PNNL-13813

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

R.G. Lucas

March 2002

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

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Pacific Northwest National Laboratory
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Summary

The state of New Mexico currently requires that new one and two family dwellings and other residential low-rise (three story or less) buildings comply with the Council of American Building Officials' (CABO) *1992 Model Energy Code* (MEC) (CABO 1992). CABO has 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) with the 2001 Supplement (ICC 2001). New Mexico's Energy, Minerals and Natural Resources Department requested that the U.S. Department of Energy (DOE) compare the 1992 MEC with the 2000 IECC to estimate impacts from updating New Mexico'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 energy consumption and construction costs.

Despite the change in the code's name and appearance, most of the requirements for residential buildings in the 1992 MEC and 2000 IECC are the same. Based on our assessment, the most significant differences between the 1992 MEC and the 2000 IECC for residential buildings that would impact energy consumption or construction costs in New Mexico are as follows:

- The wall thermal requirements for multifamily buildings (low-rise) 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.

- Glazed fenestration is required to have a solar heat gain coefficient (SHGC) of 0.40 or lower in southern New Mexico.

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 consumption or construction costs for most residential buildings. The 2000 IECC is much larger than 1992 MEC and has been restructured considerably from the MEC. Other code differences affecting construction details in New Mexico include the following:

- Vented crawlspaces must have insulation in the floor above the crawlspace because insulation in the crawlspace wall is no longer credited when the crawl space is vented.

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

- The IECC has simple, clear, and stringent requirements for additions and window replacements.

The impacts on energy consumption and construction costs 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 without any improvements. 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 where insulation is exposed.)
- improved sealing for recessed light fixtures (approximately $50, depending on the number of fixtures).

For Albuquerque, all of the changes to the 2000 IECC should be cost-effective with a time to positive cash flow of 4 years or less (a simple payback of 8 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.

The state of New Mexico also requested that we develop trade-offs that would allow reductions in energy efficiency of certain building characteristics if evaporative cooling were used and analyze their impact. Evaporative cooling uses less energy than standard refrigerated air conditioning and therefore staff in New Mexico want to explore the possibilities of incentives to encourage its use. We explored several possible trade-offs. These trade-offs should not apply to parts of the state that are colder than Albuquerque (e.g., Santa Fe) because energy efficiency related to heating should not be compromised in exchange for lower cooling costs in these locations.

Contents

1.0 Introduction

The state of New Mexico currently requires that new residential one and two family dwellings and other residential buildings three stories or less comply with the Council of American Building Officials' (CABO) *1992 Model Energy Code* (MEC) (CABO 1992). CABO has 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) with the 2001 Supplement (ICC 2001). New Mexico's Energy, Minerals and Natural Resources Department requested that the U.S. Department of Energy (DOE) compare the 1992 MEC with the 2000 IECC to estimate impacts from updating New Mexico'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 energy consumption and construction 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 energy consumption and construction costs. Section 4.0 covers possible credit for evaporative cooling. Section 5.0 contains a list of publications cited in this report. The Appendix contains the RESFEN and Energy-10 output reports used to estimate the energy impacts of the measures examined in this report.

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 one and two family dwellings and other residential low-rise buildings in New Mexico–the thermal wall requirements for low-rise multifamily buildings,[a] the provisions for recessed lighting fixtures to limit heat loss/gain by air infiltration, and the solar heat gain coefficient (SHGC) requirement of 0.4 in warm climates.

2.1 Thermal Wall Requirements for Low-Rise Multifamily Buildings

The component heat loss and heat gain (U_o) requirements for low-rise multifamily residences changed dramatically between 1992 and 2000 (specifically in 1993).

The 2000 IECC has considerably more-stringent requirements for exterior walls (including windows and doors) in low-rise 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 (HDD) that encompass New Mexico climates (note that Albuquerque has about 4400 HDD).

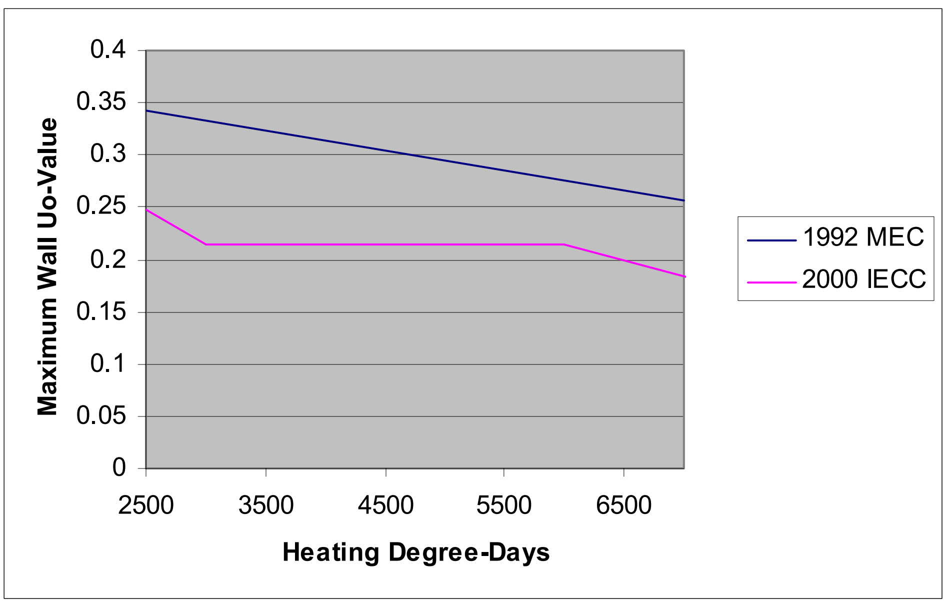

Figure 2.1. Thermal Wall Requirements for Multifamily Residences

(a) The IECC defines multifamily buildings three stories or less above grade containing three or more dwelling units (usually apartments or condominiums) as residential buildings and high-rise multifamily buildings as commercial buildings.

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 low-rise multifamily buildings (see Table 2.1). The requirements in Table 2.1 are for a building with a window area equal to 25% of the gross wall area.[(b)]

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 if there were no energy code in New Mexico, particularly in warmer parts of the state. Even though some of the foundation requirements selected for the 1992 MEC*check*™ packages are more stringent than those in the 2000 IECC packages, the 2000 IECC is considerably more stringent overall and the foundation insulation requirements in the code have not decreased. The envelope requirements for low-rise multifamily buildings in the 2000 IECC are still typically less stringent than the IECC's requirements for single-family buildings. Only about 10% of all dwelling units in new housing construction in New Mexico are multifamily, 90% are single-family houses.

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

Code	Climate Zone	Major City	Window U-Factor	Ceiling	Wall	Floor	Basement Wall	Slab Perimeter	Crawlspace Wall
1992 MEC	7	Las Cruces	0.75	R-13	R-11	R-11	R-4	R-0	R-4
	9	Albuquerque	0.75	R-19	R-11	R-13	R-6	R-0	R-6
	13	Santa Fe	0.70	R-26	R-13	R-19	R-10	R-8	R-18
2000 IECC	7	Las Cruces	0.55	R-30	R-13	R-11	R-5	R-0	R-5
	9	Albuquerque	0.54	R-30	R-13	R-11	R-5	R-0	R-5
	13	Santa Fe	0.51	R-30	R-13	R-19	R-5	R-0	R-6

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, a design having more-stringent window U-factors will

(a) MEC*check*™ is a family of products designed to help streamline the code 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.

(b) 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.

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. 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 (Sustainable Buildings Industry Council 1998) to estimate the energy savings from improved windows in a multifamily building in Albuquerque. 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 $0.60/therm and electricity at 9.0 cents/kWh were assumed. The window U-factor was assumed to improve from 0.75 to 0.54 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 $198 per year for the 6-unit building, or about $33 per dwelling unit. With an estimated incremental construction cost increase of $268 per unit, this improvement has a time to positive cash flow of less than 4 years (or a simple payback of about 8 years). This assumes a mortgage with a 7% interest rate and a 10% down payment.

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 ("can" type) lighting fixtures in the outer envelope of the building 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 improved 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 New Mexico. Therefore, investing in improved recessed light fixture sealing can pay off in energy savings in about one year.

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 New Mexico, although we suspect these types of fixtures are typically not used.

2.3 Solar Heat Gain Coefficient Requirement of 0.4 in Warm Climates

The IECC limits glazed fenestration products (windows, skylights, doors with windows) to a maximum SHGC of 0.4 in climates with less than 3500 HDD— southern New Mexico, including cities such as Las Cruces, Roswell, and Alamogordo. The intent of this requirement is to reduce air conditioning energy use (and peak summer loads) by blocking much of the sun's heat from coming through windows.

From the National Fenestration Ratings Council's Products Directory (http://www.nfrc.org/nfrcpd.html) the average aluminum window SHGC is about 0.55, the average vinyl window SHGC is about 0.50, and the average wood window SHGC is about 0.40. If the window has a low-emissivity coating, the SHGC will be lower and will likely be below the 0.40 requirement. In fact, the use of low-emissivity glass is expected to be the most common way to meet the 0.40 SHGC requirement.

The impacts of the 0.40 SHGC requirement in Las Cruces were examined using the RESFEN 3.1 software (the closest available city in RESFEN, El Paso, was used). RESFEN is specifically designed to analyze heating and cooling energy use of windows in residential buildings (Mitchell et al. 1999). We selected a 1600 ft^2 gas-heated ranch house with air conditioning (not an evaporative cooler); 240 ft^2 of windows equally distributed north, south, east, and west; and the "typical" shading option for the analysis. Lowering the SHGC from 0.55 to 0.40 saved a modest $16 a year in total energy costs. The additional cost for low-E or tinted glass is expected to be in the neighborhood of $200 to $300 for this example house. The reduced cooling loads may allow the air conditioner to be downsized, offsetting some or maybe even all of the increased cost of the windows. The lower SHGC will have the benefit of reducing summer peak electricity loads. The economics will be less favorable if an evaporative cooler is used.

3.0 Minor Differences Between 1992 MEC and the 2000 IECC

The 1992 MEC and 2000 IECC have numerous minor differences that will 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.

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 one and two family detached residences have not changed between 1992 and 2000 for most New Mexico locations (roof/ceiling U_o-values have become slightly more stringent for warm New Mexico locations with less than 3900 HDD). 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 recommended 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.

For example, in a 1600-ft^2 ranch house in Albuquerque, the MEC*check*™ software reports that a design that barely complies with the 1992 MEC would need an improvement of U-0.04 in the window U-factors to comply with the 2000 IECC. Alternately, the natural gas furnace efficiency could be improved by 2% to make the improvement necessary for the 2000 IECC for a single-family house.

- **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. We would expect construction cost increases related to this issue to be minor–generally zero, but no more than about $100.

- **Energy Consumption Impacts**: If the energy efficiency of the envelope is slightly improved 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 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 covering will protect the insulation from deterioration due to object impact and chemical deterioration from sun, wind, and water, which decreases its insulating ability.

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. We believe that ventilated crawlspaces with insulation on the walls, or for that matter any type of crawlspaces, are uncommon in new construction in New Mexico.

- **Construction Cost Impacts**: This requirement will increase construction costs where ventilated crawlspaces with wall insulation are used and the updated code option of insulating the ceiling is used instead. Insulating the crawlspace walls and not venting the crawlspace is a recommended construction method and would not increase construction costs.

- **Energy Consumption Impacts**: This requirement will 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/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. Those that do should already be insulating these shafts.

- **Energy Consumption Impacts**: This requirement may result in a modest energy savings in houses with skylight shafts where the practice has been to leave these shafts uninsulated.

3.6 Duct Insulation

The duct insulation R-value requirements in the 1992 MEC were changed and restructured for the 2000 IECC. In both the 1992 MEC and the 2000 IECC, 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, R-3.3 insulation is required where there is a temperature difference for conditioned air within the ducts to the air surrounding the ducts is between 15°F and 40°F, or at higher differences on run outs of 10 feet or less in length, to terminal devices. R-5.0 insulation is required where the temperature difference is greater than 40°F. Additionally, ducts outside the building are generally required to have R-6.5. Insulation is not required for ducts within the conditioned building in either the 1992 MEC or the 2000 IECC.

The 1992 MEC requires a duct insulation R-value equal to the temperature difference across the ducts divided by 15. For example, if the furnace heats air to 120°F and the winter design temperature is 15°F, the temperature difference is 105°F and R-7 insulation is required.

There is anecdotal information from New Mexico officials that duct insulation is not identified on building plans, indicating the current requirements are not actively enforced. The insulation requirements in the 2000 IECC are somewhat simpler than those in the 1992 MEC, making it easier for builders to know what is required, and for code officials to enforce the requirement.

- **Construction Cost Impacts**: No cost increase is expected by adopting the 2000 IECC. The duct insulation requirements have not increased and in fact may decrease in many cases.

- **Energy Consumption Impacts**: No substantial impact is expected by adopting the 2000 IECC.

3.7 Duct Sealing

Duct-sealing provisions in the 2000 IECC apply to all supply and return air 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**: No substantial impact.

- **Energy Consumption Impacts**: Potentially some improvement because some types of duct tapes are disallowed. However, UL 181B-FX duct tapes are still allowed, and these tapes have been shown to not perform very well (Sherman et al. 2000).

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. Duct sealing can be improved 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. 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. Assuming these costs and savings, the time to positive cash flow would be as little as a year or two.

3.8 Window and Door Air Leakage

The maximum air leakage rate for manufactured windows and sliding-glass doors has been decreased to from between 0.34 and 0.37 ft^3 per min. per ft^2 of area to 0.3 ft^3 per min. per ft^2 of area. The requirement applies to the unit as it comes from the factory, and not to potential infiltration around the frame of the unit when actually installed.

- **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. However the requirement lowers allowable rates of air infiltration compared to the 1992 MEC. Since lower air infiltration decreases heating and cooling energy consumption, this change should result in a minor reduction in energy consumption.

3.9 National Fenestration Rating Council Ratings

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

- **Construction Cost Impacts**: 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 should save some energy by improving the accuracy of U-factor ratings, reducing intentional and unintentional over statements of superior U-factor performance of fenestration products, and increasing compliance, awareness, and enforcement through product labeling. Without the NFRC ratings, windows have been purported to have a better U-factor than the true U-factor, lowering energy efficiency.

3.10 Steel Stud-Framed Walls

Tables of steel-framed wall equivalent insulation R-values have been added to specifically correct for increased heat loss from steel stud framing in exterior wall thermal calculations, as compared to wood framed walls. The U-factor requirements have not been changed. Because metal conducts heat more rapidly than wood, metal stud framing results in a less thermally efficient wall compared to wood framing. Metal framed walls must increase the wall cavity insulation levels or utilize insulated sheathing to meet the equivalent efficiency of a wood framed wall. For example, in New Mexico at 15 percent glazing, the prescriptive requirements for a wood stud wall is required to have either R-13, R-16 or R-18 insulation depending on the number of heating degree days where the home is built. The equivalent requirements for a metal stud wall would include R-11 with R-5 sheathing; R-11 with R-8 sheathing; and R-11 with R-9 sheathing, respectively.

- **Construction Cost Impacts**: None expected. Exterior steel stud-framed walls are rare and the 2000 IECC U-value criteria for exterior walls have not been changed.

- **Energy Consumption Impacts**: No significant impact is expected. However, equivalent insulation R-values will result in improved energy efficiency in buildings with metal framing where the thermal performance of metal framed walls have been calculated inaccurately when evaluating component performance. Enforcement and compliance will be made easier.

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. Without this simple approach, understanding exactly how to comply with envelope-related code requirements for additions is less clear. Note that the requirements in this path are stringent for most New Mexico climates: R-38 ceiling insulation, R-18 wall insulation, and U-0.40 windows in Albuquerque.

- **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).

- **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

Chapter 6 in the 1992 MEC entitled, "Building Design by Acceptable Practice," has been integrated into Chapter 5 of the 2000 IECC (Section 502.2.3). 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**: No substantial impacts. The new Section 502.2.4 and Chapter 6 add 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 its 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. The new tables add no new requirements and are not mandatory but they are a simpler option. To the extent that the other methods have a greater potential for misinterpretation and miscalculation, the availability of the prescriptive specification tables will help to assure that floors, ceilings, walls, and windows are properly designed and meet energy efficiency requirements under the code, thus promoting energy efficiency.

3.13 Expanded Set of Rules for System Analysis Approach

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 more detailed directions on what assumptions must be made in the analysis whereas the 1992 MEC does not provide these detailed directions. They limit the users' ability to manipulate many of the required input values. The directions specify assumptions for design parameters such as air infiltration, distribution system efficiency, window shading and orientation, internal heat gains, and domestic hot water consumption. 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 what to assume for thermostat operation.

The 2000 IECC has wall and fenestration U-factor assumptions for the “standard design” (Section 402.1.1) that did not exist in the 1992 MEC. These specifications were developed with conservative assumptions to ensure energy efficiency is not decreased.

- **Construction Cost Impacts**: None expected. The expanded rules only provide clarification on how to perform the analysis to estimate annual energy use.

- **Energy Consumption Impacts**: This change may improve energy efficiency somewhat when the performance path (the Chapter 4 methodology) is used. This is because they limit the users' ability to manipulate many of the required input values, thereby preventing artificial reductions in the stringency of the code. As an example, window area and orientation are now specifically addressed. The 2000 IECC stipulates that the window area of the standard design building must equal the area of the proposed building, with the area equally distributed on the north, south, east, and west exposures. Since the 1992 MEC had no such stipulations, a Chapter 4 user could assume that the windows in the standard design could be oriented primarily on the north side, a high energy use orientation. A large energy "credit" towards compliance could then be obtained simply by placing the windows in the proposed orientation; placing most windows on the south side results in a low energy use configuration. Thus the Chapter 4 changes serve to improve the energy efficiency of the 2000 code by ensuring that reasonable assumptions for the standard design and proposed buildings are made before performing the energy analyses, and an artificially high "target" for energy consumption in the standard design does not appear.

4.0 Evaporative Coolers

The state of New Mexico has asked PNNL to analyze and propose an energy efficiency credit towards IECC compliance for evaporative cooling systems. Evaporative coolers work by drawing outside air through pads soaked with water, where some of the water evaporates─a thermodynamic process that cools the air. Evaporative coolers have long been popular in New Mexico residences because of their low cost and low energy usage. The climate in New Mexico is well suited for evaporative cooling because of the low humidity and not-too-severe temperatures in summer. Several basic types of evaporative cooling systems are available; the simplest and cheapest is the "direct" system that is by far most common in residential applications.

Refrigerated air-conditioning systems are gaining in popularity in New Mexico homes. Notably, Artistic Homes, a major New Mexico builder, is now using refrigerated air conditioning (referred to here as "standard" air conditioners). Standard air conditioners have some comfort-related advantages that can be appealing to homebuyers. They can provide air as cold as the occupants' desire without a higher humidity level, regardless of how hot and humid it is outside. Standard air conditioners have much lower air flow rates, and windows do not need to be open to exhaust air, as is the case with evaporative coolers.

The state of New Mexico is interested in permitting a trade-off that would credit the use of evaporative coolers by allowing a reduction in the energy efficiency of other aspects of the building, such as increased window area and/or reduced wall insulation. The idea here is that evaporative coolers use much less energy than standard air conditioners, so this compliance option would provide an incentive to motivate the homebuyer to use evaporative cooling instead of a standard air conditioner. Assuming the estimated energy savings from the evaporative cooler is greater than the energy loss from the trade-offs that are permitted, this option in theory would lead to a net improvement in energy efficiency for the new house overall.

The reason for adding this trade-off to the state code is to reduce the use of standard air conditioning. The potential problem with this credit is that many new New Mexico residences currently use evaporative cooling without any incentive from the state simply because they cost less to own and operate. The trade-off credit will have to be allowed for all new residences, including homes and apartments where a standard air conditioner was never seriously considered by the builder and/or homebuyer and the use of the evaporative cooler was always the plan. For all residential buildings where evaporative cooling was intended all along, the trade-off credit will simply allow a reduction in energy efficiency below whatever the IECC requires without any true compensating improvement in the cooling system. A second concern with crediting evaporative coolers is that the homeowner may decide to switch out the evaporative cooler to a standard air conditioner in the future (e.g., in the first 10 years after the house is built). We advise New Mexico to consider these issues when assessing credits for evaporative cooling.

To assign an energy efficiency credit for evaporative cooling, the energy savings relative to standard air conditioning is needed. A variety of research results and estimates on the energy use of evaporative cooling exist. Data from a monitored house in Phoenix indicated a direct evaporative cooling system used about one-third of the energy of a standard air conditioner (Huang and Wu 1992). The University of Arizona (Karpiscak and Marion 1994) also estimates an evaporative cooler uses about one-third of the energy of a standard air conditioner. Another source reports that evaporative coolers use 20% to 40% (Foster 1998) or 10% to 25% (*Home Energy* 1996) of the energy of a standard air conditioner. The exact savings of an evaporative cooler compared to a standard air conditioner can vary based on several factors. These factors include the design and efficiency of the specific evaporative cooler and the specific air conditioner it is compared to; the climate; and how the occupants use the equipment, particularly the evaporative cooler. For this analysis, we will simply assume evaporative coolers use one-third of the energy of a standard air conditioner. Note that evaporative coolers should have a similar reduction in summer peak electricity loads.

From an economics standpoint, evaporative coolers should have a lower first cost and result in lower energy costs than standard air conditioners. However, evaporative coolers will result in higher water costs because of increased water usage and may result in higher maintenance costs because they require regular maintenance, including being shut off during winter months. The University of Arizona (Karpiscak et al. 1994) estimates the average evaporative cooler system costs about $700. *Home Energy* Magazine (1996) reports costs from $400 to $800. The cost of a standard air conditioner will be higher.

Evaporative coolers use a substantial amount of water. While the expected energy savings from evaporative cooling is an environmental benefit, the increased water usage is an undesirable feature from an environmental perspective. We will not attempt to judge the importance of water usage and the scope of the IECC does not include water conservation. However, water conservation is an issue that should be considered when assessing credits for evaporative cooling. The state of New Mexico reports an evaporative cooler in Albuquerque may use 10,758 gallons of water a year (Wilson 1996). A study of 46 houses by the city of Phoenix found that average daily water use by evaporative coolers was 66 gallons per day (Karpiscak et al. 1994). Evaporative coolers with no system to bleed off water used an average of 3.5 gallons per hour of run time, while coolers that reduced the salt buildup by constantly dumping and replacing part of the water while the pump ran used an average of 10.5 gallons per hour of run time. Albuquerque water officials report evaporative coolers use about 4,000 gallons (per summer). The number jumps to 5,700 gallons if a dump pump is used to empty the reservoir at timed intervals, and 13,000 gallons if a bleed-off tube is used for constant introduction of fresh water (*Albuquerque Journal* 2001).

If the state of New Mexico decides that evaporative cooling will receive a trade-off credit after considering all of the above issues, we have developed recommendations for appropriate trade-offs. We used the Energy-10 computer simulation tool to develop these recommendations (Sustainable Buildings Industry Council 1998). In our analysis, we assumed a 1600-ft^2 gas-heated ranch house in Albuquerque with the cost of air conditioning at 9 cents/kWh and gas furnace heating at $0.60/therm. The house was assumed to have 240 ft^2 of windows (15% of the floor area) equally distributed north, south, east, and west with no exterior shading and a 0.40 SHGC. Energy-10 reported the standard air conditioner would use 3465 kWh per cooling season, or $312 of electricity. Assuming an evaporative cooler uses one-third of the energy used by the standard air conditioner, a savings of $208 in electricity would be possible.

A logical trade-off would be to allow houses with higher window areas (as a percentage of wall area) to comply without highly stringent requirements if an evaporative cooler is used. The IECC requires that exterior walls (including windows and doors) have an average heat loss rate at or below a maximum rate. Because windows have a higher heat loss rate than insulated walls, the code becomes more difficult to comply with if the window area becomes a higher proportion of the wall area. This situation can be seen in the prescriptive packages in Section 502.2.4 of the 2000 IECC for 4,000-4,499 HDD (Albuquerque). A typical house with a window area equal to 15% of the gross exterior wall area is required to have U-0.45 windows and R-13 wall insulation. However, a house with a higher window area of 25% is required to have U-0.37 windows and R-19 wall insulation.

We used Energy-10 to examine whether the savings from an evaporative cooler would merit allowing houses with higher window area percentages to meet the IECC prescriptive requirements at 15% window area. The window area of the 1600-ft^2 house was increased from 240 ft^2 to 400 ft^2 with no other changes (other than the commensurate decrease in the insulated wall area). The heating costs actually decreased slightly because the higher solar gains more than made up for the conductive heat loss from the increased window area. The higher window area increases cooling energy use, from 3465 kWh to 4177 kWh, or an additional $69 a year in energy costs (including fan energy use). Assuming the homebuilder and/or owner were swayed from using standard air conditioning, the switch to evaporative cooling easily compensates for this increase. Therefore, a reasonable trade-off might be to allow residences to have a higher window area if they meet the IECC's 15% window-to-wall area package and if an evaporative cooler is used. For example, a 30% window-to-wall area limit for this trade-off might be reasonable. Note again that if a builder intends to use an evaporative cooler regardless of whatever trade-offs are in the energy code, these trade-offs will simply allow a decrease in energy efficiency below that required in the IECC.

Another possible trade-off that may be attractive to builders is higher window U-factor requirements. As mentioned above, the IECC's 15% window-to-wall area package requires U-0.45 windows, which would rule out most aluminum windows. Assuming a double-glazed aluminum window with a U-factor of 0.70, Energy-10 predicts an annual energy cost increase of $78 in Albuquerque if there is 240 ft^2 of window area. Again, the $208 savings from the evaporative cooler would appear to compensate for this increase. If an option that allows double aluminum windows is desired, some other restrictions should apply. For example, there could be a 15% window-to-floor area limit. Additionally, a U-factor requirement of 0.60 or 0.65 could be used, which would eliminate the least energy-efficient aluminum windows but permit more efficient aluminum windows.

Allowing trade-offs for any type of double-glazed aluminum window or higher window area in climates colder than Albuquerque (e.g., Santa Fe) is not recommended. Unimproved double aluminum windows perform poorly in the winter in cold climates. Houses with high window areas will have high energy bills unless incorporated in a good passive solar design. Because the potential energy savings from evaporative coolers in climates like Santa Fe are small due to the mild summers, weakening code requirements related to controlling heating costs is not justified.

An additional trade-off idea is to allow reduced wall insulation. Typically, a house can comply with R-13 wall insulation under the IECC now, although it may be difficult to comply with less than R-19 in colder parts of the state. Because walls with 2x4 framing and R-13 insulation are probably the most commonly used insulation method in New Mexico, we do not recommend trade-offs to lower wall insulation levels. Likewise, we do not recommend trade-offs that lower wall insulation from R-19 where required in cold locations because the limited savings from evaporative coolers in these locations does not merit this trade-off.

A final trade-off concept for evaporative cooling applies only to southern New Mexico locations (e.g., Las Cruces) where the IECC has the maximum 0.40 SHGC requirement for windows. When an evaporative cooler is used in these locations, the advantages of the low SHGC in reducing cooling costs are greatly diminished. Therefore, it should be reasonable to allow any SHGC if an evaporative cooler is used.

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Attachments

Energy-10 and RESFEN output reports
(attached to paper version of report)