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

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Summary

The state of Kentucky currently requires that new buildings comply with the Council of American Building Officials' (CABO) *1992 Model Energy Code* (MEC) (CABO 1992). CABO has since been transformed into the International Code Council (ICC) and the MEC has been renamed the *International Energy Conservation Code* (IECC). The most recent edition of the code is the 2000 IECC (ICC 1999). Kentucky's Department of Natural Resources, Division of Energy, requested that the U.S. Department of Energy (DOE) compare the 1992 MEC with the 2000 IECC to estimate impacts from updating Kentucky's residential energy code to comply with the new code. 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.

Despite the change in the code's appearance, most of the requirements for residential buildings in the 1992 MEC and 2000 IECC have similar energy efficiency requirements. Some specific requirements in the 2000 IECC are more stringent than those in the 1992 MEC. The most significant differences between the 1992 MEC and the 2000 IECC for residential buildings in Kentucky are as follows:

- The thermal wall requirements for multifamily buildings have become substantially more stringent in the 2000 IECC–the allowed heat loss rates are about one-third lower than those allowed in the 1992 MEC.

- Specific provisions have been added to the 2000 IECC for recessed lighting fixtures to limit heat loss/gain by air infiltration.

The 1992 MEC and 2000 IECC have numerous other differences, but most of these differences are minor and will likely have little or no impact on energy efficiency or construction costs for most residential buildings. The 2000 IECC is much larger than 1992 MEC and has been restructured considerably from the MEC. Some changes affect only certain regions of the United States that do not include Kentucky. Notable other code differences affecting Kentucky include the following:

- Vented crawlspaces must have insulation in the floor because insulation in the crawlspace wall is no longer credited when venting exists.

- Foam insulation on the exterior of foundation walls must have a protective covering when above grade.

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 and specific design elements. Some residential buildings would need several improvements to comply with an upgraded energy efficiency code; others may comply unchanged. For example, the thermal envelope requirements for multifamily buildings have become considerably more stringent, but the requirements for single-family houses are largely unchanged. Construction cost increases from adopting the 2000 IECC are expected to vary from zero to about $300 for most houses or multifamily dwelling units. Many buildings should have no construction cost increases. The main cost impacts are expected to be from

- envelope improvements to multifamily buildings (up to about $300)

- a protective covering for exposed exterior foundation insulation (up to about $200 if applicable)

- improved sealing for recessed light fixtures (up to $50 or more, depending on the number of fixtures).

All of the changes to the 2000 IECC are clearly cost-effective with a simple payback of 5.5 years or less, except the requirement for a protective covering for exposed exterior foundation insulation. This requirement cannot be shown to be cost-effective from an energy efficiency standpoint, although it is a sensible preventive measure to improve long-term durability.

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1.0 Introduction

The state of Kentucky currently requires that new buildings comply with the Council of American Building Officials' (CABO) *1992 Model Energy Code* (MEC) (CABO 1992). CABO has since been transformed into the International Code Council (ICC) and the MEC has been renamed the *International Energy Conservation Code* (IECC). The most recent edition of the code is the 2000 IECC (ICC 1999). Kentucky's Department of Natural Resources, Division of Energy, requested that the U.S. Department of Energy (DOE) compare the 1992 MEC with the 2000 IECC to estimate impacts from updating Kentucky's residential energy code to comply with the new code. 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.

This report contains the findings of this assessment. Section 2.0 discusses the major differences between the 1992 MEC and 2000 IECC and Section 3.0 discusses minor differences, including impacts on construction and energy costs. Section 4.0 contains a list of publications cited in this report. The Appendix to this report contains the Energy-10 output reports used to estimate the energy savings from improved windows in multifamily buildings in Kentucky.

2.0 Major Differences Between 1992 MEC and 2000 IECC

This section discusses the most significant differences between the 1992 MEC (CABO 1992) and the 2000 IECC (ICC 1999) for residential buildings in Kentucky−the thermal walls requirements for multifamily buildings and provisions for recessed lighting fixtures to limit heat loss/gain by air infiltration.

2.1 Thermal Wall Requirements for Multifamily Buildings

The component heat loss and heat gain (U_o) requirements for multifamily residences changed dramatically between 1992 and 2000 (specifically in 1993). (Note that the IECC defines multifamily buildings three stories or less above grade containing three of more dwelling units [usually apartments or condominiums] as residential buildings and high-rise multifamily buildings as commercial buildings.)

The 2000 IECC has considerably more-stringent requirements for exterior walls (including windows and doors) in multifamily buildings than the 1992 MEC. These requirements are contained in Figure 1 (page 66) of the 1992 MEC and Figure 502.2(1) (page 71) of the 2000 IECC. These requirements are reproduced in Figure 2.1 for the range of heating degree-days that encompass Kentucky climates.

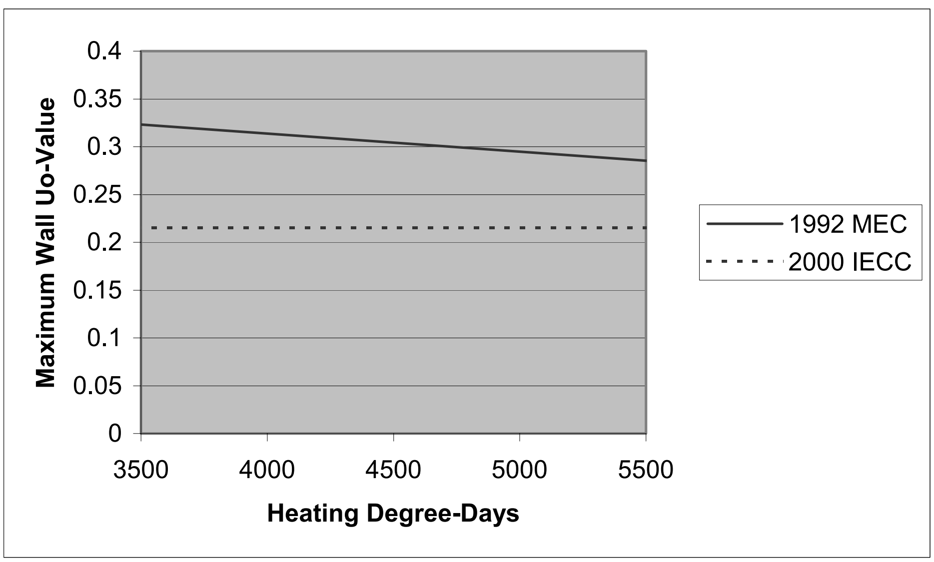

Figure 2.1. Thermal Wall Requirements for Multifamily Residences

The MEC*check*™ prescriptive packages[(a)] (PNNL 2000a, 2000b) illustrate examples of the differences in Window U-factor and wall insulation requirements between the 1992 MEC and 2000 IECC for multifamily buildings (see Table 2.1).

(a) MEC*check*™ is a family of products designed to help streamline the compliance process, allowing users to easily demonstrate and verify compliance. The prescriptive package approach, the simplest of the compliance approaches, allows users to select from “packages” of insulation and window requirements based on climate zones.

The requirements for multifamily residences in the 1992 MEC are very lenient, and would probably not result in any more energy efficiency than would occur in a free market in Kentucky with no energy code. The envelope requirements for multifamily buildings in the 2000 IECC may still be typically less stringent than the IECC's requirements for single-family buildings. About 20% of new housing construction in Kentucky is multifamily.

Table 2.1. Comparison of 1992 MEC and 2000 IECC Requirements in MEC*check*™ Prescriptive Packages for Multifamily Residences

Code	Climate Zone	Window Area Percentage[(a)]	Window U-Factor	Ceiling	Wall	Floor	Basement Wall	Slab Perimeter	Crawl Space Wall
1992 MEC	9	25	0.75	R-19	R-11	R-13	R-6	R-0	R-6
	10	25	0.75	R-26	R-13	R-11	R-5	R-0	R-6
	11	25	0.75	R-30	R-15	R-13	R-6	R-2	R-7
2000 IECC	9	25	0.54	R-30	R-13	R-11	R-5	R-0	R-5
	10	25	0.53	R-30	R-13	R-11	R-5	R-0	R-6
	11	25	0.50	R-30	R-13	R-19	R-9	R-5	R-15

(a) The MEC and IECC establish requirements for exterior walls (including windows and doors) that vary as a function of the window area as a percentage of the gross wall area. Window U-factor and wall insulation requirements become more stringent as the window area percentage increases, less stringent as the window area percentage decreases.

The IECC allows flexibility in meeting energy efficiency requirements using 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. Builders can add several possible improvements to the building design to comply with the more-stringent thermal requirements for walls in multifamily buildings. The requirements depend on the building design (e.g., the window-to-wall area percentage) and the climate where the building will be located. For example, having more-stringent window U-factors will likely result in compliance with the IECC. Vinyl (or wood) windows often have U-factors as low as those shown in Table 2.1 for 2000 IECC compliance. Because vinyl windows are already widely used in Kentucky, this improvement is reasonable. A California survey (CEC 1996) lists an incremental price of $\$1.36/ft^2$ for vinyl windows compared with less-efficient aluminum windows, resulting in a cost increase of about \$200 to \$300 for a typical multifamily unit in the 1000-to-1200-ft^2 floor area range.

We used the Energy-10 simulation tool to estimate the energy savings from improved windows in a multifamily building in Lexington (Sustainable Buildings Industry Council 1998). We assumed the building was two stories with six 1100-ft^2 dwelling units and a crawlspace foundation. The building was 27.5 ft wide and 120 ft long, with a total wall area of 4720 ft^2. To match the window area percentage used in the MEC*check*™ packages, we assumed the window area was 25% of the gross wall area, with an equal distribution of windows facing north, east, west, and south. This percentage resulted in a window area of 1180 ft^2 for the whole building or 197 ft^2 per dwelling unit. Natural gas heating at \$0.70/therm and electricity at 5.5 cents/kWh were assumed. The window U-factor was assumed to improve from 0.75 to 0.53 to match the improvement required in the MEC*check*™ prescriptive packages for compliance with the 2000 IECC. A U-factor of 0.75 approximates a typical U-factor for an aluminum window and a U-factor of 0.53 is a typical U-factor for a vinyl window. The Appendix to this report contains the Energy-10 output reports.

Energy-10 calculates the energy savings (mostly from reduced heating costs) resulting from window improvements to be $296 per year for the 6-unit building, or about $49 per dwelling unit. With an estimated incremental construction cost increase of $268 per unit, this improvement has a simple payback of about 5 ½ years.

Another trade-off example would be to use a high efficiency gas furnace (with an efficiency of 90% or above), which would likely allow the use of less energy-efficient aluminum windows (typically with a U-factor of about 0.75).

2.2 Recessed Lighting

The 2000 IECC specifically requires that recessed (canned) lighting fixtures be carefully sealed. The 1992 MEC does not have this requirement, although it does require that all "openings" in the building envelope be "caulked, gasketed, weatherstripped, or otherwise sealed." Although this requirement may seem like a minor construction detail, unsealed recessed lighting fixtures are a surprisingly large source of air leakage, resulting in increased heating and cooling costs.

The incremental cost of recessed lighting fixtures is about $5 per fixture (*Energy Design Update* 1994). We estimate the typical new house may have about 10 of these types of fixtures exposed on the top to an attic, or in a cathedral ceiling. Our sources indicate airtight recessed lighting is very cost-effective for the homeowner. Research in both the laboratory and in actual houses indicate air leaks out a single typical recessed light fixture at about 5 cfm during winter conditions in colder climates, increasing energy costs by $5 or more a year (*Energy Design Update* 1994). We estimate that properly sealing each recessed lighting fixture that is exposed to attics or other unconditioned spaces can save $5 a year in Kentucky. Therefore, investing in improved recessed light fixture sealing can pay off in energy savings in about one year.

Note that these impacts can only be expected to occur if the specific requirements for recessed lighting are enforced. Enforcing the requirement to use airtight recessed lighting should be straightforward for light fixtures that are labeled as airtight. Airtight fixtures or housings for recessed lighting may already be in use in Kentucky, although we suspect these types of fixtures are typically not used in most cases.

3.0 Minor Differences Between the 1992 MEC and the 2000 IECC

The 1992 MEC and 2000 IECC have numerous minor differences that will likely have little or no impact on energy efficiency or construction costs for most residential buildings. This section discusses these minor differences and their impacts on construction costs and energy consumption impacts.

3.1 Assumptions for Determining Wall U_o-Values for Wood-Framed Walls in Referenced Standards

The envelope component heat loss and heat gain (U_o for overall U-value) requirements for single-family residences have not changed between 1992 and 2000 for Kentucky locations. The 1992 MEC references an older version of the ASHRAE Handbook of Fundamentals (the 1985 edition) and the 2000 IECC references a newer version of the handbook (the 1997 edition) (ASHRAE 1985, 1997). This difference in referenced standards has indirectly made the 2000 IECC arguably slightly more stringent in terms of wall insulation requirements. The older version of the handbook recommends that wall U_o-values be calculated with assumptions that result in a more favorable U_o-value for any given wood-framed wall compared with the recommendation in the newer version. The new version of the handbook has formulas that more accurately account for the heat loss/gain impacts of framing. Therefore, the MEC*check*™ prescriptive packages for wood-framed buildings in the 2000 IECC are slightly more stringent than those in the1992 MEC.

Table 3.1 shows examples of the increase in stringency. It is arguable that many users will determine wall U_o-values independently using the version of the handbook that is referenced in the code, in which case the envelope insulation and glazing requirements for single-family buildings have not changed at all in Kentucky.

Table 3.1. Comparison of Window U-Factor and Wall Insulation Requirements in MEC*check*™ Prescriptive Packages for Single-Family Buildings

Code	Climate Zone	Window Area Percentage	Window U-Factor	Ceiling	Wall	Floor	Basement Wall	Slab Perimeter	Crawl Space Wall
1992 MEC	9	15	0.45	R-30	R-13	R-19	R-8	R-3	R-11
	10	15	0.40	R-30	R-13	R-19	R-9	R-4	R-15
	11	15	0.35	R-30	R-13	R-19	R-9	R-7	R-17
2000 IECC	9	15	0.45	R-38	R-13	R-19	R-8	R-3	R-11
	10	15	0.40	R-30	R-13	R-19	R-9	R-5	R-16
	11	15	0.35	R-30	R-13	R-21	R-10	R-9	R-18

- **Construction Cost Impacts**: The potential increase in construction cost is very slight because most houses that comply with the 1992 MEC will also comply with the 2000 IECC. If a house design barely complies with the 1992 MEC, it may fail to comply with the 2000 IECC. In this case, numerous options exist to make the slight improvement needed to comply with the 2000 IECC. For example, a 2% increase in furnace efficiency (AFUE) or a 0.04 improvement in the U-factor of the windows should be sufficient. We would expect construction cost increases related to this issue to be minor–generally zero, but no more than about $100 at most.

- **Energy Consumption Impacts**: If there is a slight improvement in the energy efficiency of the envelope as a result of the change in wall heat loss/gain calculations, a modest amount of energy can be saved.

3.2 Protective Covering for Exposed Foundation Insulation

The 2000 IECC requires that above-grade exposed foundation insulation have a protective covering to protect it from damage. The covering should be “rigid, opaque, and weather resistant,” and it must cover the exposed area and extend 6 in. below grade. Many houses do not have any exterior foundation insulation but instead have interior insulation in the floor above basements or crawlspaces or on basement walls. This code requirement would not affect these houses.

- **Construction Cost Impacts**: In 1996, DFI Pultruded Composites, Inc., in Erlanger, Kentucky, was reported to sell a product called Insul-Guard for $1.07 and $2.14 per lineal ft for 12-in.-wide and 24-in.-wide panels, respectively, with quantity discounts available (*Energy Design Update* 1996). For typical houses, total costs may range from $100 to $200 for the 12-in.-wide panels. Other products and methods of protecting exposed foundation insulation are available, including vinyl or stucco-like coatings. Builders are expected to quickly find the lowest cost methods of protecting exposed foundation insulation.

- **Energy Consumption Impacts**: The protective covering potentially may lengthen the life of the insulation by preventing damage.

3.3 Insulation for Vented Crawlspaces

Insulating the walls of crawlspaces with ventilation openings is no longer an option in the IECC. If the crawlspace is ventilated, insulation on the ceiling of the crawlspace is required. The levels (R-values) of insulation have not changed in the 2000 IECC, only the options for placement of the insulation have changed. The reason for this code change is that the vents may be left open in the winter allowing cold air to flow into the crawlspace, greatly reducing the benefit of the wall insulation.

- **Construction Cost Impacts**: This requirement may increase construction costs if the builder prefers ventilated crawlspaces with wall insulation and the updated code forces the builder to insulate the ceiling instead. Insulating the crawlspace walls and not venting the crawlspace is a recommended construction method.

- **Energy Consumption Impacts**: This requirement may potentially save some energy. When crawlspaces are vented, the 1992 MEC allows the wall of the crawlspace to be insulated instead of the ceiling. The value of crawlspace wall insulation is greatly diminished if the occupants fail to close the vents during the winter.

3.4 Heat Traps on Water Heaters

The 2000 IECC requires heat traps on water heaters. A heat trap is a device or arrangement of piping that keeps the buoyant hot water from circulating through the piping distribution system because of natural convection. Most new water heaters now come equipped with heat traps as a standard feature.

- **Construction Cost Impacts**: The incremental cost is only $2 to $5 (DOE 2000).

- **Energy Consumption Impacts**: The energy savings for electric water heaters is 0.20 MBtu/yr, or $4.00/yr. The energy savings for natural gas water heaters is 0.48 MBtu/yr, or $2.81/yr. (DOE 2000).

3.5 Skylight Shaft Insulation

In the 2000 IECC, skylight shafts 12 in. or greater in depth passing through unconditioned spaces, such as attics, are required to have R-19 insulation. The 1992 MEC includes all building elements separating conditioned spaces from the exterior as part of the "building envelope." Skylight shafts fit this description; thus, the 1992 MEC technically requires that they be insulated or, if not, that the design make up for the lack of insulation elsewhere. However, because this construction element is specifically called out in the 2000 IECC with a clear requirement, skylight shafts are somewhat more likely to be insulated.

- **Construction Cost Impacts**: No substantial cost impact is expected. Most new houses will not have this construction element.

- **Energy Consumption Impacts**: This requirement may result in a modest energy savings in houses with skylight shafts.

3.6 Duct Insulation

The duct insulation R-value requirements in the 1992 MEC were changed and restructured for the 2000 IECC. In both codes, minimum duct R-values depend on the temperature difference between the air inside the ducts and the air outside the ducts at design (worst-case) conditions. In the 2000 IECC, most ducts in unconditioned spaces, such as attics, basements, and crawlspaces, need to be insulated to R-5. In the 1992 MEC, the R-value requirements vary continuously with the temperature difference inside and outside the ducts.

- **Construction Cost Impacts**: None. The duct insulation requirements have not increased and, in fact, may have decreased in many cases.

- **Energy Consumption Impacts**: No significant impacts are expected. Determining the duct insulation R-value requirements in the 1992 MEC was complicated thus compliance with these requirements was probably low, particularly when high R-values were required.

3.7 Duct Sealing

Duct-sealing provisions in the 2000 IECC apply to all supply and return ducts. The code states that duct tape is no longer permitted as a sealant, although the code text is contradictory because it allows all UL-rated tapes, which can include duct tapes. The 1992 MEC did not require sealing for ducts located inside the conditioned space or return air plenums.

- **Construction Cost Impacts**: None expected because the 1992 MEC and 2000 IECC require duct sealing.

- **Energy Consumption Impacts**: None expected.

Comment: Studies have shown that even in new homes in states that have energy efficiency codes, ducts are often poorly sealed and are quite inefficient at delivering heated and cooled air to the registers. The state of Kentucky should consider targeting improved duct sealing by training HVAC installers and increasing code enforcement, including spot-testing with a "duct blaster" and similar tests. Significant improvements in duct sealing may raise construction costs by several hundred dollars but is probably a very good investment. One study reports a $214 cost for improved duct sealing (Hammon and Modera 1996). Substantial energy savings of 10% or more from heating and cooling could result from increased emphasis on duct sealing. Improved energy efficiency in ducts is a major benefit that can result from HERS (Home Energy Rating System) ratings.

3.8 Window and Door Air Leakage

The maximum air leakage rates for windows and sliding doors has been decreased to 0.3 ft^3 per min. per ft^2 of area.

- **Construction Cost Impacts**: No significant impact. The leakage rates maintain consistency with the latest industry standard (AAMA/NWWDA 1997), so most windows probably meet this requirement.

- **Energy Consumption Impacts**: No significant impact is expected.

3.9 National Fenestration Rating Council Ratings

Fenestration products must now be rated by the National Fenestration Rating Council (NFRC) standards for thermal and solar properties, although default values for products not evaluated to the NFRC standards are provided.

- **Cost Impact**: None. Window manufacturers are not required to have their products rated; default values can be used instead. Over 80,000 window products have now been rated.

- **Energy Consumption Impacts**: The requirement for rated windows may save some energy by improving accuracy and creating a level playing field. Without the NFRC ratings, windows could readily be purported to have a better U-factor than the true U-factor, lowering energy efficiency.

3.10 Steel Stud-Framed Walls

Criteria have been added to specifically correct for increased heat loss from steel stud framing in exterior wall thermal calculations.

- **Construction Cost Impacts**: None expected. Exterior steel-framed walls are rare and the 2000 IECC criteria are not intended to change the stringency of the code.

- **Energy Consumption Impacts**: None expected.

3.11 Prescriptive Path for Additions and Window/Skylight Replacement

The 2000 IECC contains a new simple prescriptive path (Section 502.2.5) of envelope requirements for replacement windows and for additions less than 500 ft^2 with a total glazing area no greater than 40% of the addition's gross wall and roof area. Skylight replacements must have a U-factor of 0.50 or less. This new option for additions and window replacements is not intended to increase or decrease the stringency of the code, but rather provide clear and unambiguous requirements. Exactly how to comply with envelope-related code requirements for additions is less clear without this simple approach. Note that the requirements in this path are stringent for Kentucky climates: R-38 ceiling insulation, R-18 wall insulation, and U-0.40 windows.

- **Construction Cost Impacts**: No significant impact is expected. The new prescriptive criteria for additions are an extra alternative compliance path; the other compliance paths are unchanged from the 1992 MEC (unless noted elsewhere in this report). Because this change only adds an extra optional path, it arguably cannot be interpreted as increasing the stringency of the code.

- **Energy Consumption Impacts**: No significant impact is expected, although this requirement may improve energy efficiency via better code compliance and enforcement for small additions and window replacements.

3.12 Optional Prescriptive Compliance Approaches – Section 502.2.4 and Chapter 6

Chapter 6 in the 1992 MEC (Building Design by Acceptable Practice) has been integrated into Chapter 5 of the 2000 IECC (Section 5.2.2.3). A new Chapter 6 has been added to the 2000 IECC that contains a 4-page optional and standalone prescriptive compliance approach for residential buildings. This approach can be used only if the window area is less than or equal to 15% of the wall area for a single-family building, and less than or equal to 25% of the wall area for a multifamily building. A more extensive prescriptive approach that allows almost any window area percentage has been added to the IECC in Section 502.2.4.

- **Construction Cost Impacts**: None. This change in Chapter 6 is basically just structural. Because this new version of Chapter 6 simply repackages other requirements in the IECC, it is not intended to create any new or different requirements−only a simpler and more concise prescriptive approach. The prescriptive packages in Section 502.2.4 and Chapter 6 are based on implementing the criteria of IECC Table 502.2 and it's associated figures for typical construction. These packages are not intended to change the energy efficiency of the code although they were developed with conservative assumptions to ensure energy efficiency is not decreased.

- **Energy Consumption Impacts**: None expected.

3.13 Expanded Set of Rules for System Analysis Approach - Chapter 4

Chapter 4 in both the 1992 MEC and 2000 IECC permits compliance via a systems analysis approach, also known as a "performance" path. This approach allows any building design to comply with the code if the builder can show that the proposed building has sufficiently low annual energy use. Software specifically designed to simulate building energy use would normally be used to show compliance. The basic performance approach in the code has not changed since 1992; however, the expanded "ground rules" (directions on how to perform this analysis) have changed. The 2000 IECC contains fairly detailed directions on what assumptions should be made in the analysis whereas the 1992 MEC does not provide these detailed directions. For example, the 2000 IECC specifies that in the input to the simulation software, the thermostat should be set at 68°F for heating with a nighttime setback to 63°F, and set to 78°F for cooling. The 1992 MEC does not provide any guidance on thermostat operation.

- **Construction Cost Impacts**: Small; usually none. These expanded rules were intended to provide clarification on how to perform the analysis to estimate annual energy use, not to make the code more or less stringent. However, the 2000 IECC has new, lower wall and fenestration U-values for the "Standard Design" that may effectively make the code more stringent for many residential buildings if the performance path is used. Because the Chapter 4 approach is only one of several options in terms of compliance paths, this change does not necessarily mean higher construction costs. In fact, the Chapter 4 compliance approach may be infrequently used because it is the most complicated approach (although user-friendly software can make this approach much more attractive).

- **Energy Consumption Impacts**: This change may improve energy efficiency somewhat when the performance path (the Chapter 4 methodology) is used.

3.14 Solar Heat Gain Coefficient Requirement of 0.4 in Warm Climates

Glazed fenestration products (windows, skylights, doors with windows) are limited to a maximum 0.4 solar heat gain coefficient (SHGC) in climates with less than 3,500 heating degree-days. From a national perspective, this requirement is perhaps the most notable residential requirement in the 2000 IECC that is not in the 1992 MEC. However, this requirement does not affect Kentucky because Kentucky does not have locations with heating degree-days this low.

- **Construction Cost Impacts**: None.

- **Energy Consumption Impacts**: None.

4.0 References

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