PNNL-14736

Pacific Northwest
National Laboratory
Operated by Battelle for the
U.S. Department of Energy

Energy Efficiency of the 2000 International Energy Conservation Code in West Virginia

R. G. Lucas

June 2004

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RL01830

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UNITED STATES DEPARTMENT OF ENERGY
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Introduction

The West Virginia State Building Code[1] contains two options for energy efficiency requirements in one- and two-family dwellings. One is the International Code Council's (ICC) 2000 *International Energy Conservation Code* (IECC) (ICC 1999a,b) (87-4-4.1.6). The second is an exception (replacement) for Chapter 11 of the ICC International Residential Code (IRC) (87-4-4.1.7). The West Virginia Energy Efficiency Program, West Virginia Development Office, has asked the U.S. Department of Energy (DOE) to compare the energy use resulting from the application of the 2000 IECC code and the IRC code, as amended by West Virginia. The Department's Pacific Northwest National Laboratory (PNNL) compared the energy use from compliance with the 2000 IECC to the exception to Chapter 11 of the IRC known as the "Alternate Energy Code." The Alternate Energy Code is less stringent than the 2000 IECC. The results of this analysis are presented below.

Methodology

The analysis examined the typical cost and energy savings from the incremental improvements from the Alternate Energy Code to the 2000 IECC using computer simulations. Two locations in West Virginia were examined: Charleston and Elkins. These cities represent a climate in the warmer and colder parts of West Virginia, respectively. The house design considered was a 2000 ft^2 two-story house, 25x40 ft, 15% window–to-wall area ratio, and a full unconditioned basement. Heating with a natural gas furnace and central electric air conditioning were assumed.

Alternate Energy Code

The prescriptive envelope requirements for the Alternate Energy Code that are constant throughout the state are shown below.

- R-13 above-grade wall insulation
- R-4 slab insulation, 2 ft deep
- R-8 crawl space wall insulation
- R-4 basement wall insulation with depth to approximately 3 ft below grade
- U-0.39 doors with one door exempt
- 6 sq. ft of window area exempt from the U-factor requirements
- Standard air infiltration requirements to seal the building envelope
- R-5 duct insulation
- Ducts outside the building envelope must be sealed by gaskets, mastics, or tapes.

Three building envelope component requirements vary by heating degree-days (HDD), ceilings, windows, and floors. These envelope component requirements, along with the above-grade and basement wall requirements, are shown in Figure 1 below (this map uses average heating degree-days by county).

[1] http://www.wvsos.com/csrdocs/wordDocs/87-04.doc

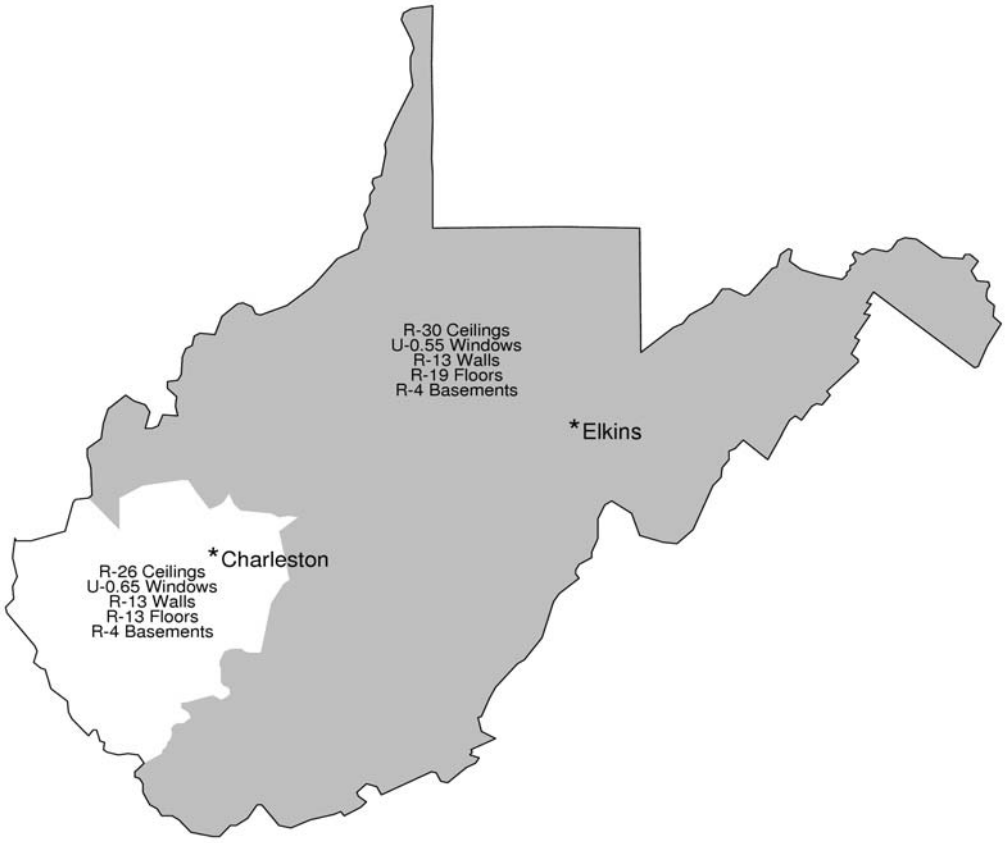

Figure 1. Alternate Energy Code Envelope Requirements by Climate

The 2000 IECC

The 2000 IECC has three alternative compliance paths: systems analysis, component performance, and simplified prescriptive requirements. The systems analysis compliance path compares an annual energy analysis of the proposed design to a standard design based on criteria in the component performance approach. The proposed design must use the same or less energy than the standard design. The component performance compliance path has figures that set U_o-value requirements for each envelope component as a function of HDD. The simplified prescriptive compliance path has tabular sets of requirements of insulation R-values and window U-factors.

The envelope requirements in the prescriptive compliance path vary with changes to the window-to-wall area ratio. For example, the prescriptive requirements for a house in Charleston with a window area of 12% of the wall area have a window U-factor requirement of 0.50, while a house with a window area of 18% of the wall area has a window U-factor requirement of 0.37 (see Tables 502.2.4(2) and 502.2.4(4), 2000 IECC).

The prescriptive requirements shown for the IECC in Figure 2 are for a window-to-wall area ratio of 15%. The 15% area is likely to be a little higher than the average window area in new West Virginia houses (estimated to be between 12 and 14%), so Figure 2 may present a slightly conservative, stringent representation of the IECC code envelope requirements.

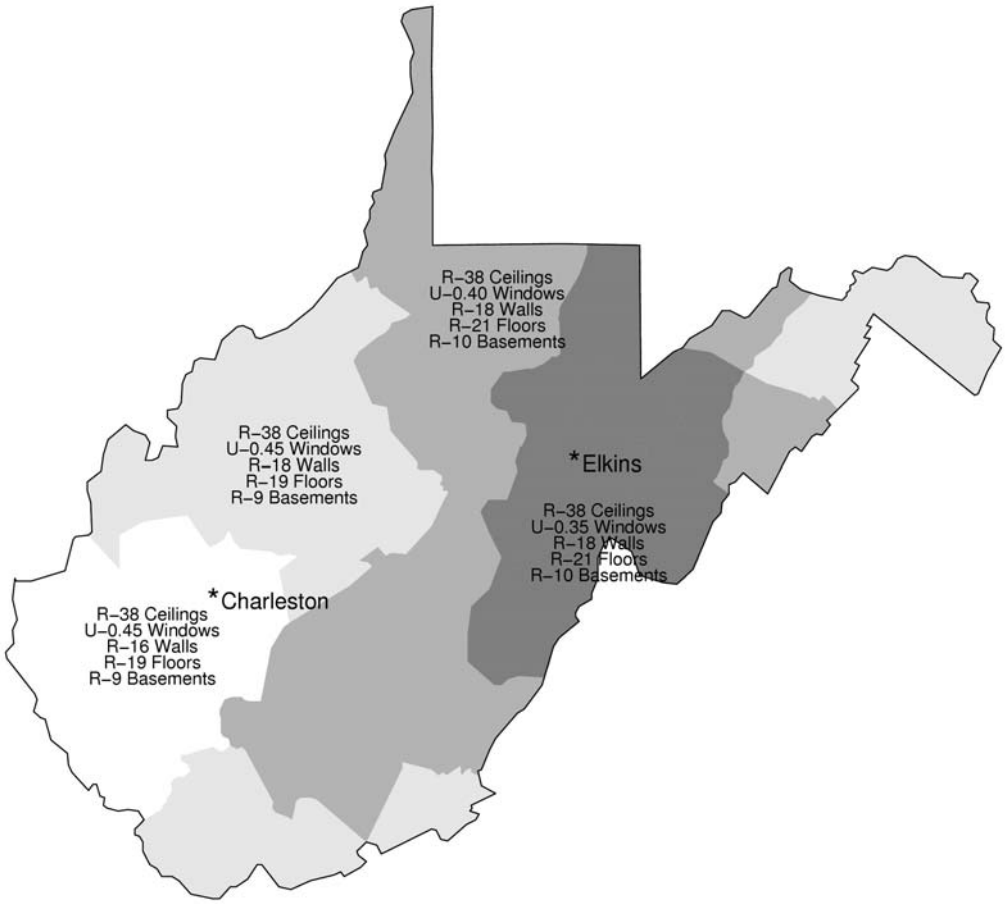

Figure 2. IECC Envelope Requirements by Climate (15% Window Area)

Comparative Analysis

A direct comparison of primary requirements of the West Virginia Alternative and the component performance compliance path, at 15% window-to-wall area ratio, are presented in Table 1.

Table 1. Comparison of WV Alternative to the 2000 IECC[1]

		Maximum		Minimum						
Code	**HDD**	**Window/ Skylight**	**Doors[2]**	**Exterior Wall**	**Floor**	**Basement Wall**	**Slab Peri-meter[3]**	**Crawl Space Wall**	**Ceil-ing**	**Ducts Outside Envelope**
WV Alternative	4,500-4,999	U-0.55[4]	U-0.39	R-13	R-13	R-4, 3 ft.[5]	R-4, 2 ft.	R-8	R-26	R-5
	5,000-6,499	U-0.65[4]			R-19				R-30	
2000 IECC	4,500-4,999	U-0.45[6]	U-0.35	R-16	R-19	R-9[7]	R-6, 2 ft.	R-17	R-38	R-6.5
	5,000-5,499			R-18			R-6, 2 ft.			
	5,500-5,999	U-0.40[6]			R-21	R-10[7]	R-9, 2 ft.	R-19		
	6,000-6,499	U-0.35[6]					R-9, 4 ft.	R-20		

1. Criteria at 15% glazing area, Table 502.2.4(3) of the IECC
2. One door is exempt in both code criteria.
3. R-value and depth of insulation.
4. Six square feet of window is exempt. Skylights are required to be double glazed and wood, vinyl, or fiberglass.
5. To a depth of 3 feet below grade.
6. 1% of the window area is exempt.
7. To a depth of 10 feet below grade or to the level of the basement floor, whichever is less.

The IECC has more stringent envelope requirements than the Alternate Energy Code. In comparison to the IECC, the Alternate Energy Code generally has lower insulation requirements, less stringent window U-factor requirements, and more flexible options for duct sealing. These factors are accounted for in the energy analysis below. The Alternate Energy Code also differs from the IECC in ways that may further reduce energy efficiency.

Section N1101.4.5 in the West Virginia revision of the IRC does not prohibit vents in crawl spaces with crawl space wall insulation. Open vents in winter will allow cold air to flow into the crawl space and therefore undercut the benefit of the wall insulation. Occupants may close the vents in the winter, but codes traditionally decline to depend on occupant intervention. The energy efficiency requirements in the IECC do not allow vents if the method of insulating the crawl space is with insulation on the crawl space walls.

Table N1101, note 5 and Section N1101.4.6 require that basement wall insulation should extend down to the frost depth, which will be about 3 ft below grade in West Virginia. The IECC requires basement wall insulation to extend down to the basement floor. The conductivity of soil varies, but there will be substantial heat loss from the lower area of the basement wall through the soil to the outside air if full basement insulation is not used. Interior basement wall insulation extending only part way down the wall allows heat transfer to the outside from the bottom of the basement wall up through the concrete to the exterior (bypassing the insulation).

The WV code allows heated basements to completely forgo wall insulation if, 1) not more than 12 inches of the top of the wall is above ground, and 2) the gas furnace efficiency is 88% or higher (or the heat pump efficiency (HSPF) is 7.8 or higher). Uninsulated basement walls are permitted even if the basement is a conditioned living space. The component performance path of the IECC requires R-9 or R-10 basement wall insulation.

While the IECC does not have these prescriptive trade-offs, the system performance compliance path allows any trade-offs that do not increase the annual energy consumption of the proposed house above the standard design. The trade-off to allow basement walls to be uninsulated if a high efficiency furnace is installed, should not significantly reduce energy efficiency, if the basement is unconditioned and the ducts and air handler in the basement are properly sealed and insulated.[1] However, as described below, the duct sealing requirements in the Alternate Energy Code are lax. Most importantly, no basement wall insulation for basements that are conditioned, living spaces is a major flaw regardless of how efficient the furnace is.

Unlike the IECC, there is no U-factor requirement for skylights in the Alternate Energy Code. However, skylights must be double-glazed, and cannot be metal frame, so the skylight requirement in the Alternate Energy Code is reasonably energy efficient.

The RES*check* software, developed by the U.S. Department of Energy,[2] allows users to easily examine different energy efficiency measures to determine if they comply with a particular code. The energy efficiency requirements were set in RES*check* to comply with the 2000 IECC for the 2000 ft^2 house examined here. The RES*check*-compliant packages, shown in Table 2, were then used in the energy analysis.

[1] Note that the minimum heat pump efficiency (HSPF) of 7.8, which allows the trade-off for no basement insulation, is only modestly better than the minimum national manufacturing standard of a 7.4 HSPF, which will take effect in 2006.

[2] http://www.energycodes.gov/RES*check*.

Table 2. IECC Compliance Measures Using RES*check*

	Ceiling R-value	Wall R-value	Window U-factor	Basement Ceiling R-value	Furnace AFUE[(a)]
Charleston	30	13	0.40	19	80%
Elkins	38	15	0.38	19	80%

[(a)] annual fuel utilization efficiency

Fuel Costs and HVAC Equipment

Fuel costs used in the energy analysis were obtained from DOE Energy Information Administration data for West Virginia (2003). The average fuel cost of $7.8/Mcf from the winter of 2002/2003 was used. The average July 2003 West Virginia residential electricity price of 6.3 cents/kWh was used for air conditioning. A gas furnace with an efficiency of 80% and an air conditioner with a Seasonal Energy Efficiency Ratio (SEER) of 10 were assumed.

Energy Analysis

The EnergyGauge simulation tool (Florida Solar Energy Council) was used to estimate the savings from improving energy efficiency of a home designed to the Alternate Energy Code to the home designed to the 2000 IECC (using the measures in Table 2). EnergyGauge utilizes the DOE-2 simulation model that estimates the building energy use for all 8760 hours in a year. Tables 3 and 4 show the comparative energy costs and saving differential for the home in Charleston and Elkins. These tables include space heating and air conditioning only.

Table 3. Annual Energy Costs in Charleston

	2000 IECC	Alternate Energy Code
Heating	$361	$445
Cooling	$132	$127
Total	$493	$572
Energy cost savings of IECC	$79 or 14%	

Table 4. Annual Energy Costs in Elkins

	2000 IECC	Alternate Energy Code
Heating	$489	$582
Cooling	$49	$49
Total	$538	$631
Energy cost savings of IECC	$93 or 15%	

The WV Alternative Energy Code requires ducts outside the building to be insulated to R-5. The 2000 IECC requires ducts outside the building to be insulated to R-6.5. Both codes require ducts in unconditioned spaces to be insulated to R-5.

The WV Alternative Energy Code does not require any type of sealing for ducts within the building thermal envelope. The code allows ducts outside the thermal envelope to be sealed by any type of tape. In contrast, the IECC requires that ducts be sealed with welds, gaskets, mastics (adhesives), mastics-plus-embedded-fabric systems, or tapes. The IECC requires tapes and mastics be listed and labeled in accordance with UL 181A and 181B. The IECC requires all ducts to be sealed and requires tapes to meet UL Standards 181A or 181B.

The IECC has the potential to reduce energy loss from duct leakage because of the improved duct sealing specifications. Data from the National Association of Home Builders (NAHB) and anecdotal information suggest that ductwork in unheated basements is generally not insulated or properly sealed. A homebuilder survey reported that 83% of builders in Illinois use duct tape to seal ducts (ISU 1997). Ironically, duct tape performs poorly at sealing ducts (Sherman et al. 2000).

One study estimates heating and cooling savings from improved duct sealing to be 12% in new homes (Hammon and Modera 1996). Another report predicts that sealing 80% of the duct leaks in the basement and insulating the basement ducts to R-5 will produce a 10% savings in energy use (Triedler 1993). Duct sealing measures in existing homes achieved a 5% to 10% annual energy use reduction (Boe 1998). The potential for properly sealing ducts is better in a new building than in a retrofit because the ducts will be fully accessible.

It is estimated that HVAC energy costs can be reduced by 10% by sealing the ducts, as required by the IECC. This would increase the savings from $79 (14%) to $128 (22%) in Charleston and from $93 (15%) to $146 (23%) in Elkins.

Conclusion

In almost all respects the West Virginia Alternate Energy Code is less stringent than the 2000 IECC. This includes less stringent envelope and duct insulation levels; window, door and skylight U-factors; duct sealing; crawl space wall insulation; and the trade-off that allows heated basement to be uninsulated. Building a home to the requirements of the 2000 IECC is conservatively estimated to reduce energy use

from space heating and air conditioning by between 14% and 23% in new homes in West Virginia, compared to the Alternate Energy Code.

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