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Assessment of Impacts from Updating Idaho's Residential Energy Code to Comply with the 2000 International Energy Conservation Code

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Summary

The state of Idaho currently requires that new buildings comply with the Idaho Residential Energy Standards (IRES). Idaho is considering updating its residential energy standards to the International Code Council (ICC) *2000 International Energy Conservation Code* (IECC) (ICC 1999). Idaho's Department of Water Resources, Energy Division, requested that the U.S. Department of Energy (DOE) compare the current construction practice in Idaho with the 2000 IECC to estimate impacts from improving the energy efficiency of new residential buildings throughout the state to comply with the IECC. Under DOE's direction, Pacific Northwest National Laboratory (PNNL) completed an assessment of the impacts from this potential code upgrade, including impacts on construction and energy consumption costs.

The most significant differences between current construction practice and the 2000 IECC for residential buildings in Idaho are as follows:

- Vented crawl spaces must have insulation in the floor because insulation on the crawl space wall is no longer credited when external venting exists. Alternatively, crawl space wall insulation can be used but the crawl space must be unvented.

- Many houses built with typical construction practices will likely comply with the 2000 IECC without requiring any significant modifications.

- Many houses will need some type of substantial improvement to comply with the IECC, particularly for houses with windows having a high window area as a percentage of wall area. The types of improvements that are likely to show compliance are low-emissivity windows, 2-by-6 wall construction with R-19 insulation, or 90%+ efficiency furnaces.

- The IECC allows flexibility in achieving an overall level of energy efficiency for a residential building. Therefore, builders are free to find the lowest cost method to obtain code compliance.

The impacts on construction costs and energy savings from updated residential energy efficiency standards vary greatly depending on several factors, including the type of dwelling, the specific design elements, and the location. Many buildings may not require any changes. Some residential buildings would need several improvements to comply with an upgraded energy efficiency code. Construction cost increases from adopting the 2000 IECC are expected to vary from zero to about $500 for most houses or multifamily dwelling units. In some cases where houses are very large and/or inefficient houses would otherwise be built, the construction cost increases to show code compliance could reach $1000 or more, but these situations are expected to be relatively uncommon. The requirements of the 2000 IECC are cost-effective, typically with a simple payback of 5 years or less if the most cost-effective methods of code compliance are chosen. However, more aggressive code enforcement will likely be needed to realize the energy efficiency improvements that are required by the IECC.

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1.0 Introduction

The state of Idaho currently requires that new buildings comply with the Idaho Residential Energy Standards (IRES). Idaho is considering updating its residential energy standards to the International Code Council (ICC) *2000 International Energy Conservation Code* (IECC) (ICC 1999). Idaho's Department of Water Resources, Energy Division, requested that the U.S. Department of Energy (DOE) compare the current construction practice in Idaho with the 2000 IECC to estimate impacts from improving the energy efficiency of new residential buildings throughout the state to comply with the IECC. Under DOE's direction, Pacific Northwest National Laboratory (PNNL) completed an assessment of the impacts from this potential code upgrade, including impacts on construction and energy consumption costs.

Section 2.0 of this report discusses the major differences between the requirements in the Idaho Residential Energy Standards (IRES) and the residential requirements in the International Code Council (ICC) *2000 International Energy Conservation Code* (IECC) (ICC 1999). Section 3.0 lists publications referenced in this report.

2.0 Major Differences Between Idaho Current Practice and the 2000 IECC

This section discusses PNNL's assessment of the major differences between Idaho current practice and the 2000 IECC and the impacts of adopting the 2000 IECC on construction and energy consumption costs.

2.1 Idaho Current Construction Practices

IRES establishes minimum residential energy standards throughout the state, although local jurisdictions can adopt more stringent standards. For example, Coeur d'Alene, Idaho Falls, Nampa, Caldwell, and Lewiston have adopted the 1995 Model Energy Code (MEC) (CABO 1995). A study (Baylon, Borrelli, and Kennedy 2000, referred to here as the Baseline Survey) of actual construction practice related to energy efficiency in 104 new houses in Idaho found that although IRES is a mandatory code, full compliance often does not occur, particularly in the southwestern part of the state (Boise area). Because current practice so often falls short of the IRES code, we compared the IECC requirements to this construction practice baseline instead of the IECC to the IRES.

The Baseline Survey reported characteristics of typical new houses in Idaho, with a focus on energy efficiency measures. Table 2.1 shows the average house size used in the Baseline Survey. The smaller house size in the Boise area is attributed to the fact that basements are uncommon in Boise.

Table 2.1. Average Size of Homes Reported in Baseline Survey

Location	Number of Homes	Floor Area (ft^2)	Standard Deviation	Median (ft^2)	Percent with Basements
Idaho	104	1,941	761	1678	17.3
Boise	63	1,810	629	--	6.4
Other	41	2,143	900	--	34.1

Table 2.2 shows the wall characteristics reported in the Baseline Survey. Walls with 2x4 construction normally have R-13 insulation; walls with 2x6 construction normally have R-19 insulation. Under the IRES code, 2x4 construction is deemed to comply with the prescriptive path if it has R-13 insulation and at least 85% of the total wall area is sheathed in R-3.6 rigid-foam sheathing insulation. Most new homes in the Boise area have 2x4 walls but no foam sheathing insulation and are therefore failing to meet the IRES requirement. In parts of the state other than the Boise area, 2x6 walls are very common but are relatively uncommon in and around Boise.

Table 2.2. Wall Characteristics Reported in Baseline Survey (fraction of total wall)

Type	Boise Area	Other Areas	Entire State
2x4	0.67	0.11	0.45
2x4 w/ foam	0.06	0.01	0.04
2x6	0.21	0.69	0.40
Below grade	0.03	0.16	0.08
Unknown/other	0.03	0.03	0.03

Window characteristics have important implications on energy efficiency and code compliance. The Baseline Survey reported that the average window U-factor in new Idaho homes was 0.47 and houses had an average window area equal to 12.7% of the floor area. We assumed that most windows installed in houses in the southwest part of the state are double-glazed vinyl or wood without low-emissivity (low-E) coatings and have an average U-factor of 0.50. We assumed windows in other parts of the state to be a mix of windows with and without low-E coatings. Double-glazed vinyl or wood windows with low-E coatings have an average U-factor of about 0.36.

Table 2.3 shows the type of floor/foundation construction reported in the Baseline Survey. Most houses statewide have a crawl space. Insulation in crawl spaces can either be put in the floor above the crawl space or inside the walls around the perimeter of the crawl space. In Idaho, most builders choose crawl space perimeter insulation, which is almost always R-19 insulation. As shown in Table 2.1, basements are uncommon in the southwest part of the state but fairly common in colder parts of Idaho. The large majority of new houses in the southwest area have crawl spaces. Over 90% of crawl spaces have operable vents to the outside.

Table 2.3. Floor/Foundation Construction Reported in Baseline Survey

Floor Type	Percent of Floor Area
Frame Over Crawl	
Floor Insulation	23.6
Perimeter Insulation	51.3
Unknown Insulation	0.2
Frame Over Garage/Air	4.8
Slab On Grade	2.1
Heated Basement	17.3
Total	100.0

Table 2.4 shows ceiling insulation levels reported in the Baseline Survey. R-38 is by far the most common ceiling insulation level.

Table 2.4. Ceiling Insulation Reported in Baseline Survey

Ceiling Type					
Attic		Scissors		Vault	
%	R	%	R	%	R
52.6	38.0	40.8	37.5	6.6	28.9

Gas furnaces are the most common type of heating system, as shown in Table 2.5. Gas furnaces in new homes have an average efficiency (AFUE) of 82%, with 16% being high-efficiency condensing-type furnaces (AFUE of 90% or higher). Air conditioning is installed in 72% of new homes in the state and 93% of new homes have forced air systems (ducts).

Table 2.5. Heating Equipment Reported in Baseline Survey

Fuel Type (Percent of Floor area)				
Gas	Electric		Propane	Other
	Resistance	H.P.		
87.8	5.7	0.9	5.7	0.0

2.2 Energy Efficiency Requirements in the 2000 IECC

House Bill 611 was introduced in Idaho's 2000 Legislative Session. The bill required that all Idaho jurisdictions adopt and enforce the same building code as adopted by the Division of Building Safety effective July 1, 2000. The Division of Building Safety will likely adopt the 2000 International Building Code (IBC) (ICC 2000) in January 2002, which references the 2000 International Residential Code (IRC) (ICC 2000) and the 2000 IECC.

The 2000 IECC establishes energy efficiency requirements for all buildings, which apply not only to new buildings, but also to additions, alterations, and repairs. For residential buildings,[a] requirements include insulation levels, window U-factors, envelope sealing for reducing air infiltration, heating and cooling system requirements, and water heating requirements. This report focuses on envelope requirements−specifically insulation and window U-factors. The 2000 IECC has fundamentally the same energy efficiency requirements as the 1995 MEC and the existing code in Idaho Falls and several other Idaho cities. At least nine other states are currently either in the process of adopting the 2000 IECC or considering adopting the 2000 IECC.

The most notable IECC requirements, other than envelope requirements, are as follows:

- All joints, seams, and penetration in the building envelope must be caulked, gasketed, or covered with a house-wrap.

(a) Residential buildings include all single-family and duplex residences and all multifamily buildings three stories or less above grade containing “permanent” dwelling units (separate bathrooms and kitchens in each unit).

- Windows and doors must meet leakage rate limits.

- All ducts must be sealed with mastic or UL-rated tapes; R-5 insulation is required for ducts in unconditioned spaces.

- The IECC has equipment efficiency requirements for space heating, air-conditioning, and water heating equipment; however, these requirements are the same as mandatory Federal minimum requirements.

For this analysis, we used the MEC*check*™ software, Version 3.2[(a)] (PNNL 2000), to determine location-specific envelope requirements in the 2000 IECC for single-family buildings.[(b)] Table 2.6 shows examples of insulation, window, and heating system packages that will comply with the 2000 IECC. The IECC envelope requirements become more stringent as the climate becomes colder.

Table 2.6. Examples of Packages Complying With the 2000 IECC for Single-Family Residences[(a)]

City	Package	Window U-Factor	Wall	Gas Furnace Efficiency (%)
Boise	1	0.47	R-13	81
	2	0.40	R-13	78[(b)]
Coeur d'Alene	1	0.47	R-19	78
	2	0.47	R-13	90
	3	0.34	R-13	78
Idaho Falls	1	0.40	R-19	78
	2	0.40	R-13	92

(a) All packages have R-38 ceiling insulation. For foundations, all packages have either R-19 crawl space wall or floor insulation or basements with R-13 wall insulation. All packages have a window area equal to 12.7% of the conditioned floor area.
(b) 78% efficiency is the minimum allowed by Federal law.

The packages shown in Table 2.6 are referred to as examples because the IECC allows flexibility in meeting energy efficiency requirements. The IECC (specifically Chapter 4 and Section 502.2.2) allows trade-offs so that buildings can comply with the code if the annual energy use is sufficiently low, even if individual code requirements are not met. The requirements depend on the building design (e.g., the window-to-wall area percentage) and the climate where the building will be located. In Table 2.6, a 2000-ft^2, two-story building was assumed. The building was 25 ft wide and 40 ft long, with a total wall area of 2080 ft^2. To match the window area percentage from the Baseline Survey, we assumed the

(a) MEC*check*™ is a family of products designed to help streamline the compliance process, allowing users to easily demonstrate and verify compliance. The software allows users flexibility in determining a set of energy efficiency measures that meet the code.
(b) The IECC has separate envelope requirements for multifamily buildings. These requirements are typically less stringent than the IECC's requirements for single-family buildings.

window area was 12.7% of the conditioned floor area, or 254 ft^2, with an equal distribution of windows facing north, east, west, and south. Note that the IECC requirements change as the window area changes–for any given house plan, the more the window area, the better the energy efficiency measures (e.g., insulation levels, window U-factors) have to be.

2.3 Economic and Energy Impacts from Adopting the 2000 IECC

The most important issue when considering whether to adopt an energy code such as the 2000 IECC is the economic impacts on the homebuyer. How much will the cost of a house increase and how much will the homebuyer save in annual energy costs if the home is built to meet the adopted code? The estimated impacts for homebuyers in Idaho are presented below. The cities examined are Boise, Coeur d'Alene, and Idaho Falls. These cities represent the climate variation within the state as well as the areas with the most housing construction. The energy efficiency requirements for the IECC are taken from Table 2.6 and impacts are for the 2000-ft^2 house described above. In all cases, it is assumed that there will be R-38 ceiling insulation, R-19 crawl space insulation (either in the floor or wall), or R-13 basement wall insulation.

2.3.1 Boise

For the Boise area, the typical current construction practice as identified in the Baseline Survey is relatively close to complying with the envelope requirements of the 2000 IECC. In fact, the average house from the Baseline Survey complies with IECC as shown in the first option for Boise in Table 2.6. However, many houses will fall short of the IECC and will generally need modest improvements in energy efficiency. For example, many houses will have natural gas furnaces with efficiencies a percent or two below the 81% efficiency in the first option in Table 2.6. Also, the IECC requires houses with high window areas to have improved energy efficiency. For example, if an extra sliding glass door were added to the house described above, the average window U-factor for all windows would need to be improved by about U-0.05 (e.g., U-0.50 to U-0.45) to remain in compliance (other improvements could be made instead of better windows).

An important requirement in the 2000 IECC is that it does not credit crawl space wall insulation when the crawl space has any type of vents to the outside. This type of construction is common in the Boise area. The problem with this type of construction is that in the winter, cold outside air can pass through the vents and bypass the insulation, exposing the uninsulated floor and any ducts or heating equipment in the crawl space to the cold air. The result is increased heat loss and energy use. The occupant cannot be counted on to close these vents in winter, and even if they are closed, they are likely to leak air and not be insulated.

Two basic options exist to comply with the IECC in this situation. First, the insulation can be installed in the floor between the crawl space and the first floor. R.S. Means lists the installed cost of R-19 floor insulation at \$0.87/ft^2 (Means 2000). However, Idaho Department of Water Resources Energy Division staff report Southwest Idaho floor insulation costs of only \$0.44/ft^2 for R-19 or \$440 for the house examined here (costs will be higher for one-story houses because of larger crawl space areas). This lower cost is not surprising because R.S. Means cost estimates are often considered to be somewhat high. Insulating the crawl space wall should be considerably less expensive given that the crawl space wall area is lower than the floor area. Because the Baseline Survey reports that R-19 floor insulation is already used in 24% of the total floor area in new Idaho houses, this construction practice of floor insulation is clearly accepted by many builders. Note that attention to sealing and insulating ducts in the crawl space is very important if the floor insulation method is used.

The second option is to not vent the crawl space to the outside, but rather condition the crawl space and keep the perimeter wall insulation. For more information on this option, visit

http://www.goodcents.com/web/to_vent_or_not_to_vent.asp

The crawl space walls need to be well sealed and a polyethylene ground cover should be carefully installed. The insulation must extend down to at least the interior ground surface and may need to extend horizontally along the ground for a foot or two. Research suggests that moisture problems will not occur in unvented crawl spaces (Tsongas 1994). Sealing the crawl space should result in little change in the construction cost and will reduce energy costs. A sealed and insulated crawl space has the considerable advantage that the heating system and ducts in the crawl space are effectively moved inside the house, eliminating energy losses from ducts. This type of construction needs to be accepted by Idaho code officials.

To determine how much open vents in a crawl space with perimeter wall insulation will affect energy use, a small 1150-ft^2, one-story house in Indiana was monitored over four years with crawl space vents opened two years and closed two years (Hill 1998). Note that the house was in a location with 5900 heating degree-days, or approximately the same winter coldness as Boise. The crawl space had six vents with a combined 5-ft^2 total area. The supply ducts were located in the crawl space. The same occupants were in the house the entire period. The gas furnace energy use data were collected weekly. With the vents closed and insulated, the heating energy use decreased by 21%, or an estimated $50 a year in heating costs (natural gas costs of $0.50/therm). Insulating the crawl space access door and further measures to seal the entire crawl space increased these savings to 32% and an estimated $100 a year. Because the house was well built and insulated, was one-story, and had a low window area, the crawl space was a major share of the overall building heat loss. Assuming $0.70/therm gas costs in Idaho, the savings from closing and insulating the vents increases to $70 a year. Because little or no cost is involved in eliminating vents and conditioning the crawl space, this type of construction is clearly cost-effective. It is not clear how much energy would be saved if the insulation were installed in the floor above the crawl space instead of the perimeter insulation with venting. Using floor insulation will leave ducts in the crawl space exposed to cold outside air. Although the IECC requires the ducts to be insulated and well sealed, several studies have shown that the ducts are typically quite leaky and are major contributors to heating and cooling costs.

Even if the IECC crawl space insulation requirements are met, Boise area houses often may need further improvements over current practice to comply with the 2000 IECC. The IECC allows different compliance options. If improving energy efficiency is necessary to achieve compliance with the 2000 IECC, one possibility is to use low-E windows (Package 2 in Table 2.6). This option will typically improve the window U-factor from about 0.50 to about 0.36. A U-factor of 0.50 approximates an average U-factor for a wood or vinyl window without low-E and a U-factor of 0.36 is an average U-factor for the same type of window with low-E.[a] The RESFEN 3.1 software was used to examine the energy impacts of adding low-E coatings to the windows. RESFEN is specifically designed to analyze heating and cooling energy use of windows in residential buildings (Mitchell et al. 1999). The improvement to low-E glazing is estimated to reduce annual energy costs by $38 a year for the typical house in Boise described above. This estimate is based on natural gas heating at $0.70/therm and electricity at 5.6 cents/kWh. Assuming an estimated incremental cost increase of $1.5/$ft^2$ for the low-E glass (Kulakowski et al. 1998), the cost would be $380 per house and the simple payback would be 10 years. Given the relatively long payback, builders should check on costs from their window suppliers to make sure the added cost of low-

(a) For the two-story house examined here, a U-0.40 window, representing a relatively inefficient low-E window, is sufficient for compliance with the IECC in Boise.

E windows is reasonably low. Note that if low-E glazing is used, products with a high solar heat gain coefficient (SHGC) should be used to take advantage of solar heat gains in the winter.

If needed, another way to make improvements necessary to comply with the IECC would be to use a high-efficiency condensing gas furnace. The IECC credits high-efficiency heating, cooling, and water heating equipment in the Chapter 4 "systems analysis" compliance approach. These types of furnaces have an efficiency of 90% or more–well above the code minimum of 78%. These furnaces are estimated to cost $500 more than a standard gas furnace (*Energy Design Update* 1998). The Energy-10 simulation tool (Sustainable Buildings Industry Council 1998) was used to estimate an annual energy savings of $106 from the condensing furnace in the 2000-ft^2 house in Boise, resulting in a simple payback of less than 5 years.

2.3.2 Coeur d'Alene

Coeur d'Alene is slightly colder than Boise and therefore has similar but slightly more stringent envelope requirements in the IECC. The notable requirement in the first package in Table 2.6 is the use of 2x6 walls with R-19 insulation. The Baseline Survey suggests that this construction technique is predominate in the Coeur d'Alene area. A second improvement that will help with complying with the IECC is to use the condensing 90%-efficient gas furnace (Package 2 in Table 2.6, which easily complies with the IECC). Another design possibility is to use low-E windows, which allows 2x4 walls and a standard furnace. A third possibility is shown in Package 3, which has slightly better-than-average low-E windows with a 0.34 U-factor are required to comply with the IECC. As with Boise, the cost for these types of improvements ranges from about $380 to $500 and should have a 5-to-10-year payback from energy cost savings. However, the adoption of the 2000 IECC is expected to have almost no economic impact on the homebuyer in Coeur d'Alene because the current code is the 1995 MEC, which has essentially the same requirements as the 2000 IECC.

2.3.3 Idaho Falls

Idaho Falls is about the coldest city in Idaho and therefore has the most stringent IECC requirements. Table 2.6 shows two options for complying with the IECC. Typically, low-E windows will be necessary. For many house designs, compliance with 2x4 walls will be difficult; 2x6 walls with R-19 insulation may be necessary. The use of condensing-type natural gas furnaces will greatly assist in achieving compliance with the IECC.

The adoption of the 2000 IECC should have little impact in Idaho Falls because the current code is the 1995 MEC, which has essentially the same requirements as the 2000 IECC. For other Idaho locations that are extremely cold, construction cost impacts can be substantial (e.g., about $900 for low-E windows and a high-efficiency furnace), although many builders may voluntarily be reaching the level of energy efficiency required by the IECC. The Baseline Study indicates evidence exists that this voluntary high level of energy efficiency is occurring in Montana (similar climate to the coldest areas of Idaho).

3.0 References

Baylon, D., S. Borrelli, and D. Kennedy. 2000. *Baseline Characteristics of the Residential Sector in Idaho, Montana, Oregon and Washington.* Ecotope, Seattle, Washington.

Council of American Building Officials (CABO). 1995. *1995 Model Energy Code*. Falls Church, Virginia.

Energy Design Update. August 1998. "How Town and Country Reinvented Itself Through New Designs and Quality Control." 18(8):7.

Hill, W. W. 1998. "Measured Energy Penalties From Crawl Space Ventilation." In *Proceedings for the 1998 ACEEE Summer Study*, vol. 1, p. 135. American Council for an Energy-Efficient Economy, Washington, D.C.

International Code Council (ICC). 1999. *2000 International Energy Conservation Code*. Falls Church, Virginia.

International Code Council (ICC). 2000. *2000 International Building Code*. Falls Church, Virginia.

International Code Council (ICC). 2000. *2000 International Residential Code*. Falls Church, Virginia.

Kulakowski, S. L., M. W. Rufo, and S. R. Schwab. 1998. "Residential Windows: Haven't We Been Transforming Markets All Along?" In *Proceedings for the 1998 ACEEE Summer Study*, vol. 10, p. 41. American Council for an Energy-Efficient Economy, Washington, D.C.

Mitchell, R., J. Huang, D. Arasteh, R. Sullivan, and S. Phillip. 1999. *RESFEN 3.1: Program Description – A PC Program for Calculating the Heating and Cooling Energy Use of Windows in Residential Buildings*. LBNL-40682, Lawrence Berkeley National Laboratory, Berkeley, California.

Pacific Northwest National Laboratory (PNNL). 2000. *MECcheck Workbook for the 1998 and 2000 International Energy Conservation Code*, Version 3.0. Richland, Washington.

R.S. Means, Inc. (Means). 2000. *2001 Residential Cost Data*. Kingston, Massachusetts.

Sustainable Buildings Industry Council. 1998. *Energy-10 Software*, Version 1.2. Washington, D.C.

Tsongas, G. A. 1994. "Crawl Space Moisture Conditions in New and Existing Northwest Homes." ASHRAE Transactions, Vol. 100, Part 1, p. 1325. Atlanta, Georgia.