213	1034	193	245	14

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