# DRAFT MINUTES
# MHCC MEETING

August 9, 2016

Via Teleconference

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# MANUFACTURED HOUSING CONSENSUS COMMITTEE (MHCC) MEETING

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## Call to Order

MHCC Chairman, Richard Weinert, called the meeting to order at 10:15 a.m. (EDT). Public comments would be allowed only after the committee has had a chance to discuss each topic, if time permits.

## Roll Call

Kevin Kauffman, Program Manager of the Administering Organization (AO) Home Innovation Research Labs, called the roll and announced that a quorum was present. Guests were asked to introduce themselves. See Appendix A for a list of meeting participants. Ishbel Dickens, Mark Mazz, and Garold Miller were unable to attend the meeting.

## Opening Remarks

Pamela Beck Danner, Administrator of the Office of Manufactured Housing Programs (DFO), welcomed the MHCC committee members and introduced Loretta Dibble, a manufactured homeowner, as a new MHCC member in the User category replacing Charles Onsum who resigned.

DFO Danner noted that this is a meeting of the Manufactured Housing Consensus Committee (MHCC) and that the meeting notice was published in the *Federal Register* dated July 25, 2016. DFO Danner noted that purpose of the meeting was to review and provide comments to the DOE Notice of Proposed Rule (NOPR) published in the *Federal Register*, Vol. 81, No. 117, June 17, 2016 (see Appendix B). It was noted that comments were due to DOE regarding the environmental assessment and the Proposed Rule by August 15, 2016 and August 16, 2016, respectively. Kevin Kauffman will summarize all comments and submit them to DOE on behalf of the MHCC.

Mr. Kauffman provided a brief summary of meeting procedures to ensure compliance with MHCC Bylaws and that Robert's Rules of Order were followed. Due to the need to respond expeditiously, there will not be a letter ballot following the actions of the meeting.

DFO Danner informed the meeting participants that all documents pertaining to the meeting that were uploaded to Dropbox are available on the hud.gov/mhs website.

## Approval of the Minutes

**MHCC Motion to approve the January 19-21, 2016 MHCC Committee meeting minutes.**

Maker: Steven Anderson Second: Debra Blake

Meeting Vote: Unanimously Approved.

# Discussion – Proposed DOE Rule on Manufactured Housing Energy Standards

## Richard Mendlen Comments Regarding the July 13, 2016 DOE Presentation

Richard Mendlen, Senior Structural Engineer, Office of Manufactured Housing Programs from HUD, noted the list of documents provided for today's discussion:

1. The *Federal Register* notice of proposed rulemaking (Appendix B).
2. The slides presented at DOE's public hearing on July 13, 2016 – which we will be using and referring to in today's presentation (Appendix C).
3. The list of more than 30 issues on which DOE seeks public comment – some of which we will be discussing today (Appendix D).
4. HUD's list of key issues on the Proposed Rule (Appendix E); and
5. DOE's Environmental Impact Assessment (Appendix F)

Mr. Mendlen began his review of the July 13, 2016 presentation and covered the following slides:

- **The Energy Independence and Security Act**

  *(Slide 10)*
  Under The Energy Independence and Security Act of 2007 or EISA, DOE was directed to establish energy efficiency standards for manufactured housing within four years of the date of enactment of EISA.

  These energy standards were to be based on the most recent version of the International Energy Conservation Code (IECC). However, due to unanticipated delays, DOE selected the 2015 code edition as the basis for its standards. The IECC was to be used unless DOE found those requirements not to be cost effective. The Act also required DOE to consider the impact of the IECC code on the purchase price of manufactured housing and on total life-cycle construction costs.

  *(Slide 14)*
  Although not mandatory, EISA also allowed DOE in developing its standards to consider:

  1. Design and factory construction techniques used to produce manufactured homes;
  2. Whether the standards should be based on HUD's 3 climate zones rather than the 8 climate zones in the IECC; and
  3. Allow alternative practices that would result in net energy consumption equal to or less than the specified standards

  In 2014 DOE elected to pursue the development of the standards through negotiated rulemaking and established a working group under its Appliance Standards and Rulemaking Federal Advisory Committee (ASHRAC) for that purpose, which finalized its consensus recommendations to DOE on December 1, 2014.

  *(Slide 11)*
  Under the EISA legislation, DOE was directed to consult with HUD who in turn could seek further counsel from its Manufactured Housing Consensus Committee (MHCC). This slide highlights, from DOE's perspective, its view of the required HUD consultation that was envisioned under the Act.

  From HUD's perspective, the primary consultation with DOE occurred when we were able to offer our recommendations and comments as part of the lengthy interagency review coordinated by OMB's Office of Information and Regulatory Affairs (OIRA).

This interagency review finally culminated in the notice of proposed rulemaking on DOE's *Energy Conservation Standards for Manufactured Housing*, published in the *Federal Register* on June 17, 2016, and the public hearing that was held in Washington DC on July 13, 2016.

Mr. Mendlen's review of the materials on DOE's proposed *Conservation Energy Standards for Manufactured Housing*, focused on the more significant issues that were discussed during the recent public hearing and the issues of concern and recommendations previously identified to DOE by HUD during the aforementioned interagency review. Mr. Mendlen reviewed the following with the MHCC:

- **Affordability**

  *(Slides 43 and 45)*

- **Reduced Future Availability of Manufactured Housing**

  *(Slides 48, 49, and 51)*

- **Enforcement and Regulatory Compliance**
- **Impact on Small Manufacturers**
- **Technical Considerations**

***Thermal Zone Map***

*(Slide 16)*
This slide depicts the four (4) climate zones and map recommended by DOE in the Proposed Rule. The four (4) zone map differs from the three (3) zone map in the HUD standards in two important ways:

*(Slide 17)*

1. First, in the DOE proposed map, certain states have been split or bifurcated by counties; and
2. Second, certain states have been placed in more restrictive climate zones than currently required by the HUD standards.

***Thermal Envelope Requirements and Solar Glazing Requirements***

*(Slides 19, 20, 38, and 21)*

***Potential Health Effects Resulting from Proposed Measures to Increase Home Tightness***

*(Slide 67), (Slides 24 and 25)*

These slides depict the detailed and enhanced requirements DOE proposes for tightening of the thermal envelope and would include:

1. Complete sealing of all joints, seams, and penetrations of the thermal envelope without exception;
2. Sealing of all gaps, wiring, recessed lighting fixtures, and light tubes;
3. Sealing of rough openings of windows, doors, and skylights with caulk, foam, or other suitable materials;
4. Sealing of duct system register boots that penetrate the thermal envelope; and
5. Establish criteria for the installation of air barriers for walls, ceilings, and floors.

*(Slide 26)*
In addition, air supply ducts would also be required to be sealed to limit air leakage to four (4) cubic feet per minute per 100 square feet of conditioned floor area.

DOE's environmental impact assessment also raised questions regarding the impact of the overall reduction in air leakage which could result in increased time averaged concentrations and exposure levels for manufactured home occupants to indoor pollutants such as CO, $CO_2$, $NO_2$, radon, formaldehyde, and VOCs.

DOE requested information in its environmental assessment of the potential impacts of its Proposed Rule on indoor air quality and occupant health for manufactured homes on:

1. The relationship of indoor air quality to natural air infiltration and mechanical ventilation in manufactured homes;
2. The adequacy of HUD's whole ventilation requirements to be protective of human health; and
3. Any data on unsafe levels of indoor pollutants in manufactured homes and other residential buildings.

HUD remains concerned over the potential impact on occupant health that may result from the additional sealing and reductions in the air circulation and leakage being proposed by DOE, without corresponding increases in mechanical ventilation requirements to dilute the effects of indoor air pollutants.

- **Conflicts or Differences between the DOE Proposed Rule and HUD Standards.**

One of the asks in the DOE Proposed Rule was to identify any conflicts between its proposals and the HUD standards. The review of the Proposed Rule has identified the following conflicts and differences between the DOE proposed energy conservation standards and the HUD standards:

*(Slide 39)*
1. Under the DOE performance path proposal, there are four (4) climate zones that would be delineated by home size throughout and by county boundaries in climate zones 1 and 2 with solar glazing provisions required in climate zones 1, 2, and 3. The HUD standards have three (3) climate zones with some states located in different zones than in the DOE Proposed Rule; and HUD does not currently require windows in any zone to meet solar glazing provisions.

   The DOE proposal would require $U_0$ values in climate zone 1 and 2 of .087 for single section homes and .084 for multiple section homes, while the HUD standards currently require a $U_0$ value of 0.116 for all homes in climate zone 1. Similarly, in climate zone 3, DOE proposes a $U_0$ value of .070 for single section homes and .068 for multiple section homes, while HUD requires .096 for all homes in climate zone 2. Finally, in DOE climate zone 4, DOE would require a $U_0$ value of .059 for single section units and .056 for multiple section units, while HUD currently requires a $U_0$ of .079 for all homes in climate zone 3.

   In addition, the DOE proposal would require a solar glazing value of 0.25 in climate zone 1 and a solar glazing value of 0.33 for climate zones 2 and 3. HUD has no solar glazing requirements in the current standards. In addition, higher solar glazing values of 0.40 to 0.50 are permitted under the current ENERGY STAR program.

*(Slides 20 and 23)*
2. Under the DOE proposal, specific requirements would be established for the installation of insulation, including provisions for uniform density or thickness of ceiling insulation and requirements for

5-1/2-inch-high heel trusses for its prescriptive path option and the seeming impractical proposed requirement for the floor insulation to be in contact with the floor decking. There are no corresponding requirements in the HUD standards.

*(Slides 24 and 25)*

3. Under the DOE proposal, enhanced provisions would be established for sealing all seams, joints, and penetrations of the building thermal envelope against air leakage—the HUD standards do contain certain similar, but less restrictive, requirements to those proposed by DOE.

*(Slide 26)*

4. Under the DOE rule, air supply ducts would also be required to be sealed to limit air leakage to four (4) cubic feet per minute per 100 square feet of conditioned floor area. The HUD standards require supply air ducts to be substantially airtight as determined by the static pressure in the duct system being not less than 80% of the pressure measured in the furnace casing.

*(Slide 19)*

5. Under the DOE proposal, default values would be established for fenestration and door u factors, solar heat gain coefficients and skylights. By contrast, the HUD standards allow the use of the ASHRAE handbook of fundamentals or determination of glazing U values by using AAMA or NFRC test methods (24 CFR § 3280.508).

6. Under the DOE proposal, there are no requirements for providing and completing a heating and cooling certificate as currently required by the 24 CFR § 3280.510 and § 3280.511 of the HUD standards.

*(Slide 29)*

7. Under the DOE proposal, all heating and cooling equipment must be sized in accordance with ACCA Manuals S and J. The HUD standards do not currently reference these methods for determining heating and cooling equipment sizing.

*(Slide 26)*

8. Under the DOE proposal, thermostats controlling heating and cooling systems must be capable of maintaining different setback temperatures at different times of the day.

9. Under the DOE Proposed Rule (see *Federal Register* page 39806), framing members are not permitted to be used as return air ducts as currently allowed in the HUD standards.

*(Slide 28)*

10. Under the DOE Proposed Rule, only mechanical whole house fans are permitted while the HUD standards currently permit the use of combination mechanical and passive fans. The DOE Proposed Rule would require whole house mechanical fans to also meet minimum efficacy requirements not required in the HUD standards.

*(Slide 27)*

11. Under the DOE proposal, all hot water piping outside of the conditioned space and from the service water heating system to a distribution manifold would be required to be insulated to a minimum value of *R*-3. The HUD standards do not have any requirements for insulating hot water piping.

**Summary**

In summary, the committee is now apprised of the major issues discussed at the DOE public hearing and an overview of the DOE Proposed Rule based on HUD's analysis and perspective.

While HUD is certainly in favor of enhanced energy conservation for manufactured homes, HUD believes that DOE needs to provide a more in-depth assessment of the impact of its Proposed Rule on affordability and future availability of manufactured homes for low income families. HUD continues to believe that DOE's retail cost estimates, payback, and operational cost savings estimates should be revised to consider industry economic factors such as those used for mark-up and price elasticity on demand.

DOE did not include enforcement provisions or include cost impacts associated with compliance in its Proposed Rule.

DOE's proposed climate zone map and the possible consolidation of reducing the four (4) zone map to three (3) zones by combining zones 1 and 2 and by using the higher solar heat gain coefficient for glazing materials of 0.33 was discussed.

The potential impact on indoor air quality was reviewed and HUD's concerns with potential health effects resulting from the proposed measures to further tighten the thermal envelope and reduce the amount of natural air infiltration into the home from eight (8) to five (5) air changes per hour.

The MHCC was then advised that it needed to determine whether the Committee believes that the proper balances between the DOE and HUD Acts have been met by DOE with its Proposed Rule, and to determine whether the Committee will elect to offer any comments to DOE in response to its request for feedback and comments on the Proposed Rule.

Richard Mendlen asked if there were any questions or comments.

William Freeborne said DOE did a wonderful job and asked if DOE provided any cost information with the new energy requirements, i.e., adding additional ceiling insulation and caulking the entire home. Mr. Mendlen replied that DOE has provided information in a separate document.

Timothy O'Leary noted that initial cost is only half of the story, the main point to improving energy efficiency is to reduce the operating costs to the homeowner. The banking industry should recognize that with the moderate increase of a loan payment of about $5 per month, the operating costs could be decreased by $35 to $55 depending on the house.

Steven Anderson agreed with Mr. O'Leary, however, the banking industry does not consider operating costs. The banking industry uses predetermined underwriting standards of a 25% debt-to-loan ratio.

Richard Weinert said that what is missing from the DOE proposal is its plan for implementation or compliance onsite. Mr. Mendlen responded that there is not any information at this time as we don't know the plan is for compliance or enforcement provisions.

Leo Poggione said he researched the potential increased monthly cost to the homeowner by using an amortization calculator with a 9.5% interest rate chattel loan:

- Single-wide home 10-year amortization of $2,200 = $28.47 per month increase
- Double-wide home 15-year amortization of $3,100 = 39.27 per month increase

Richard Nolan asked if the proposed DOE rule will potentially replace Subpart F. Mr. Mendlen said that currently there is a potential conflict and that Subpart F might become mute, but we just don't know yet as DOE has not provided any information on enforcement at this time. DFO Danner further clarified that DOE stated that it will publish a separate rule on enforcement.

John Weldy said enforcement is a key part of this proposal, and we haven't heard any more than we were just told. It is cost prohibitive to have additional audits and inspections. We talked about cost, an ENERGY STAR style rebate, or some sort of lending type of credit. There will be a certain number of homeowners that this proposal will exclude. When you look at the cost analysis itself, it doesn't seem that DOE considered this. There will continue to be people living in older, less efficient homes that will actually increase the energy use. The numbers that DOE used just aren't reality.

## Review of Skyline Comments to DOE Proposed Rule on Energy Conservation Standards for Manufactured Homes

Jeffrey Legault submitted comments from Skyline (see Appendix G). He said that most of them parallel Richard Mendlen's comments. The most important thing is the lack of understanding on how the Proposed Rule will be enforced. That piece needs to be in place before we start.

A member suggested that the MHCC might want to develop its own enforcement criteria without waiting for DOE as manufactured housing is a unique industry.

Timothy O'Leary said that in the Pacific Northwest there are in-plant inspections four times a year, all the ENERGY STAR homes are inspected on the line by an independent third-party inspector. Duct testing is done on all ENERGY STAR homes. The majority of manufacturers noticed that the duct tests have resulted in fewer call backs and are now testing all homes. There is a 1% onsite quality assurance assessment performed on a five-year cycle and those results are passed on to the manufacturers and installers. The result is a program that continuously improves. It is the consumer that is impacted the most when things are done improperly, not the manufacturer. We also have training sessions for installers and provide energy training. This might be something for MHCC to consider. In reply to a question on costs raised by Debra Blake, Mr. O'Leary replied that the cost of the upgrade from a standard home to an ENERGY STAR home is around $3k to $5k to the consumer. Over time, the changes in manufacturing technique, has reduced the cost to the manufacturer and produced a better product.

Debra Blake wanted to know what problem the DOE Proposed Rule is really trying to address as the industry already builds energy efficient homes. Richard Mendlen informed the committee that DOE is doing what their statute tells them to do. Robin Roy added that Congress saw the differences in energy efficiency in a manufactured home and a site built home in terms of code requirements.

DFO Danner reminded the Committee that DOE participated in two MHCC meetings and gave presentations and on July 13, 2016, held a public hearing. DOE provided HUD with their presentation regarding the Proposed Rule to review and provide comments. The MHCC is now tasked to provide those comments.

Jeffrey Legault provided a brief overview of the Skyline submission.

1) *Table 460.101-1 & 2. The State of California is not included in the tables. It appears the entire State of California is located in Climate Zone III.*

As this issue appears to be an oversight, the committee agreed to take action.

**Motion to submit comment to DOE:**

> **Table 460.101-1 & 2. The State of California is not included in the tables. It appears the entire State of California is located in Climate Zone III.**

Maker: John Weldy Second: Jeffery Legault
Meeting Vote: unanimously approved.

2) *460.102 Building thermal envelope requirements. Climate Zones I and II of the 2015 IECC closely matches Climate Zone I of the Proposed Rule. Climate Zone I and II of the 2015 IECC allows a window U-factor of 0.40, which is significantly higher than the window U-factor of 0.35 in the Proposed Rule for the same area. I recommend raising the window U-factor in the Proposed Rule to 0.40 for climate zone 1.*

Jeffry Legault said the climate zone that includes Florida, in the 2015 IECC, has a *U*-factor for a window of 0.40 and for Dade County it is 0.50.

Timothy O'Leary said that it does not matter whether it is three or four climate zones. The point of an energy efficiency calculation is predicated on the solar heat gain coefficient or the *U*-factor according to the cooling/heating needs of the zone. What should be used is heating degree days. In Idaho there are two climate zones and that is not a problem for manufacturers building homes there. The number of climate zones should be increased to accommodate microclimates.

**Motion to submit comment to DOE:**

Maker: John Weldy Second: Debra Blake
Meeting Vote: 7-5-0 motion failed.

3) *460.102 Building thermal envelope requirements. The only difference between Climate Zone I and II of the Proposed Rule is the SHGC. I recommend combining these climate zones into a single zone, and use a SHGC of 0.33.*

Richard Mendlen noted that he proposed the same in his comments.

Timothy O'Leary said if you want to build a cheap home and charge the same amount to the consumer, go ahead and use a SHGC of .33. The consumer is the one who will lose. If climate zones are combined, then the worst case scenario of SHGC of .25 should be used.

John Weldy said that the point is to simplify the map and combine zones.

William Freeborne said the SHGC is a major factor in sizing equipment to control the climate of the home and while it does increase the work involved, it is beneficial to the consumer.

Lois Starkey said that an analysis on the SHGC, as presented in the Proposed Rule, showed that the benefit did not outweigh the cost for the consumer.

**Motion to submit comment to DOE:**

Maker: John Weldy Second: Richard Nolan
Meeting Vote: 8-5-0 motion failed.

4) *Table 460.102-1. Note 3 states "Ceiling Insulation must have either a uniform thickness or uniform density." Uniform thickness will not generally be possible. Therefore a uniform density will be required in the prescriptive method. This seems to not allow compression of insulation in the truss heel area. It will be very difficult to build a roof with the insulation levels required by the Proposed Rule without some compression.*

Jeffrey Legault said the uniform thickness is probably not practical with the heel height of 5.5 in.—uniform density should be used. Can compressed insulation be used in that area?

Richard Mendlen agreed there is a need for clarification and did not think it was possible to reach *R*-38 with a 5.5 in. heel height.

It was noted that a 10 in. heel height would be required to reach *R*-38 and that would not be practical.

This is only in the prescriptive path.

Timothy O'Leary suggested rather than using uniform thickness or uniform density, a uniform *R*-value should be used. That would allow the manufacturer to adjust the heel height to accommodate a variety of different types of insulation. *R*-38 is not enough to handle some of the climates. The 5.5 in. heel should be considered a *minimum* standard.

After a discussion of how to comment on this issue the committee took action.

**Motion to submit comment to DOE:**

> **Table 460.102-1. Note 3 states "Ceiling Insulation must have either a uniform thickness or uniform density." Uniform thickness will not generally be possible. Therefore, a uniform density will be required in the prescriptive method. This seems to not allow compression of insulation in the truss heel area. It will be very difficult to build a roof with the insulation levels required by the Proposed Rule without some compression.**
>
> **MHCC recommends eliminating this requirement.**
>
> **Remove text ~~(3) Ceiling insulation must have either a uniform thickness or a uniform density.~~**
>
> Maker: John Weldy Second: Myles Standish
> Meeting Vote: 10-1-0

5) *Table 460.102-1. Note 7 requires a maximum glazing area of 12% of the floor area, when using the prescriptive method. There is no such glazing area restriction in the 2015 IECC. I recommend eliminating this requirement.*

Jeffrey Legault said 12% seems low and he did not remember it in the discussions with DOE. There is no such glazing restriction in the 2015 IECC. In the 2015 IECC, there can be 30% glazing and still meet the requirement and he would like to see this removed.

Richard Mendlen noted that this issue was also mentioned in the public hearing.

Timothy O'Leary said the 12% maximum glazing area requirement is lower than what is allowed in the ENERGY STAR program.

After a discussion of how to comment on this issue the committee took action.

**Motion to submit comment to DOE:**

> **Table 460.102-1. Note 7 requires a maximum glazing area of 12% of the floor area, when using the prescriptive method. There is no such glazing area restriction in the 2015 IECC.**
>
> **MHCC recommends eliminating this requirement.**
>
> **Remove text ~~(7) The total area of glazed fenestration must be no greater than 12 percent of the area of the floor.~~**
>
> Maker: Steven Anderson Second: John Weldy
> Meeting Vote: 12-0-0

6) *Table 460.103 – Installation of Insulation. Under floors, the Proposed Rule requires floor insulation to be installed in contact with the underside of the floor decking. This requirement has been debunked by building scientists, and has been removed from the 2015 IECC. It serves no purpose since the rim joist is required to be insulated. It is extremely difficult to do in a factory environment. I recommend this section be removed.*

Myles Standish said if this becomes a requirement, costs will significantly increase and it is not practical.

Richard Weinert said it appears there is nothing in the rule about loose fill or sprayed insulation and asked if the issue was addressed at all. Richard Mendlen answered that it would be allowed, but it would have to meet all the criteria.

Timothy O'Leary said, as an energy specialist, having the insulation in contact with the air barrier makes a huge difference as air gaps create a huge pathway for energy loss.

John Weldy provided some background on this subject. In the 2012 IECC, there was a requirement that the insulation be tight to the floor decking. However, the 2015 IECC, they backed off this requirement somewhat by requiring that the insulation be tight to the decking or continuous underneath the decking. This is important because it seemed to be in conflict with the building code where there is a need to protect pipes from freezing in the conditioned space.

Timothy O'Leary said that there has been a change in philosophy and that included a heated crawl space. In manufactured housing, the area beneath the home is not typically conditioned—it is skirted and has the potential for a high loss of energy in areas with cold temperatures. The insulation and the air barrier work together.

Lois Starkey said based on the research that has been done regarding the tightness of the home, she is not sure if the benefit is worth the effort to meet this standard.

Dominic Frisina provided the perspective of an installer. When a home is installed, it is checked to make sure that there are no tears that happened during the transportation and installation process. The underbelly is very well sealed and will prevent a lot of air filtration.

Myles Standish said from a manufacturer's perspective, this requirement is very difficult and he does not know how any manufacturer would be able to meet this requirement.

Timothy O'Leary said NAIMA recommends that insulation be in contact with the air barrier. The road barrier is not an air barrier, it allows air to go in and out which helps to mitigate moisture in the floor area. The floor is the air barrier, it is on the warm in winter side and if the insulation is not in contact with the air barrier, then there is a space where air can move. Insulation is not an air barrier; it is a filter for the air moving through it.

After a discussion of how to comment on this issue the committee took action.

**Motion to submit comment to DOE:**

> **Table 460.103 – Installation of Insulation. Under floors, the Proposed Rule requires floor insulation to be installed in contact with the underside of the floor decking. This requirement has been debunked by building scientists, and has been removed from the 2015 IECC. It serves no purpose since the rim joist is required to be insulated. It is extremely difficult to do in a factory environment.**
>
> **MHCC recommends this section be removed.**
>
> Maker: John Weldy  Second: Dominic Frisina
> Meeting Vote: 10-2-0

7) *460.201 Duct system – The Proposed Rules states "Each manufactured home must be equipped with a duct system." This seems to imply that ductless systems, such as mini split heat pumps are not allowed. I recommend revising the section to state "when a duct system is installed."*

Jeffrey Legault said there is an increased use of mini split systems and, as written, these would not be allowed.

Timothy O'Leary said duct systems cause the most energy loss and eliminating them would be great, or locating them inside the thermal envelope would help. He agreed that Mr. Legault made a good point on the use of mini split heat pumps.

After a discussion of how to comment on this issue the committee took action.

**Motion to submit comment to DOE:**

> **460.201 Duct system – The Proposed Rule states "Each manufactured home must be equipped with a duct system." This seems to imply that ductless systems, such as mini split heat pumps are not allowed.**
>
> **MHCC recommends revising the section to state "<u>when a duct system is installed</u>."**
>
> Maker: Myles Standish  Second: John Weldy
> Meeting Vote: unanimously approved.

8) *460.201 Duct system – Section (b) states "Building framing cavities must not be used as ducts or plenums". Does this section apply to return air plenums? I recommend revising this section to state "…supply ducts or plenums…"*

Jeffrey Legault said the industry uses these kinds of things for return air all the time. Richard Mendlen said the issue was raised with DOE and they did not agree.

Timothy O'Leary said the industry has been doing this for decades. It does not matter if they are supply or return ducts, you cannot seal them – it is a bad idea. If the ducts are inside the thermal envelope and they are sealed, that is a different story. Framing cavities should never be used as ducts or plenums.

After a discussion of how to comment on this issue the committee took action.

**Motion to submit comment to DOE:**

**460.201 Duct system – Section (b) states "Building framing cavities must not be used as ducts or plenums". Does this section apply to return air plenums?**

**MHCC recommends revising this section to state "…Building framing cavities must not be used as ducts or plenums <u>when directly connected to mechanical systems</u>."**

Maker: Myles Standish Second: John Weldy
Meeting Vote: unanimously approved.

**BREAK**

9) *The use of 2x4 exterior walls will be extremely difficult to make work under the Proposed Rule for thermal Zone III and IV. This will encompass approximately 75% of the country. This will impose a significant financial burden on the industry.*

Steven Anderson asked what would the impact on costs be if 2x6 walls are used. Leo Poggione said, according to his retail pricing book, the increase for a 44 ft. home is $520 and a 76 ft. home is $720 which equates to $11.82 per lineal ft. for small home and $9.47 lineal ft. for a larger home.

Timothy O'Leary informed the committee that the International Building Code requires 2x6 walls. All energy professionals agree that 2x6 walls are more energy efficient. The cost estimates do not include the benefits to the homeowner. Maybe the amount of thermal bridging, the thickness of the insulation, or *R*-value should be considered as well as using a 24 in. on center instead of using 16 in. on center.

Dominic Frisina said he does not stock 2x4 homes because the customers will not buy them.

Alan Spencer said there are people who will not qualify for loans under the new regulation and he would recommend that 2x4 remain as a minimum standard.

Ultimately, there were not enough votes for or against including the issue in MHCC comments to DOE and it will not be included in MHCC comments to DOE.

10) *The Proposed Rule does not address how these standards will be enforced. Does DOE have an enforcement plan? How are plan review and inspections to be performed? It would be a burden on the industry to have to deal with an additional Federal Agency. There needs to be regulatory clarity before this rule can be final.*

Jeffrey Legault said there is a need for regulatory clarity and the Proposed Rule does not address enforcement. Clarification is needed before the rule can be final so manufacturers can understand what their burden will be and what the requirements will be. This should be part of the HUD standard so manufacturers can comply with one federal agency and not two.

Richard Weinert asked if enforcement was part of the mandate to DOE? Or can the MHCC force its hand in rulemaking and keep enforcement with HUD. Richard Mendlen noted that there is a provision for enforcement in EISA that is not very specific and quoted:

> *"Enforcement – Any manufacturer of manufactured housing that violates a provision of the regulations under subsection (a) is liable to the United States for a civil penalty in an amount not exceeding 1 percent of the manufacturer's retail list price of the manufactured housing."*

DFO Danner said DOE has enforcement authority and that DOE is considering possible options including the possibility of transferring enforcement to HUD. HUD has strongly encouraged DOE to adopt HUD's enforcement process, but DOE has decided to leave the enforcement issue unresolved at this time.

Rick Nolan said without knowing what the process for enforcement regulations are, the costs associated with Proposed Rule are flawed.

Timothy O'Leary strongly advised that inspections need to be required. As Ronald Regan said, "You don't get what you expect, you get what you inspect."

After a discussion of how to respond to the enforcement issue the committee took action.

**Motion to submit comment to DOE:**

> **The Proposed Rule does not address how these standards will be enforced. Does DOE have an enforcement plan? How are plan review and inspections to be performed? It would be a burden on the industry to have to deal with an additional Federal Agency. There needs to be regulatory clarity before this rule can be final.**
>
> **The DOE Proposed Rule is substantially incomplete as stated. The Proposed Rule does not contain compliance and enforcement details to ensure that homes are constructed and installed in compliance with the standard. Neither does its cost analysis include or support the cost efficiency or justification for compliance costs. The enforcement of the Proposed Rule significantly affects the costs, planning, and implementation. Therefore, the MHCC cannot recommend this proposal be adopted as a final rule until the enforcement and compliance path is included.**
>
> **MHCC recommends enforcement and compliance be performed by HUD.**
>
> Maker: Steven Anderson Second: Timothy O'Leary
> Meeting Vote: 13-0-0.

## Public Comment

Mark Weiss said the timing of the comment period is ludicrous. Mr. Weiss served on the DOE Working Group and voted against this Proposed Rule because it will have a devastating impact on the small manufacturer. If DOE's numbers are reviewed, including the life-cycle supposed cost benefit, they cannot be accurate because they do not include enforcement testing and regulatory compliance. The numbers also do not include exclusion from the market. The only information provided to the Working Group was that for each $1,000 you increase the price of a single section home, there are 347,000 households excluded from the market; for a double section home is 315,000. For the people who are excluded from the market, there is not life-cycle cost benefit. The agency that has the ability to quantify the social costs of carbon somehow does not have the ability to quantify the social costs of homelessness.

MHARR's estimates are that the cost increases are about $4,600 to single sections and almost $6,000 double sections (see Appendix H). Also not included, is the two-year cycle of the IECC and these changes can potentially be updated on a bi-annual basis.

Lois Starkey said Jeffrey Legault's comments are consistent with what MHI will be submitting. The Proposed Rule attempts to address factory production and energy efficiency issues such as duct testing. There are different issues regarding the site-built side. We need to look for a protocol that will ensure the standard is met, and keeping in mind factory production and the efficiencies it produces. The ENERGY STAR program will need to change for manufactured housing because the steps are a little different to achieve ENERGY STAR certification. The enforcement should be part of 3280/3285 regulatory structure to ensure that there is compliance in both the factory and onsite.

The Committee returned its attention to Richard Mendlen's questions.

## Richard Mendlen Questions Regarding the July 13, 2016 DOE Proposed Rule

To facilitate the MHCC review of the *DOE Proposed Rule: Energy Efficiency Standards for Manufactured Housing*, the following areas, issues, and questions have been prepared for review and consideration (see Appendix E).

1) *Has DOE adequately considered the impact of the Proposed Rule on the future affordability and access to credit for low income purchasers?*

Steven Anderson asked the committee to review the cost estimates he provided with input from MHARR (Appendix H).

Kevin Kauffman clarified that this information (Appendix H) and a submittal from John Weldy, *Methodology for Developing the REScheck™ Software Through Version 3.7* (Appendix I) were new submittals that were not distributed *prior* to the meeting. However, they were distributed to all Committee members.

Tom Heinemann, MHI, said there needs to be consultation with other federal regulators, i.e., the Consumer Finance Protection Bureau (CFPB) regarding debt to income ratios or QM guidelines; the Treasury Dept. to see if there could be an ENERGY STAR type rebate; or the FHA to see if there is any flexibility with Title I or Title II to allow greater flexibility on how these loans are underwritten to allow for the increased payment. It is unacceptable to simply state that a homeowner will get their money back over a seven (7) year period with the energy savings provided.

Steven Anderson agreed in principal; however, individual states do not always adopt federal guidelines on lending practices. The point is there are people who will not be able to qualify for loans under the new regulations.

Dominic Frisina said none of these regulations have kept up with financing. There is very little chattel lending available. All the regulations have done is force people who need affordable housing into substandard housing. The whole market is out of whack in helping people get financing.

John Weldy said DOE has not adequately provided a cost/benefit analysis for the industry or the homeowner. Regarding loan acquisition, there is a big difference in interest rates for chattel vs. real property. He said he used interest rates based on real property in his calculations. Steven Anderson agreed that this was an important note; however, he used chattel rates in his calculation because most loans regarding manufactured housing are financed as chattel.

After a discussion of how to comment on this issue the Committee took action.

**Motion to submit comment to DOE:**

> **DOE has not adequately considered the impact of the Proposed Rule on the future affordability and access to credit for low income purchasers. DOE projected an average retail cost increase of 5% or $2,226 for single section homes and $3,109 for a multi-section homes.**
>
> **MHCC recommends that DOE should further revise its retail cost impact analysis based on the past industry projected retail cost mark-up factor of 2.30, rather than 1.67 factor used by DOE in its cost analysis.**

Maker: William Freeborne  Second: Steven Anderson
Meeting Vote: unanimously approved.

2) *Has DOE under estimated the reduction in production levels and future availability of manufactured homes due to implementation of its proposed standards?*

After a discussion of how to comment on this issue the Committee took action.

**Motion to submit comment to DOE:**

> **DOE has under estimated the reduction in production levels and future availability of manufactured homes due to the implementation of its proposed standards. DOE projections, based on 2014 shipment data, would suggest a loss in production and availability of over 40,000 homes over a 30-year period using a -0.48 elasticity in demand factor (as price goes up-demand goes down). Past HUD estimates of elasticity on demand used a higher factor of -2.40 which would suggest a loss of production of over 200,000 homes over the same 30-year period. However, based on more recent and current industry production growth rates, shipment data, and potential underestimates of retail costs by DOE, these projected production losses would appear to also underestimate the future losses in production, shipments, and availability of manufactured homes.**

Maker: Steven Anderson  Second: Alan Spencer
Meeting Vote: unanimously approved.

3) *Should DOE develop enforcement regulations before issuing a final rule for its energy standards? Currently, compliance is not covered in the Proposed Rule or included in DOE's cost estimates and analysis.*

The Committee agreed that this issue had already addressed and moved on to the next item.

4) *Has DOE adequately addressed the impact of the rule on small manufacturers.*

Lois Starkey said MHI provided information to DOE for all size manufacturers and that it was considered.

Mark Weiss said the impact on the small manufacturer in DOE's Proposed Rule, with regard to production, will be greater because DOE failed to consider higher supply costs and the fact that they cannot amortize the costs over a long period of time as the larger manufacturers can. This has the potential to reduce competition, which will not be good for the consumer. MHARR has addressed this significantly in their comments.

After a discussion of how to comment on this issue the Committee took action.

**Motion to submit comment to DOE:**

> **DOE has not adequately addressed the impact of the Proposed Rule on small manufacturers. Small manufacturers may not be able to compete in the marketplace due to economies of scale afforded to large manufacturers that are able to purchase materials in volume at discounted rates not available to smaller manufacturers. DOE could not certify that the Proposed Rule would not have a significant impact on small manufacturers.**

Maker: Steven Anderson Second: William Freeborne
Meeting Vote: unanimously approved.

5) *Should DOE use 3 climate zones divided along state lines rather than the 4 climate zones indicated in its Proposed Rule for bifurcated climate zones 1 and 2, due only to different solar glazing requirements?*

Richard Mendlen clarified that if you combine climate zones 1 and 2 of DOE's proposal, there would still be differences between the current HUD climate zone map (Appendix J) and DOE's proposed map, but at least the demarcations would be along the state lines.

Joseph Anderson said people do not understand climate zones in a bifurcated state and when dealing with a customer, it is difficult to explain to them why they can or cannot have a certain product delivered to their property because it is on the wrong side of the road.

Timothy O'Leary disagreed and said manufacturers build homes for multiple climate zones and ship them all over the country. He said the extra climate zone for the gulf states is beneficial as the weather does not recognize state boundaries.

Jeffrey Legault disagreed with Mr. O'Leary on this issue. It should be one climate zone and the only difference is the solar heat gain coefficient and the current code does not have any requirements.

**Motion to submit agreement to the 4 climate zones to DOE.**

Maker: Timothy O'Leary Second: William Freeborne
Meeting Vote: 7-8-0 motion failed.

**Motion to recommend that DOE use HUD's climate zone map with 3 climate zones.**

Maker: Debra Blake Second: Joseph Anderson
Meeting Vote: 4-10-1 motion failed.

Ultimately, there were not enough votes for or against including the issue in MHCC comments to DOE and it will not be included in MHCC comments to DOE.

6) *Has DOE adequately addressed the potential health effects on indoor air quality that may result from several proposed measures to increase the tightness and thereby reduce natural air infiltration through the thermal envelope, with no proposed increase in mechanical ventilation requirements?*

Lois Starkey said DOE did not have enough information or literature and that there are too many variables regarding indoor air quality, i.e., temperature, climate, location, and consumer habits.

Steve Andersen suggested that ASHRAE 62.2 or other HVAC standards should be considered in order to get back to a more acceptable air exchange rate. The AMA suggests a minimum rate of seven (7) air exchanges per hour.

James Demitrus said homeowners do not really understand indoor air quality and the need for ventilation. There is a need for public education on this topic.

Mark Weiss said there is another cost factor to this Proposed Rule and that is the cost of litigation. There is no protection from liability.

After a discussion of how to comment on this issue the Committee took action.

**Motion to submit comment to DOE:**

> **DOE has not adequately addressed the potential health effects on indoor air quality that may result from several proposed measures to increase the tightness and thereby reduce natural air infiltration through the thermal envelope, with no proposed increase in mechanical ventilation requirements. Implementation should be deferred pending study of this issue. The measures are currently designed to enhance the tightness of the thermal envelope needed to achieve the projected reduction of natural air infiltration from eight (8) air changes per hour to five (5) air changes per hour and other benchmarks should be considered.**

Maker: Steven Anderson Second: William Freeborne
Meeting Vote: 14-2-0 motion passed.

## Wrap UP

DFO Danner thanked the Committee members for their time and instructed them to contact Kevin Kauffman (AO) if they had any questions and that Kevin will send out the final submission when it is ready. Committee members were encouraged to submit their own comments as individuals or on behalf of their organizations directly to DOE.

EPA has published its final EPA Formaldehyde Rule for various products on its website. Kevin Kauffman will send it to committee members and schedule an MHCC meeting on this topic.

Kevin Kauffman provided information on how this information will be submitted to DOE: 1) submit using the regulations.gov website; and 2) send an email with the submittal as an attachment. All correspondence received will be forwarded to the entire MHCC to keep everyone apprised.

## Adjourn

The MHCC meeting was adjourned at 4:50 p.m. (EDT).

# APPENDIX A: PARTICIPANT LIST

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MHCC MEETING
August 9, 2016

# APPENDIX B:
# DOE NOTICE OF PROPOSED RULE (NOPR)

*Federal Register*, Vol. 81, No. 117, June 17, 2016

FEDERAL REGISTER

Vol. 81 Friday,
No. 117 June 17, 2016

Part II

# Department of Energy

10 CFR Part 460

Energy Conservation Standards for Manufactured Housing; Proposed Rule

**DEPARTMENT OF ENERGY**

**10 CFR Part 460**

**[Docket No. EERE–2009–BT–BC–0021]**

**RIN 1904–AC11**

## Energy Conservation Standards for Manufactured Housing

**AGENCY:** Office of Energy Efficiency and Renewable Energy, Department of Energy.

**ACTION:** Notice of proposed rulemaking and public meeting.

**SUMMARY:** The U.S. Department of Energy (DOE) is publishing a proposed rule to implement the Energy Independence and Security Act of 2007, which directs DOE to establish energy conservation standards for manufactured housing. DOE proposes to establish energy conservation standards for manufactured housing based on the negotiated consensus recommendations of the manufactured housing working group (MH working group). The MH working group's recommendations were based on the 2015 edition of the International Energy Conservation Code (IECC), the impact of the IECC on the purchase price of manufactured housing, total lifecycle construction and operating costs, factory design and construction techniques unique to manufactured housing, and the current construction and safety standards set forth by U.S. Department of Housing and Urban Development.

**DATES:** DOE will accept comments, data, and information regarding this proposed rule before and after the public meeting, but no later than August 16, 2016 DOE will hold a public meeting on Wednesday, July 13, 2016 from 9:00 a.m. to 4:00 p.m. in Washington, DC.

**ADDRESSES:** The public meeting will be held at the U.S. Department of Energy, Forrestal Building, Room 1E–245, 1000 Independence Avenue SW., Washington, DC 20585–0121. To attend, please notify Ms. Brenda Edwards at (202) 586–2945. Please note that foreign nationals visiting DOE Headquarters are subject to advance security screening procedures. Any foreign national wishing to participate in the public meeting should advise DOE as soon as possible by contacting Ms. Brenda Edwards at (202) 586–2945 to initiate the necessary procedures.

Any comments submitted must identify the notice title, docket number EERE–2009–BT–BC–0021, and/or the regulatory identifier number (RIN) 1904–AC11. Comments may be submitted using any of the following methods:

1. *Federal eRulemaking Portal: www.regulations.gov.* Follow the instructions for submitting comments.
2. *Email: ManufacturedHousing2009BC0021@ee.doe.gov.* Include docket number EE–2009–BT–BC–0021 and/or RIN 1904–AC11 in the subject line of the message.
3. *Mail:* Ms. Brenda Edwards, U.S. Department of Energy, Building Technologies Program Mailstop EE–2J, 1000 Independence Avenue SW., Washington, DC 20585–0121.
4. *Hand Delivery/Courier:* Ms. Brenda Edwards, U.S. Department of Energy, Building Technologies Program, Suite 600, 950 L'Enfant Plaza SW., Washington, DC 20024. Telephone: (202) 586–2945.

Due to potential delays in DOE's receipt and processing of mail sent through the U.S. Postal Service, DOE encourages respondents to submit electronically to ensure timely receipt.

For detailed instructions on submitting comments and additional information on the rulemaking process, see section V of this document (''Public Participation'').

*Docket:* The docket is available for review at *www.regulations.gov* and includes **Federal Register** notices, public comments, meeting transcript summaries, and other supporting documents and materials. All documents in the docket are listed in the *regulations.gov* index. However, not all documents listed in the index may be publicly available, such as information that is exempt from public disclosure.

A link to the docket Web page can be found at: *http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx?ruleid=97.* This Web page contains a link to the docket for this notice on the *regulations.gov* site. The *regulations.gov* Web page also contains instructions on how to access all documents, including public comments, in the docket. See section V of the **SUPPLEMENTARY INFORMATION** for more information on how to submit comments for this rulemaking through *regulations.gov.*

For further information on how to submit or review public comments, participate in the public meeting, or view hard copies of the docket, contact Ms. Brenda Edwards, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Building Technologies Program, EE–2J, 1000 Independence Avenue SW., Washington, DC 20585–0121; (202) 586–2945; *Brenda.Edwards@ee.doe.gov.*

**FOR FURTHER INFORMATION CONTACT:** Mr. Joseph Hagerman, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Building Technologies Program (EE–2J), 1000 Independence Avenue SW., Washington, DC, 20585; (202) 586–4549; *joseph.hagerman@ee.doe.gov.*

For information on legal issues presented in this document, contact: Ms. Kavita Vaidyanathan, U.S. Department of Energy, Forrestal Building, Office of the General Counsel (GC–33), 1000 Independence Avenue SW., Washington, DC, 20585; (202) 586–0669; *kavita.vaidyanathan@hq.doe.gov.*

DOE proposes to incorporate by reference into part 460 the following industry standards:

(1) Manual J—Residential Load Calculation (8th Edition).

(2) Manual S—Residential Equipment Selection (2nd Edition).

Copies of Manual J and Manual S may be purchased from Air Conditioning Contractors of America, Inc., (ACCA), 2800 S. Shirlington Road, Suite 300, Arlington, VA 22206, 703–575–4477, *http://www.acca.org/.*

(3) Overall U-Values and Heating/Cooling Loads—Manufactured Homes. Conner C.C., Taylor, Z.T., Pacific Northwest Laboratory, published February 1, 1992.

You may purchase a copy of Overall U-Values and Heating/Cooling Loads—Manufactured Homes from *http://www.huduser.org/portal/publications/manufhsg/uvalue.html* 800–245–2691.

For a further discussion of these standards, see section V.N of this document.

**SUPPLEMENTARY INFORMATION:**

## I. Synopsis of the Proposed Rule

### *A. The Proposed Regulations*

The Energy Independence and Security Act of 2007 (EISA, Pub. L. 110–140) directs the U.S. Department of Energy (DOE) to establish energy conservation standards for manufactured housing. EISA directs DOE to base the standards on the most recent version of the International Energy Conservation Code (IECC) and any supplements to that document, except where DOE finds that the IECC is not cost-effective or where a more stringent standard would be more cost-effective, based on the impact of the IECC on the purchase price of manufactured housing and on total lifecycle construction and operating costs. *See* 42 U.S.C. 17071. In accordance with this statutory directive, DOE is proposing energy conservation standards for manufactured housing. These energy conservation standards would be codified in a new part of the Code of Federal Regulations (CFR) under 10 CFR part 460 subparts A, B, and C.

Subpart A discusses generally the scope of the proposed rule and provides proposed definitions of key terms. The subpart also would provide manufacturers with a one-year lead time for compliance such that the standards would apply to all manufactured homes manufactured on or after one year following the publication of a final rule.

Subpart B would establish requirements related to climate zones and the building thermal envelope of manufactured homes. DOE proposes to base its energy conservation requirements on four climate zones, which generally follow state borders, with some exceptions. Regarding the building thermal envelope, DOE proposes two approaches to compliance. The first is a prescriptive approach that would establish specific requirements for component and fenestration thermal resistance (*R*-value), thermal transmittance (*U*-factor), and solar heat gain coefficient (SHGC). The second is a performance-based approach that would establish a maximum overall thermal transmittance ($U_o$) requirement for the building thermal envelope and additional *U*-factor and SHGC requirements. Subpart B also would include provisions for determining *U*-factor, *R*-value, SHGC, and $U_o$. Finally, subpart B would establish prescriptive requirements for insulation and sealing the building thermal envelope to limit air leakage.

Subpart C would establish requirements related to duct leakage; heating, ventilation, and air conditioning (HVAC); service hot water systems; mechanical ventilation fan efficacy; and heating and cooling equipment sizing.

### *B. Benefits and Costs to Purchasers of Manufactured Housing*

As explained in greater detail in section IV of this document and in chapter 9 of the technical support document (TSD) accompanying this proposed rule, DOE estimates that benefits to manufactured homeowners in terms of lifecycle cost (LCC) savings and energy cost savings under the proposed rule would outweigh the potential increase in purchase price for manufactured homes. As presented in Table I.1, DOE estimates that the average purchase price of a manufactured home under the proposed rule would increase as much as $2,423 for a single-section and $3,745 for a multi-section manufactured home as a result of the increased construction costs associated with energy conservation improvements.

TABLE I.1—NATIONAL AVERAGE MANUFACTURED HOUSING PURCHASE PRICE (AND PERCENTAGE) INCREASES UNDER THE PROPOSED RULE

| | Single-section | | Multi-section | |
|---|---|---|---|---|
| | ($) | (%) | ($) | (%) |
| Climate Zone 1 | 2,422 | 5.3 | 3,748 | 4.5 |
| Climate Zone 2 | 2,348 | 5.1 | 3,668 | 4.4 |
| Climate Zone 3 | 2,041 | 4.5 | 2,655 | 3.2 |
| Climate Zone 4 | 2,208 | 4.8 | 2,877 | 3.4 |
| National Average | 2,226 | 4.9 | 3,109 | 3.7 |

As explained in more detail in section IV.A of this document and in chapter 9 of the TSD, Table I.2 presents the estimated national average LCC savings and energy savings that a manufactured homeowner would experience under the proposed rule as compared to a manufactured home constructed in accordance with the minimum requirements of the existing HUD Code at 24 CFR part 3282. Table I.2 and Figure I.1 present the nationwide average simple payback period (purchase price increase divided by first year energy cost savings) under the proposed rule.

TABLE I.2—NATIONAL AVERAGE PER-HOME COST SAVINGS UNDER THE PROPOSED RULE

| | Single-section | Multi-section |
|---|---|---|
| Lifecycle Cost Savings (30-Year Lifetime) | $3,211 | $4,625. |
| Annual Energy Cost Savings in 2015 dollars | $345 | $490. |
| Simple Payback | 7.1 years | 6.9 years. |

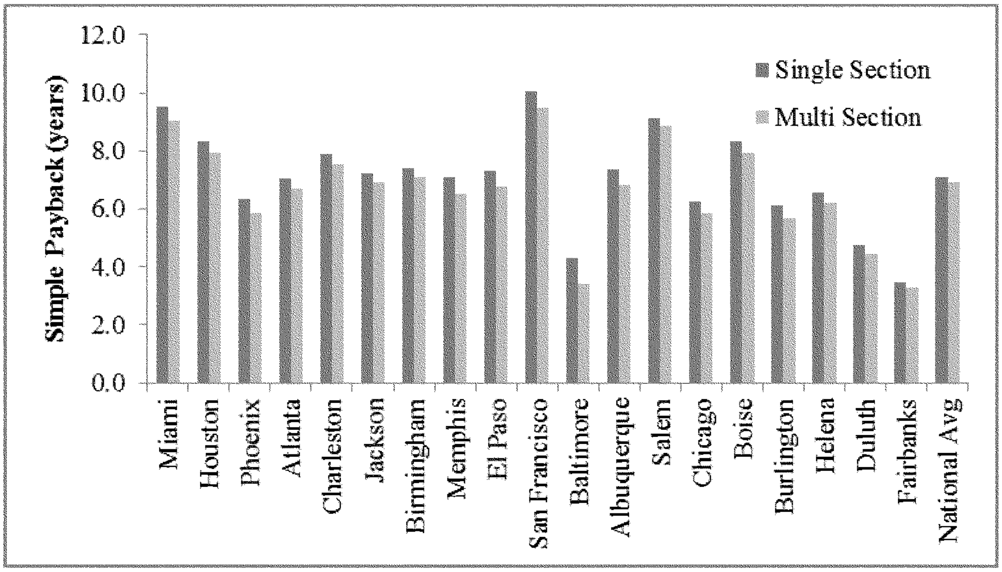



**Figure I.1: Simple Payback Period of the Proposed Rule**

*C. Manufacturer Impact*

As discussed in more detail in section IV.B of this document and chapter 12 of the TSD, the industry net present value (INPV) is the sum of the discounted cash flows to the industry from the announcement year (2016) through the end of the analysis period (2046). Using a real discount rate of 9.2 percent, DOE estimates the base case INPV for manufacturers to be $716.7 million. Under the proposed standards, DOE expects that the INPV will be reduced by 0.7 to 6.8 percent. Industry conversion costs are expected to total $1.6 million.

*D. Nationwide Impacts*

As described in more detail in section IV.C of this document and chapter 11 of the TSD, DOE's national impact analysis (NIA) projects a net benefit to the nation as a whole as a result of the proposed rule in terms of national energy savings (NES) and the net present value (NPV) of expected total manufactured homeowner costs and savings as compared with manufactured homes built to the minimum standards established in the HUD Code. As part of its NIA, DOE has projected the energy savings, operating cost savings, incremental equipment costs, and NPV of manufactured homeowner benefits for manufactured homes sold in a 30-year period from 2017 through 2046. The NIA builds off the LCC analysis discussed by the MH working group by aggregating results for all affected shipments over a 30-year period. All NES and percent energy savings calculations are relative to a no regulatory action alternative, which would maintain energy conservation requirements at the levels established in the existing HUD Code.

Table I.3 and Table I.4 illustrate the cumulative NES over the 30-year analysis period under the proposed rule on a full-fuel-cycle (FFC) energy savings basis. FFC energy savings apply a factor to account for losses associated with generation, transmission, and distribution of electricity, and the energy consumed in extracting, processing, and transporting or distributing primary fuels. NES differ among the different climate zones because of varying energy conservation requirements and varying shipment projections in each climate zone. All NES and percent energy savings calculations are relative to a no regulatory action alternative, which would maintain energy conservation requirements at the levels established in the existing HUD Code.

TABLE I.3—CUMULATIVE NATIONAL ENERGY SAVINGS INCLUDING FULL-FUEL-CYCLE OF MANUFACTURED HOMES PURCHASED 2017–2046 WITH A 30-YEAR LIFETIME

| | Single-section quadrillion British thermal units (BTUs) (quads) | Multi-section quadrillion BTUs (quads) |
|---|---|---|
| Climate Zone 1 | 0.179 | 0.294 |
| Climate Zone 2 | 0.130 | 0.245 |
| Climate Zone 3 | 0.272 | 0.474 |
| Climate Zone 4 | 0.303 | 0.416 |

TABLE I.3—CUMULATIVE NATIONAL ENERGY SAVINGS INCLUDING FULL-FUEL-CYCLE OF MANUFACTURED HOMES PURCHASED 2017–2046 WITH A 30-YEAR LIFETIME—Continued

| | Single-section quadrillion British thermal units (BTUs) (quads) | Multi-section quadrillion BTUs (quads) |
|---|---|---|
| Total | 0.884 | 1.428 |

TABLE I.4—PERCENTAGE OF CUMULATIVE NATIONAL ENERGY SAVINGS INCLUDING FULL-FUEL-CYCLE OF MANUFACTURED HOMES PURCHASED 2017–2046 WITH A 30-YEAR LIFETIME

| | Single-section (%) | Multi-section (%) |
|---|---|---|
| Climate Zone 1 | 25.3 | 29.9 |
| Climate Zone 2 | 25.4 | 30.6 |
| Climate Zone 3 | 26.0 | 28.1 |
| Climate Zone 4 | 25.4 | 26.6 |
| Total | 25.6 | 28.3 |

Table I.5 and I.6 illustrate the NPV of customer benefits over the 30-year analysis period under the proposed rule for a discount rate of 7 percent and 3 percent, respectively. The NPV of customer benefits differ among the four climate zones because of differing initial costs and corresponding operating cost savings, as well as differing shipment projections in each climate zone. Under the proposed rule, all climate zones have a positive NPV for both discount rates.

TABLE I.5—NET PRESENT VALUE OF CUSTOMER BENEFITS FOR MANUFACTURED HOMES PURCHASED 2017–2046 WITH A 30-YEAR LIFETIME AT A 7% DISCOUNT RATE

| | Single-section (billion 2015$) | Multi-section (billion 2015$) |
|---|---|---|
| Climate Zone 1 | 0.19 | 0.34 |
| Climate Zone 2 | 0.16 | 0.35 |
| Climate Zone 3 | 0.39 | 0.74 |
| Climate Zone 4 | 0.52 | 0.74 |
| Total | 1.26 | 2.18 |

TABLE I.6—NET PRESENT VALUE OF CUSTOMER BENEFITS FOR MANUFACTURED HOMES PURCHASED 2017–2046 WITH A 30-YEAR LIFETIME AT A 3% DISCOUNT RATE

| | Single-section (billion 2015$) | Multi-section (billion 2015$) |
|---|---|---|
| Climate Zone 1 | 0.66 | 1.16 |
| Climate Zone 2 | 0.54 | 1.10 |
| Climate Zone 3 | 1.22 | 2.26 |
| Climate Zone 4 | 1.60 | 2.24 |
| Total | 4.03 | 6.75 |

*E. Nationwide Environmental Benefits*

As discussed in section IV.D of this document and in the NIA included in chapter 11 of the TSD accompanying this proposed rule, DOE's analyses indicate that the proposed rule would reduce overall demand for energy in manufactured homes. The proposed rule also would produce environmental benefits in the form of reduced emissions of air pollutants and greenhouse gases associated with electricity production. DOE estimates that 18.1 million metric tons of carbon dioxide emissions would be avoided through the end of 2030 as a result of the proposed rule.

Emissions avoided under the proposed rule are related to the energy savings that would be achieved within manufactured homes. DOE estimates that, under the proposed rule, 2.3 quadrillion Btu (quads) of FFC energy would be saved relative to manufactured homes constructed under the minimum requirements of the HUD Code over a 30-year analysis period. DOE estimates reductions in emissions of six pollutants associated with energy savings: Carbon dioxide ($CO_2$), mercury (Hg), nitric oxide and nitrogen dioxide ($NO_X$), sulfur dioxide ($SO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$). These emissions reductions are referred to as ''site'' emissions reductions. Furthermore, DOE estimates reductions in emissions associated with the production of these fuels (including extracting, processing, and transporting these fuels to power plants or manufactured homes). These emissions reductions are referred to as ''upstream'' emissions reductions. Together, site emissions reductions and upstream emissions reductions account for the FFC.

Table I.7 lists the emissions reductions under the proposed rule for both single-section and multi-section manufactured homes.

TABLE I.7—EMISSIONS REDUCTIONS ASSOCIATED WITH ELECTRICITY PRODUCTION FOR MANUFACTURED HOMES PURCHASED 2017–2046 WITH A 30-YEAR LIFETIME

| Pollutant | Single-section | Multi-section |
|---|---|---|
| **Site Emissions Reductions** | | |
| $CO_2$ (million metric tons) | 56.5 | 91.1 |
| Hg (metric tons) | 0.0904 | 0.146 |
| $NO_X$ (thousand metric tons) | 223 | 356 |
| $SO_2$ (thousand metric tons) | 27.6 | 44.4 |
| $CH_4$ (thousand metric tons) | 3.78 | 6.09 |
| $N_2O$ (thousand metric tons) | 0.632 | 1.02 |
| **Upstream Emissions Reductions** | | |
| $CO_2$ (million metric tons) | 4.01 | 6.45 |
| Hg (metric tons) | 0.000944 | 0.00153 |
| $NO_X$ (thousand metric tons) | 51.8 | 83.2 |
| $SO_2$ (thousand metric tons) | 0.615 | 0.991 |
| $CH_4$ (thousand metric tons) | 239 | 385 |
| $N_2O$ (thousand metric tons) | 0.0294 | 0.0474 |
| **Total Emissions Reductions** | | |
| $CO_2$ (million metric tons) | 60.5 | 97.6 |
| Hg (metric tons) | 0.0913 | 0.148 |
| $NO_X$ (thousand metric tons) | 275 | 439 |
| $SO_2$ (thousand metric tons) | 28.2 | 45.4 |
| $CH_4$ (thousand metric tons) | 243 | 391 |
| $N_2O$ (thousand metric tons) | 0.661 | 1.07 |

Additionally, DOE has considered the estimated monetary benefits likely to result from the reduced emissions of $CO_2$ and $NO_X$ that would be expected to result from the proposed rule. DOE calculated the monetary values for each of these emissions reductions using the social cost of carbon (SCC) model, which estimates the monetized damages associated with an incremental increase in carbon emissions within a given year. The SCC is intended to account for, but is not limited to, changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services.

Table I.8 provides the NPV of monetized emissions benefits from $CO_2$ and $NO_X$ under the proposed rule. DOE estimates that the monetized benefits from emissions reductions associated with the proposed rule would be $5,541.5 million ($4,731.4 million in $CO_2$ emissions reductions plus $810.1 million in $NO_X$ emissions reductions) over a 30-year analysis period at the 3 percent discount rate and the $CO_2$ cost associated with the average SCC case.

TABLE I.8—NET PRESENT VALUE OF MONETIZED BENEFITS FROM $CO_2$ AND $NO_X$ EMISSIONS REDUCTIONS UNDER THE PROPOSED RULE

| Monetary benefits | Discount rate (%) | Net present value (million 2015$) | |
|---|---|---|---|
| | | Single-section | Multi-section |
| $CO_2$, Average SCC Case * | 5 | 368.2 | 593.7 |
| $CO_2$, Average SCC Case * | 3 | 1,810.9 | 2,920.5 |
| $CO_2$, Average SCC Case * | 2.5 | 2,925.0 | 4,717.3 |
| $CO_2$, 95th Percentile SCC Case * | 3 | 5,581.5 | 9,001.5 |
| $NO_X$ Reduction at $2,755/metric ton * | 3 | 311.5 | 498.6 |
| | 7 | 119.8 | 191.9 |

* The $CO_2$ values represent global monetized values (in 2015$) of the social cost of $CO_2$ emissions reductions for manufactured homes shipped from 2017–2046 with a 30-year lifetime under several different scenarios of the SCC model. The ''average SCC case'' refers to average predicted monetary savings as predicted by the SCC model. The ''95th percentile case'' refers to values calculated using the 95th percentile impacts of the SCC model, which accounts for greater than expected environmental damages. The value for $NO_X$ (in 2015$) is the average of the low and high values used in DOE's analysis.

*F. Total Benefits and Costs*

As explained in greater detail in section IV of this document and chapter 15 of the TSD, Table I.9 presents the total benefits and costs to manufactured homeowners associated with the proposed rule, expressed in terms of annualized values.[1]

TABLE I.9—TOTAL ANNUALIZED BENEFITS AND COSTS TO MANUFACTURED HOMEOWNERS UNDER THE PROPOSED RULE

| | Discount rate (%) | Monetized (million 2015$/year) | | |
|---|---|---|---|---|
| | | Primary estimate ** | Low estimate ** | High estimate ** |
| **Benefits *** | | | | |
| Operating (Energy) Cost Savings | 7 | 516 | 400 | 688. |
| | 3 | 843 | 617 | 1,191. |
| $CO_2$, Average SCC Case *** | 5 | 63 | 46 | 85. |
| $CO_2$, Average SCC Case *** | 3 | 241 | 176 | 331. |
| $CO_2$, Average SCC Case *** | 2.5 | 365 | 266 | 503. |
| $CO_2$, 95th Percentile SCC Case *** | 3 | 744 | 543 | 1,022. |
| $NO_X$ Reduction at $2,755/metric ton *** | 7 | 25 | 20 | 32. |
| | 3 | 41 | 31 | 56. |
| Total (Operating Cost Savings, $CO_2$ Reduction and $NO_X$ Reduction). | 7 plus $CO_2$ range | 604 to 1,285 | 466 to 962 | 805 to 1,742. |
| | 7 | 783 | 596 | 1,052. |
| | 3 | 1,126 | 824 | 1,578. |
| | 3 plus $CO_2$ range | 947 to 1,628 | 694 to 1,191 | 1,332 to 2,269. |
| **Costs *** | | | | |
| Incremental Purchase Price Increase | 7 | 220 | 165 | 285. |
| | 3 | 277 | 192 | 378. |
| **Net Benefits/Costs *** | | | | |
| Total (Operating Cost Savings, $CO_2$ Reduction and $NO_X$ Reduction, Minus Incremental Cost Increase to Homes). | 7 plus $CO_2$ range | 384 to 1,065 | 301 to 797 | 520 to 1,457. |
| | 7 | 563 | 431 | 767. |
| | 3 | 849 | 632 | 1,200. |
| | 3 plus $CO_2$ range | 670 to 1,351 | 502 to 999 | 954 to 1,891. |

* The benefits and costs are calculated for homes shipped in 2017–2046.

** The Primary, Low, and High Estimates utilize forecasts of energy prices from the 2015 *AEO* Reference case, Low Economic Growth case, and High Economic Growth case, respectively.

*** The $CO_2$ values represent global monetized values (in 2015$) of the social cost of $CO_2$ emissions reductions over the analysis period under several different scenarios of the SCC model. The ''average SCC case'' refers to average predicted monetary savings as predicted by the SCC model. The ''95th percentile case'' refers to values calculated using the 95th percentile impacts of the SCC model, which accounts for greater than expected environmental damages. The value for $NO_X$ (in 2015$) is the average of the low and high values used in DOE's analysis.

## II. Introduction

*A. Authority*

Section 413 of EISA directs DOE to:

Establish standards for energy conservation in manufactured housing;

• Provide notice of and an opportunity for comment on the proposed standards by manufacturers of manufactured housing and other interested parties;

• Consult with the Secretary of HUD, who may seek further counsel from the Manufactured Housing Consensus Committee (MHCC); and

• Base the energy conservation standards on the most recent version of the IECC and any supplements to that document, except where DOE finds that the IECC is not cost effective or where a more stringent standard would be more cost effective, based on the impact of the IECC on the purchase price of manufactured housing and on total lifecycle construction and operating costs.

Section 413 of EISA also provides that DOE may:

Consider the design and factory construction techniques of manufactured housing;

• Base the climate zones under the proposed rule on the climate zones established by HUD in 24 CFR part 3280 rather than the climate zones under the IECC; and

• Provide for alternative practices that, while not meeting the specific standards established by DOE, result in net estimated energy consumption equal to or less than the specific energy conservation standards as proposed.

DOE is directed to update its standards not later than one year after any revision to the IECC. Finally, section 413 of EISA authorizes DOE to impose civil penalties on any manufacturer that violates a provision of part 460.

*B. Background*

1. Current Regulation of Manufactured Housing

Section 413 of EISA provides DOE with the authority to regulate energy conservation in manufactured housing, an area of the building construction industry traditionally regulated by HUD.

[1] As stated in this preamble, DOE used a two-step calculation process to convert the time-series of costs and benefits into annualized values. First, DOE calculated a present value in 2015, the year used for discounting the net present value of total consumer costs and savings, for the time-series of costs and benefits using discount rates of three and seven percent for all costs and benefits except for the value of $CO_2$ reductions. For the latter, DOE used a range of discount rates, as shown in Table I.8. From the present value, DOE then calculated the fixed annual payment over a 30-year period, starting in 2017 that yields the same present value. The fixed annual payment is the annualized value. Although DOE calculated annualized values, this does not imply that the time-series of cost and benefits from which the annualized values were determined would be a steady stream of payments.

HUD has regulated the manufactured housing industry since 1976, when it first promulgated the HUD Code. The purpose of the HUD Code has been to reduce personal injuries, deaths, property damage, and insurance costs, and to improve the quality, durability, safety, and affordability of manufactured homes. *See* 42 U.S.C. 5401(b).

The HUD Code includes requirements related to the energy conservation of manufactured homes. Specifically, Subpart F of the HUD Code, entitled ''Thermal Protection,'' establishes requirements for $U_o$ of the building thermal envelope. $U_o$ is a measurement of the heat loss or gain rate through the building thermal envelope of a manufactured home; therefore, a lower $U_o$ corresponds with a more insulated building thermal envelope. The HUD Code contains maximum requirements for the combined $U_o$ value of walls, ceilings, floors, fenestration, and external ducts within the building thermal envelope for manufactured homes installed in different climate zones. *See* 24 CFR 3280.507(a).

The HUD Code also provides an alternate pathway to compliance that allows manufacturers to construct manufactured homes that meet adjusted $U_o$ requirements based on the installation of high-efficiency heating and cooling equipment in the manufactured home. *See id.* 3280.508(d). Moreover, Subpart F of the HUD Code establishes requirements to reduce air leakage through the building thermal envelope. *See id.* 3280.505.

Subpart H of the HUD Code, entitled ''Heating, Cooling and Fuel Burning Systems,'' establishes requirements for sealing air supply ducts and for insulating both air supply and return ducts. *See id.* 3280.715(a). *R*-value is the measure of a building component's ability to resist heat flow (thermal resistance). A higher *R*-value represents a greater ability to resist heat flow and generally corresponds with a thicker level of insulation. The HUD Code contains no requirements for fenestration SHGC, mechanical system piping insulation, or installation of insulation.

It is important to note that the statutory authority for DOE's rulemaking effort is different from the statutory authority underlying the HUD Code. EISA directs DOE to establish energy conservation standards for manufactured housing without reference to existing HUD Code requirements that also address energy conservation. In development of the proposed regulations, DOE seeks to make every effort to ensure that compliance with this proposed requirements would not impinge a manufacturer from complying with the requirements set forth in the HUD Code.

Additionally, DOE is seeking to avoid any potential redundancy between the proposed requirements and the HUD Code. Accordingly, section III.D of this document charts the relationship between the energy conservation requirements in the HUD Code and the proposed DOE requirements. Given the level of detail required in analyzing all aspects of energy conservation contained in both the proposed rule and the HUD Code, DOE requests comment on any potential inconsistencies that would result from promulgation of the proposed regulations.

2. The International Energy Conservation Code

The statutory authority for this rulemaking requires DOE to base its standards on the most recent version of the IECC and any supplements to that document, except where DOE finds that the IECC is not cost-effective or where a more stringent standard would be more cost-effective, based on the impact of the IECC on the purchase price of manufactured housing and on total lifecycle construction and operating costs. *See* 42 U.S.C. 17071. The IECC is a nationally recognized model code, developed under the auspices of, and published by, the International Code Council (ICC), which many state and local governments have adopted in establishing minimum design and construction requirements for the energy efficiency of residential and commercial buildings, including site-built residential and modular homes. The IECC is developed through a consensus process that seeks input from industry stakeholders and is updated on a rolling basis, with new editions of the IECC published approximately every three years. The IECC was first published in 1998, and it has been updated continuously since that time. The 2015 edition of the IECC (the 2015 IECC) was published in May 2014.

Chapter 4 of the 2015 IECC sets forth specifications for residential energy efficiency, including specifications for building thermal envelope energy conservation, thermostats, duct insulation and sealing, mechanical system piping insulation, circulating hot water system piping, and mechanical ventilation. Chapter 4 of the 2015 IECC was developed for residential buildings generally and are not specific to manufactured housing. To the extent that the HUD Code regulates similar aspects of energy conservation as the 2015 IECC, the 2015 IECC is generally considered to be more stringent than the corresponding requirement in the HUD Code given that many areas of the HUD Code are not updated as frequently as the IECC.

3. Development of the Proposed Rule

Manufactured housing accounts for approximately six percent of all homes in the United States.[2] Because the purchase price of manufactured homes often is lower than similarly sized site-built homes, manufactured homes serve as affordable housing options, particularly for low-income families. Nevertheless, the operational costs to the homeowner may not be reflected in the purchase price of the home. Manufactured housing home owners often have higher utility bills than comparably built site-built and modular homes in part due to different criteria for energy conservation and variability among building codes and industry practice.

Establishing robust energy conservation requirements for manufactured homes would result in the dual benefit of substantially reducing manufactured home energy use and easing the financial burden on owners of manufactured homes in meeting their monthly utility expenses. Improved energy conservation standards are expected to provide nationwide benefits of reducing utility energy production levels that would in turn reduce greenhouse gas emissions and other air pollutants.

On February 22, 2010, DOE published an advance notice of proposed rulemaking (ANOPR) to initiate the process of developing energy conservation standards for manufactured housing and to solicit information and data from industry and stakeholders. *See* 75 FR 7556. The ANOPR identified thirteen specific issue areas on which DOE sought additional information. DOE received a total of twelve written comments in response to the ANOPR, all of which are available for public viewing at the regulations.gov Web page.[3]

DOE also has consulted with HUD in developing the proposed requirements and in obtaining input and suggestions that would increase energy conservation in manufactured housing while maintaining affordability. In addition to meeting with HUD on multiple occasions, DOE attended three MHCC

[2] *See* U.S. Census Bureau, *American Housing Survey 2013—National Summary Tables.*

[3] The ANOPR comments can be accessed at: *http://www.regulations.gov/#!docketDetail;D=EERE-2009-BT-BC-0021.*

meetings, where DOE gathered information from MHCC members. DOE also initiated further discussions with members of the manufactured housing industry following the issuance of the ANOPR, including the Manufactured Housing Institute and several of its member manufacturers, the State of California Department of Housing and Community Development, the State of Georgia Manufactured Housing Division, three private sector third-party primary inspection agencies under the HUD manufactured housing program, and one private sector stakeholder familiar with manufactured housing. A summary of each meeting is available at the regulations.gov Web page.

The following section provides a summary of comments DOE received in response to the ANOPR. Generally, the comments can be grouped into five main areas: Climate zones; the basis for the proposed standards; specific building thermal envelope requirements; enforcement of DOE's proposed energy conservation standards; and the need for, and scope of, the proposed rule.

Regarding the issue of climate zones, DOE received comments recommending that DOE define climate zones at the county level, possibly based on the climate zones established in the IECC or on a subset of those climate zones to align with the requirements for site-built homes. Generally, these commenters stated that the IECC climate zones are recognized and understood by the manufacturing and regulatory sectors. Conversely, DOE received other comments indicating a preference for retaining the three climate zones established in the HUD Code. DOE also received comments suggesting that DOE consider more refined climate zones in the southern United States, noting the abundance of manufactured homes sold in that region of the country. As discussed in section III.B.2.a) of the document, DOE proposes to base its energy conservation standards on four climate zones. DOE requests comment on the proposed use of four climate zones relative to adopting the three HUD climate zones and whether there are any potential impacts on manufacturing costs, compliance costs, or other impacts, in particular in Arizona, Texas, Louisiana, Mississippi, Alabama, and Georgia, where the agency has proposed two different energy efficiency standards within the same state.

DOE received numerous comments suggesting that DOE base its proposed energy conservation standards on the IECC rather than on the energy conservation standards established by HUD. Specifically, one commenter stated that IECC training and related support services would be available if DOE based its energy conservation standards on the IECC that would be absent if DOE used a different basis for the proposed energy conservation standards. Another commenter suggested that the proposed energy conservation standards should be at a minimum as efficient as the requirements contained in the most recent edition of the IECC or better where lifecycle cost effective. One commenter stated that the IECC was not intended to apply to manufactured housing and that DOE should consider altering IECC standards to be compatible with manufactured housing building processes. However, another commenter stated that there are no intrinsic differences between site-built and factory-built construction techniques that would limit DOE from proposing energy conservation standards to the level set forth in the most recent edition of the IECC and beyond.

Other commenters discussed specific energy conservation requirements that should be included in the proposed rule, including requiring high-efficiency furnaces, boilers, and heat pump heating in colder climate zones, high-efficiency air conditioners in warmer climate zones, ENERGY STAR appliances, and improved lighting systems, where cost-effective. Commenters also requested that DOE consider requiring *R*-5 windows, passive solar design, and establishing provisions to address barriers to future technology. Conversely, one commenter stated that the HUD Code balances requirements related to both air leakage and condensation. Other commenters requested that DOE consider the National Fire Protection Association (NFPA) Standard on Manufactured Housing in developing its proposed standards and that DOE also consider certain applicable requirements contained in the International Residential Code. Another commenter suggested that DOE develop standards that would allow above-code programs, such as ENERGY STAR, to build upon the requirements set forth by DOE. DOE also received several comments that manufactured homes should be as energy efficient as site-built and modular homes while asserting that DOE's energy conservation standards be no more stringent than the requirements for site-built housing. However, it also was suggested that DOE consider establishing one or more performance tiers above the minimum DOE energy conservation standards, with associated incentives for manufacturers, to drive the market for high performance manufactured housing.

As discussed further in section III.A of this document, DOE proposes to base its energy conservation standards on the 2015 IECC while accounting for the potential effects on purchase price, total lifecycle construction and operating costs, and design and factory construction techniques unique to manufactured homes.

With respect to the potential effects of the proposed rule on purchase price and total lifecycle construction and operating costs, DOE received comments providing specific information that assisted DOE in its preliminary economic analyses for developing the proposed requirements. Regarding the issue of home financing, commenters recommended that DOE's economic analysis on financing assume terms of loans similar to those for new site-built homes, accompanied by a three percent discount rate. Other commenters suggested that DOE's economic analyses assume terms of loans that reflect a mix of real estate and personal property loans that are reflective of the market share of each type of loan and that account for historical trends in loans for manufactured housing. Another commenter suggested that DOE account for conventional financing rates of five to seven percent and assume full resale recovery, as recognized by the National Automobile Dealers Association in appraisal value for ENERGY STAR-labeled manufactured homes.

It was suggested that DOE account for volume procurement purchasing prices, collect cost data from manufacturers and major suppliers provided in manufactured homes by state and region, and use standard industry mark-ups in conducting its economic analyses. Commenters also stated that any increase in the purchase price of a manufactured home could exacerbate the lack of affordable housing. Commenters further stated that although manufacturers offer manufactured homes that exceed the energy conservation requirements contained in the HUD Code, financing the cost of those additional energy features often is an obstacle to such homes being purchased. Accordingly, it was suggested that DOE apply the same analytical framework that DOE uses for developing energy efficiency standards for appliances in developing the proposed energy conservation standards. Specifically, one commenter suggested that DOE conduct parametric and statistical modeling analyses accounting for various factors, including single-wide versus multi-wide manufactured homes, differences among fuel types, duct locations, eliminating various ''trade-offs,'' and evaluating solar thermal and photovoltaic systems in establishing the proposed standards.

With respect to design and construction techniques unique to manufactured homes, DOE received several comments highlighting that the manufactured housing industry has been producing manufactured homes that exceed the energy conservation requirements contained in the HUD Code. One commenter stated that since 1989, over 100,000 manufactured homes had been built in the Pacific Northwest region of the United States that have an energy efficiency level that complies with the most recent version of the IECC. Another commenter provided specific examples of manufactured homes that exceeded the energy conservation requirements contained in the HUD Code. Indeed, DOE received comments stating that 90 percent of manufactured housing builders had adopted the U.S. Environmental Protection Agency (EPA) ENERGY STAR program for manufactured housing. Another commenter suggested that DOE utilize research results and information from the DOE Building America Program and the Partnership for Advancing Technology in Housing program at HUD in developing the proposed energy conservation standards and in determining the costs and benefits of more stringent standards. It was suggested that DOE also evaluate products such as foam wall sheathing, innovative roof systems, and solar thermal and photovoltaic systems in developing the proposed energy conservation standards, and to obtain information from HVAC equipment manufacturers on available equipment efficiencies specific to manufactured homes.

With respect to design and construction techniques unique to manufactured homes, one commenter suggested that DOE adopt the energy efficiency specifications contained in the IECC unless something unique about the production of a manufactured home necessitated a different standard. Another commenter stated that DOE should coordinate with HUD on the development of the proposed rule and to make recommendations to HUD on non-energy-related issues for HUD consideration in updating the HUD Code. Specifically, it was suggested that DOE recognize exterior height and width limitations of manufactured homes in its proposed standards. DOE has attempted to address these comments by proposing thermal performance requirements that are similar to the HUD Code, while proposing other specific energy conservation requirements that are based on the requirements set forth in the 2015 edition of the IECC. DOE also has attempted to address unique aspects of manufactured homes in the proposed rule that would not be addressed by the proposed requirements for overall thermal performance.

Regarding specific building thermal envelope requirements, DOE received a number of comments requesting that DOE retain the thermal envelope performance approach set forth in the HUD Code, rather than component prescriptive measures, in order to facilitate application and use of innovative technology and materials. Another commenter suggested that DOE consider HUD's *U*-factor calculation manual in developing the proposed standards. As discussed in section III.B.2.b) of this document, DOE proposes to establish thermal envelope requirements as a function of the overall thermal transmittance of the building thermal envelope of a manufactured home for consistency with the approach set forth in the HUD Code. DOE also proposes prescriptive requirements as an alternative to the $U_o$ requirement.

Regarding compliance with, and enforcement of, DOE's proposed energy conservation standards, DOE received a range of comments. First, DOE received comments suggesting that DOE rely on HUD's existing enforcement system rather than develop a separate DOE system of enforcement. Specifically, one commenter suggested that DOE consider using the existing HUD-approved third-party primary inspection agencies to ensure compliance with both HUD and DOE requirements for manufactured housing in order to avoid an increase in manufacturer fees and the creation of a duplicative system of compliance certification. Another commenter suggested that the HUD label be modified to reflect compliance with both the HUD and DOE requirements. Secondly, DOE received a comment that DOE develop a separate compliance certification system that would be independent of the existing HUD certification system. In this regard, it was suggested that DOE conduct in-plant and onsite inspections and audits using the DOE Building America Program and ENERGY STAR quality assurance protocols. It also was suggested that DOE's certification system ''complement'' the existing HUD system and that prospective DOE third-party certifiers receive adequate training to ensure that inspections would be conducted properly. Another commenter suggested that DOE rely on the EPA ENERGY STAR verification and labeling program to ensure compliance with the DOE energy conservation standards. One commenter suggested that DOE check the quality of construction while asserting that HUD should enforce violations of the DOE energy conservation standards. Furthermore, a commenter suggested that all manufactured homes be labeled using the DOE EnergySmart Home scale tool to demonstrate compliance with the proposed energy conservation standards.

Finally, DOE received comments questioning the need for the development of energy conservation standards, noting the state of the housing market and the time and cost associated with the process to develop such requirements. Conversely, DOE received other comments indicating that more stringent energy conservation requirements are ''urgently needed'' to prevent lost opportunities for energy and operating cost savings that are not currently being captured. DOE also was asked to consider adopting various energy efficiency improvements contained in the 2010 version of NFPA Standard 501. DOE received further comments indicating that the manufactured housing industry is in the unique position to meet national energy conservation goals while preserving home affordability. One commenter stated that increases in the purchase price of manufactured homes due to energy conservation improvements could raise issues of affordability without government subsidies or incentives. Another commenter similarly stated that raising energy conservation standards too quickly could impact manufacturers' ability to modify their in-plant production and site-installation processes and procedures. Other commenters requested that DOE delay the effective date of any energy conservation requirements due to current economic conditions in order to give manufacturers sufficient time to meet the new energy conservation standards. Finally, commenters urged DOE to consult and collaborate with HUD, EPA, and the manufactured housing industry in development of the proposed rule. DOE notes that it is required by statute to set forth energy conservation standards for manufactured homes, and DOE carefully has considered comments regarding the scope of the proposed rule in developing the energy conservation requirements proposed herein.

On June 25, 2013, DOE published a request for information (RFI) seeking information on indoor air quality, financing and related incentives, model systems of enforcement, and other studies and research relevant to DOE's effort to establish conservation standards for manufactured housing. (78 FR 37995) With regard to indoor air quality, one commenter mentioned that reductions in air leakage can lead to increased formaldehyde concentrations and noted that increased mechanical ventilation also can increase moisture infiltration in humid climates, potentially leading to deleterious impacts such as mold growth. Several other commenters noted that there have been no reported issues with occupant health in energy efficient homes that have been sealed tightly to reduce air infiltration. Moreover, commenters noted that a home that is equipped with proper mechanical ventilation, such as the mechanical ventilation level required by the HUD Code, is adequate to ensure indoor air quality. DOE is preparing the draft EA in parallel with this rulemaking, and it will be posted to the DOE Web site separately. This draft EA will discuss the relationship among indoor air quality, air leakage, and occupant health.

Comments on financing focused on the affordability of manufactured housing and the potential impacts of the proposed rule on the ability of purchasers of manufactured homes to qualify for financing. Commenters noted that increased costs associated with more energy efficient homes could have a negative impact on affordability in an industry in which the majority of home purchasers are low-income individuals and families. DOE has designed the proposed standards to achieve greater energy conservation in manufactured housing while accounting for the costs and benefits of the proposed standards on manufactured homeowners. In this regard, DOE has analyzed the lifecycle costs to low-income purchasers of manufactured homes (*see* chapter 9 of the TSD) and potential changes in manufactured home shipments in response to changes in purchase price (*see* chapter 10 of the TSD).

Commenters generally agreed that DOE should integrate a program of compliance and enforcement into the existing structure utilized by HUD. Commenters also noted, however, that DOE should maintain a role in overseeing enforcement of its standards. Although DOE is not considering compliance and enforcement in this proposed rule, DOE will consider these comments in a future rulemaking if appropriate.

DOE received other comments and data, including information on the average term of a manufactured housing loan. Another commenter stated that DOE should establish requirements that achieve the greatest possible energy conservation in manufactured housing, as the benefits of potential energy savings would outweigh potential increased purchase prices. Another commenter suggested that DOE develop standards that match the IECC as closely as possible. Finally, a commenter suggested that DOE abandon its rulemaking effort and begin the process anew while a set of joint commenters urged DOE to expedite publishing of a proposed rule. DOE has considered these comments in its analysis and the development of this proposed rule.

After reviewing the comments received in response both to the ANOPR and to the June 2013 RFI and other stakeholder input, DOE ultimately determined that development of proposed manufactured housing energy conservation standards would benefit from a negotiated rulemaking process. On June 13, 2014, DOE published a notice of intent to establish a negotiated rulemaking MH working group to discuss and, if possible, reach consensus on a proposed rule. *See* 79 FR 33873. On July 16, 2014, the MH working group was established under ASRAC in accordance with the Federal Advisory Committee Act and the Negotiated Rulemaking Act. *See* 79 FR 41456; 5 U.S.C. 561–70, App. 2. The MH working group consisted of representatives of interested stakeholders with a directive to consult, as appropriate, with a range of external experts on technical issues in development of a term sheet with recommendations on the proposed rule. The MH working group consisted of 22 members, including one member from ASRAC and one DOE representative. The MH working group met in person during six sets of public meetings held in 2014 on August 4–5, August 21–22, September 9–10, September 22–23, October 1–2, and October 23–24. *See* 79 FR 48097; 79 FR 59154.

On October 31, 2014, the MH working group reached consensus on energy conservation standards in manufactured housing and assembled its recommendations for DOE into a term sheet that was presented to ASRAC. *See* public docket EERE–2009–BT–BC–0021–0107 (Term Sheet). ASRAC approved the term sheet during an open meeting on December 1, 2014, and sent it to the Secretary of Energy to develop a proposed rule.

On February 11, 2015, DOE published an RFI (the 2015 RFI) requesting information that would aid in its determination of proposed SHGC requirements for certain climate zones. (80 FR 7550) One commenter indicated that DOE's negotiated rulemaking process was analytically flawed and made many procedural errors in carrying out the rulemaking process, including the operation of the MH working group and the interpretation of the underlying statutory directive on accounting for cost-effectiveness. This commenter also provided alternative cost data for use in the cost-benefit analysis. DOE has included a more detailed discussion of the comments received in response to the request for information in section III.B of this document.

Following preparation and submission of the term sheet by the MH working group, DOE engaged in further consultation with HUD regarding DOE's proposed energy conservation standards. In addition to meeting with HUD, DOE prepared two presentations to discuss the proposed rule with the MHCC members, designed to gather information on the development of the proposed standards.

DOE has considered all information ascertained from HUD, state agencies, the manufactured housing industry, and the public in developing the proposed rule. In an attempt to understand how certain requirements included in DOE's proposed rule would impact other aspects of the design and construction of manufactured homes, DOE also has carefully reviewed the HUD Code to ensure that the proposed rule would avoid unintended conflicts with HUD requirements both related and unrelated to energy conservation.

The MH working group was established to negotiate energy conservation standards for manufactured housing and did not address options for systems of compliance and enforcement. DOE thus has not included proposed compliance and enforcement provisions in this document. DOE maintains its authority to address these issues in a future rulemaking.

DOE also has not included proposed provisions related to waivers or exception relief that would be available to manufacturers in achieving compliance with this Part. Regarding waivers, DOE is interested in receiving information on whether a process is warranted by which a manufacturer could petition DOE for relief from an individual requirement. DOE also seeks public input on whether to establish proposed provisions for exception relief, which would be warranted in instances in which compliance with the proposed regulations would result in serious hardship, gross inequity, or unfair distribution of burdens on the part of a manufacturer. DOE may consider including proposed provisions in this regard in a future rulemaking.

## III. Discussion

### *A. The Basis for the Proposed Standards*

EISA requires that DOE establish energy conservation standards for manufactured housing that are ''based on the most recent version of the [IECC] . . . , except in cases in which [DOE] finds that the [IECC] is not cost-effective, or a more stringent standard would be more cost-effective, based on the impact of the [IECC] on the purchase price and on total life-cycle construction and operating costs.'' *See* 42 U.S.C. 17071(b). Given that the 2015 edition of the IECC (the 2015 IECC) constitutes ''the most recent version of the IECC,'' the MH working group based its recommendations on the specifications included in the 2015 IECC that are appropriate for manufactured homes, which DOE has considered in developing the proposed rule.

As noted above, the 2015 IECC applies generally to residential buildings, including site-built and modular housing, and is not specific to the manufactured housing industry. Consistent with the recommendations of the MH working group, DOE proposes standards that are based on certain specifications included in the 2015 IECC and that account for the unique aspects of manufactured housing. DOE carefully considered the following aspects of manufactured housing design and construction in developing the proposed standards:

- Manufactured housing structural requirements contained in the HUD Code;
- External dimensional limitations associated with transportation restrictions;
- The need to optimize interior space within manufactured homes; and
- Factory construction techniques that facilitate sealing the building thermal envelope to limit air leakage.

Based on these considerations, and consistent with the recommendations of the MH working group, DOE is proposing certain requirements that differ from similar provisions contained in the 2015 IECC. These include presenting the building thermal envelope requirements in terms of $U_o$ of the entire building thermal envelope, accounting for space limitations in ceiling assemblies when establishing insulation requirements and other revisions to ensure the text is applicable to manufactured housing.

Additionally, the MH working group recommended, and DOE considered, in developing this proposed rule the potential effects on purchase price and total lifecycle construction and operating costs, design and factory construction techniques unique to manufactured homes, and the impacts of reliance on the climate zones established by HUD and as set forth in the 2015 IECC. A detailed discussion of each of these issues is contained in chapter 8 of the TSD and sections III.B and III.C of this document.

The following section discusses in detail the proposed energy conservation standards as set forth in the proposed rule. Subpart A as proposed contemplates the scope of the proposed standards, proposed definitions of key terms, and other commercial standards that would be incorporated by reference into this part. The subpart also proposes a compliance date of one year following the publication of the final rule.

Proposed subpart B would include energy conservation requirements associated with the building thermal envelope of a manufactured home according to the climate zone in which the home is located. DOE proposes to base its building thermal envelope energy conservation standards on four climate zones, which generally follow state borders with some exceptions. DOE proposes two options to ensure an appropriate level of thermal transmittance through the building thermal envelope. The first approach contemplates prescriptive requirements for components of the building thermal envelope. The second is a performance-based approach under which a manufactured home would be required to achieve a maximum $U_o$ in addition to fenestration *U*-factor and SHGC requirements. Subpart B also would establish prescriptive requirements for insulation and sealing the building thermal envelope to limit air leakage.

Subpart C would include requirements related to duct leakage; HVAC thermostats and controls; service water heating; mechanical ventilation fan efficacy; and equipment sizing.

As noted in this preamble, EISA requires DOE to update its energy conservation standards for manufactured housing not later than one year after any revision to the IECC. Pursuant to this statutory direction, DOE intends to update its energy conservation standards for manufactured housing, if promulgated, within one year of the publication of any revision to the 2015 IECC. This proposed rule invites comments on all DOE proposals and issues presented herein, and requests comments, data, and other information that would assist DOE in developing a final rule.

### *B. Proposed Energy Conservation Requirements*

1. Subpart A: General

(a) § 460.1 Scope

Pursuant to section 413 of EISA, Congress directed DOE to establish standards for energy conservation in manufactured housing. Section 460.1 would restate the statutory requirement and introduce the scope of the proposed requirements. Section 460.1 also would require manufactured homes that are manufactured on or after one year following publication of the final rule to comply with the requirements established in part 460.

DOE proposes a one-year period following publication of a final rule to allow manufacturers to transition their designs, materials, and factory operations and processes to comply with the finalized DOE energy conservation standards and regulations. A one-year notice period is common industry practice for amendments to the IECC and other changes to building codes; however, DOE seeks input on whether these standards are analogous to IECC or whether they would impose a different level of manufacturer research and effort to comply. In addition, DOE seeks comment on whether additional lead time is necessary to harmonize compliance and enforcement with HUD's manufactured housing program, redesign manufactured housing to meet the standards, and test and certify the new designs. The agency also requests comment on whether there are any particular timing considerations that the agency should consider due to manufacturers choosing to comply with either the prescriptive or thermal envelope compliance paths. DOE requests comment on the scope and effective date of the proposed rule and whether the proposed effective date would provide manufacturers sufficient lead time to prepare to comply with the standards.

(b) § 460.2 Definitions

Section 460.2 would define key terms used throughout the proposed regulations, many of which were derived from either the 2015 IECC or the HUD Code, with modifications where further clarification was needed in the context of manufactured housing. Proposed definitions based on terms included in the 2015 IECC were developed in accordance with recommendations from the MH working group. *See* Term Sheet at 1. DOE has included a discussion of each of the proposed definitions in the following paragraphs.

(a) Accessible. DOE proposes to adopt the definition of the term ''accessible'' from the 2015 IECC while clarifying that the definition would allow access to certain labels or control interfaces that require close approach upon inspection or repair.

(b) Air barrier. The term ''air barrier'' also would be based on the definition of the same term in the 2015 IECC while clarifying that an air barrier could consist of a single material or combination of materials. DOE intends for the definition of this term to include the materials involved in limiting air leakage to meet air sealing requirements and requests comment on whether further clarification is needed on the meaning in this regard.

(c) Automatic. DOE proposes to adopt the definition of the term ''automatic'' from the 2015 IECC. The terms ''automatic'' and ''manual'' would differentiate between controls that are operated by impersonal (automatic) and personal (manual) influences.

(d) Building thermal envelope. DOE has derived the proposed definition of ''building thermal envelope'' from the definition of the same term in the 2015 IECC, with revisions that account for the manner in which manufactured homes are designed and constructed. The proposed definition does not include basement walls, for example, given the unique construction of a manufactured home relative to a site-built home.

(e) Ceiling. DOE proposes to define the term ''ceiling,'' which is not defined in the 2015 IECC or the HUD Code, to ensure specificity with the proposed prescriptive standards of part 460.

(f) Circulating hot water system. DOE would define the term ''circulating hot water system'' to be consistent with the 2015 IECC to describe water distribution systems in a manufactured home that uses a pump to circulate water between water-heating equipment and fixtures.

(g) Climate zone. DOE proposes to define the term ''climate zone'' in accordance with the term as defined in the 2015 IECC, with revisions as applicable to the specific geographic regions set forth in the proposed rule. The proposed rule establishes different energy conservation standards for manufactured homes located in different climate zones.

(h) Conditioned space. DOE would adopt the definition of the term ''conditioned space'' from the 2015 IECC to describe areas, rooms, or spaces that are enclosed within the building envelope.

(i) Continuous air barrier. DOE proposes to adopt the definition of the term ''continuous air barrier'' from the 2015 IECC to encompass the material or combination of materials that limit air leakage through the building thermal envelope.

(j) Door. DOE would define the term ''door,'' which is not defined in the 2015 IECC or the HUD Code, to ensure specificity with the proposed prescriptive standards of part 460.

(k) Dropped ceiling. DOE proposes to define the term ''dropped ceiling,'' which is not defined in the 2015 IECC or the HUD Code, to ensure specificity with the proposed standards under §§ 460.103(a) and 460.104.

(l) Dropped soffit. DOE would define the term ''dropped soffit,'' which also is not defined in the 2015 IECC or the HUD Code, to ensure specificity with the proposed prescriptive standards under §§ 460.104(a) and 460.104.

(m) Duct. DOE proposes to adopt the definition of the term ''duct'' from the 2015 IECC to include tubes or conduits, except air passages within a self-contained system, used for conveying air to or from heating, cooling, or venting equipment.

(n) Duct system. DOE proposes to define the term ''duct system'' as derived from the meaning of the term under the 2015 IECC to refer to a continuous passageway for the transmission of air, composed of ducts and other required accessories.

(o) Eave. DOE would define the term ''eave,'' which is not defined in the 2015 IECC or the HUD Code, to ensure specificity with the proposed prescriptive standards under §§ 460.103(a) and 460.104.

(p) Equipment. DOE proposes to define the term ''equipment,'' which is not defined in the 2015 IECC or the HUD Code, to add further clarification to the meaning of the proposed prescriptive provisions of this part.

(q) Exterior wall. DOE proposes to adopt the definition of the term ''exterior wall'' from the 2015 IECC and describes walls that enclose conditioned space.

(r) Fenestration. DOE would derive the definition of the term ''fenestration'' from the 2015 IECC, which encompasses both vertical fenestration and skylights. DOE requests comment on whether to amend the definition of ''fenestration'' to include tubular daylighting devices.

(s) Floor. DOE proposes to define the term ''floor,'' which is not defined in the 2015 IECC or the HUD Code, to ensure specificity with the proposed prescriptive standards of part 460.

(t) Glazed or glazing. DOE would define the terms ''glazed'' or ''glazing,'' which are not defined in the 2015 IECC or the HUD Code, to ensure specificity with the proposed prescriptive standards of this Part and for consistency with the meaning of the terms as used in the National Fenestration Rating Council Standard 100–2004.

(u) Infiltration. DOE proposes to adopt the definition of the term ''infiltration'' from the 2015 IECC, which describes the uncontrolled air leakage into a manufactured home.

(v) Insulation. DOE would define the term ''insulation'' to mean material qualifying as ''insulation'' for consistency with the U.S. Federal Trade Commission definition of insulation and to ensure specificity with the proposed standards of part 460.

(w) Manufactured home. DOE proposes to adopt the same definition of ''manufactured home'' as used in the HUD Code in order to ensure consistency among both agencies' regulations.

(x) Manufacturer. As discussed below, the underlying statutory authority for this rulemaking does not define the term ''manufacturer.'' DOE proposes to adopt the definition of the term under the HUD Code to mean any person engaged in the factory construction or assembly of a manufactured home, including any person engaged in import of a manufactured home for resale.

(y) Manual. DOE proposes to define the term ''manual'' to be consistent with the 2015 IECC. As stated in this preamble, the terms ''automatic'' and ''manual'' would differentiate between controls that are operated by impersonal (automatic) and personal (manual) influences.

(z) *R*-value (thermal resistance). DOE would adopt the definition of the term ''*R*-value'' from the 2015 IECC to refer to a defined quantitative measure of the resistance to heat flow of a material or assembly of materials.

(A) Rough opening. The term ''rough opening,'' which is not defined in the 2015 IECC or the HUD Code, would identify the location corresponding to the area of an assembly containing fenestration.

(B) Service hot water. DOE proposes to adopt the definition of the term ''service hot water'' from the 2015 IECC to refer to the supply of hot water for uses other than space or comfort heating, such as for bathing.

(C) Skylight. DOE proposes to define the term ''skylight'' based on the meaning of the term in the 2015 IECC, clarifying that the term includes the entire assembly of glass or other transparent or translucent glazing material and the frame, installed at a slope of less than 60 degrees from the horizontal.

(D) Solar heat gain coefficient (SHGC). DOE would adopt the definition of the term ''solar heat gain coefficient'' from the 2015 IECC. SHGC is an important property of transparent or translucent fenestration that affects the heat gain and loss of the building thermal envelope. The SHGC of a fenestration assembly is defined as the ratio of the amount of solar heat gain transmitted or reradiated through the assembly to the amount of incident solar radiation.

(E) State. The term ''state'' would include each of the 50 states, the District of Columbia, the Commonwealth of Puerto Rico, Guam, the U.S. Virgin Islands, and American Samoa.

(F) Thermostat. DOE proposes to adopt the definition of the term ''thermostat'' from the 2015 IECC to describe automatic control devices used to maintain a given temperature.

(G) *U*-factor (thermal transmittance). DOE would adopt the definition of the term ''*U*-factor'' from the 2015 IECC to refer to a defined quantitative measure of the transmittance of heat of a material or assembly of materials.

(H) $U_o$ (overall thermal transmittance). DOE proposes to define the term $U_o$ (overall thermal transmittance), which is not defined in the 2015 IECC or HUD Code, as the coefficient of heat transmission (air to air) through the entire building thermal envelope, equal to the time rate of heat flow per unit area and unit temperature difference between the warm side and cold side air films.

(I) Ventilation. DOE proposes to adopt the definition of the term ''ventilation'' from the 2015 IECC to refer to the supply or removal of air from any space by natural or mechanical means.

(J) Vertical fenestration. DOE would adopt the definition of the term ''vertical fenestration'' from the 2015 IECC to include materials, such as windows and doors that may be glazed or opaque, installed at an angle of greater than or equal to 60 degrees from horizontal.

(K) Wall. DOE proposes to define the term ''wall,'' which is not defined in the 2015 IECC or the HUD Code, to ensure specificity with the proposed standards under this Part.

(L) Whole-house mechanical ventilation system. DOE proposes to adopt the definition of the term ''whole-house mechanical ventilation system'' from the 2015 IECC to refer to a mechanical system that is designed to exchange indoor air with outdoor air either periodically or continuously.

(M) Window. DOE proposes to define the term ''window,'' which is not defined in the 2015 IECC or the HUD Code, to ensure specificity with the proposed standards under this part.

(N) Zone. DOE would adopt the definition of the term ''zone'' from the 2015 IECC to apply to controls within a manufactured home and to refer to a space or group of spaces within a manufactured home with sufficiently similar requirements for heating and cooling that can be maintained using a single controlling device.

DOE would not include certain definitions that are contemplated in the 2015 IECC, including ''above-grade wall,'' ''addition,'' ''alteration,'' ''approved,'' ''approved agency,'' ''basement wall,'' ''building,'' ''building site,'' ''C-factor,'' ''code official,'' ''commercial building,'' ''conditioned floor area,'' ''continuous insulation,'' ''curtain wall,'' ''demand recirculation water,'' ''DOE,'' ''energy analysis,'' ''energy cost,'' ''energy simulation tool,'' ''energy rating index (ERI) reference design,'' ''fenestration product,'' ''site-built,'' ''F-factor,'' ''heated slab,'' ''high-efficacy lamps,'' ''historic building,'' ''insulating sheathing,'' ''insulated siding,'' ''labeled,'' ''listed,'' ''low-voltage lighting,'' ''proposed design,'' ''rated design,'' ''readily accessible,'' ''repair,'' ''reroofing,'' ''residential building,'' ''roof assembly,'' ''roof recover,'' ''roof repair,'' ''roof replacement,'' ''standard reference design,'' ''sunroom,'' ''thermal envelope,'' ''thermal isolation,'' ''ventilation air,'' and ''visible transmittance.'' These terms are either not relevant to manufactured housing or not relevant to the energy conservation requirements proposed in this subpart.

DOE requests comment on each of the proposed definitions and seeks input on the need for additional clarification to ensure consistency among the HUD Code and general industry practice.

(c) § 460.3 Materials Incorporated by Reference

DOE proposes to incorporate certain materials by reference in the proposed rule, including Air Conditioning Contractors of America (ACCA) Manual J; ACCA Manual S; and ''Overall *U*-Values and Heating/Cooling Loads—Manufactured Homes'' by Conner and Taylor (the Battelle Method). ACCA Manuals J and S would be incorporated by reference in accordance with § 460.205 of this subpart and would relate to the selection and sizing of heating and cooling equipment. The Battelle Method is an industry standard methodology for calculating the overall thermal transmittance of a manufactured home. The Battelle method currently is referenced in the HUD Code for calculation of overall thermal transmittance. To maintain consistency with the practices of the manufactured home industry, DOE has determined these materials are appropriate for inclusion in the proposed rule.

2. Subpart B: Building Thermal Envelope

DOE proposes to establish energy conservation standards for manufactured housing based on the size and geographic location of a home, as doing so would allow DOE to capture a more accurate balance between energy conservation and cost-effectiveness in developing its standards. For example, manufactured homes frequently are identified by size, including single-section and multi-section homes. Manufactured homes of varying size are capable of reaching different levels of energy conservation based on the ratio of floor square footage to building thermal envelope surface area. A single energy conservation standard for manufactured homes of all sizes thus would be more difficult to achieve in a single-section homes as compared to a multi-section home. Consistent with the recommendations of the MH working group, DOE proposes to establish different standards for manufactured homes located in different regions of the country and for manufactured homes of different size. Subpart B reflects DOE's proposed approach in this regard, and DOE requests comment in this regard.

(a) § 460.101 Climate Zones

Pursuant to EISA, DOE may consider basing its energy conservation standards on the climate zones established by HUD rather than on the climate zones contained in the IECC. *See* 42 U.S.C. 17071(b)(2)(B). The potential for climatic differences to affect energy consumption supports an approach in which energy conservation standards account for geographic differences in climate. For example, the appropriate level of insulation for a manufactured home located in southern Florida would not necessarily be appropriate for a manufactured home located in New Hampshire.

As indicated in Figure III.1, the HUD Code divides the United States into three distinct climate zones for the purpose of setting its building thermal envelope requirements, the boundaries of which are separated along state lines. Conversely, as indicated in Figure III.2, section R301.1 of the 2015 IECC divides the country into eight climate zones, the boundaries of which are separated along county lines. The 2015 IECC also provides requirements for three possible variants (dry, moist, and marine) within certain climate zones, as indicated in Figure III.2. The HUD Code climate zones were developed to be sensitive to the manner in which the manufactured housing industry constructed and placed manufactured homes into the market. The 2015 IECC climate zones are separated along county lines to reflect a more accurate overview of climate distinctions within the United States and to facilitate state and local enforcement of the IECC for residential and commercial buildings, including site-built and modular construction.

**Figure III.1 Climate Zones in the HUD Code**

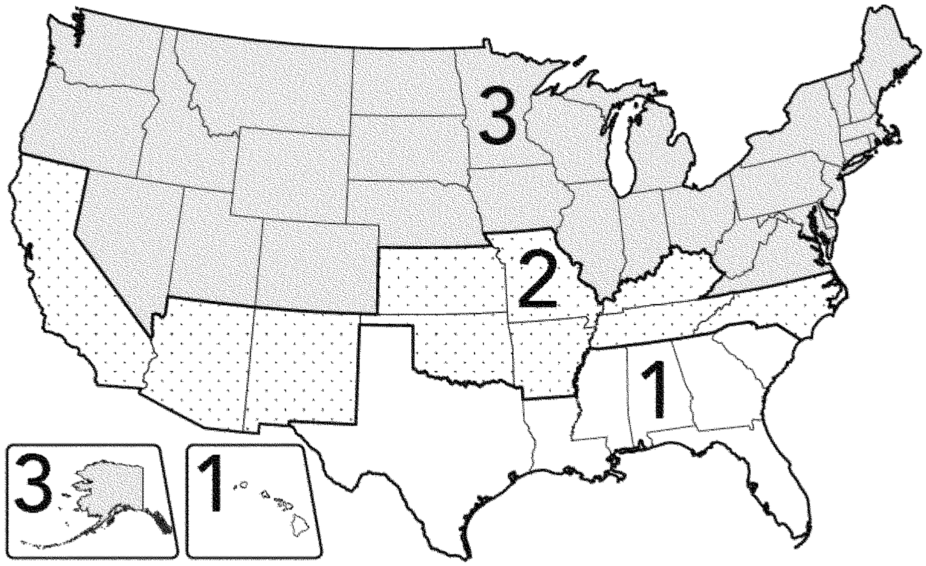
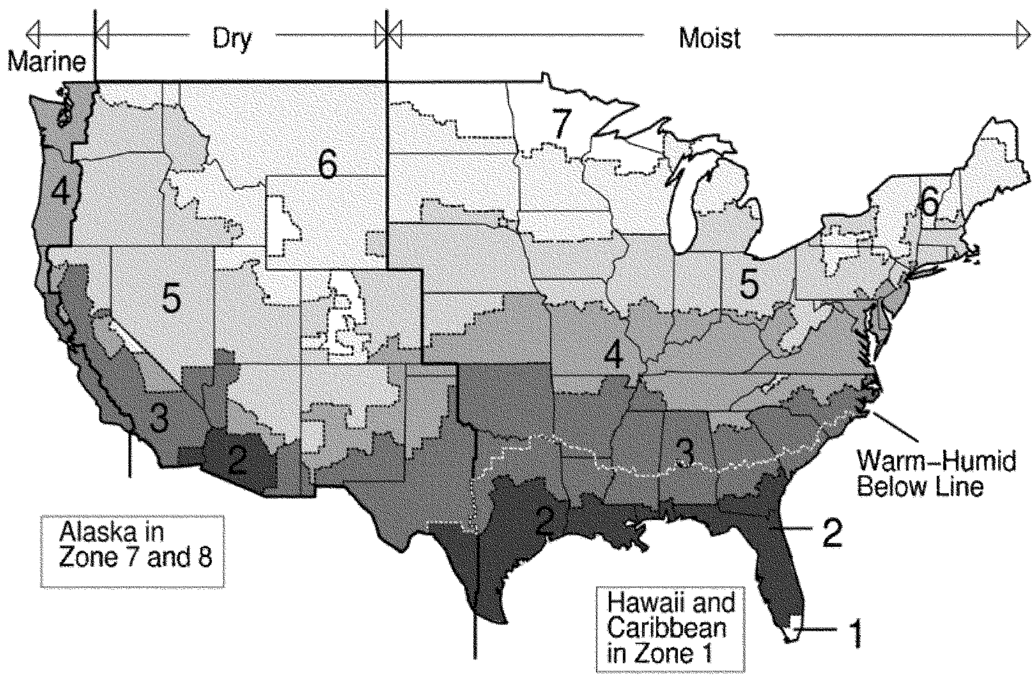


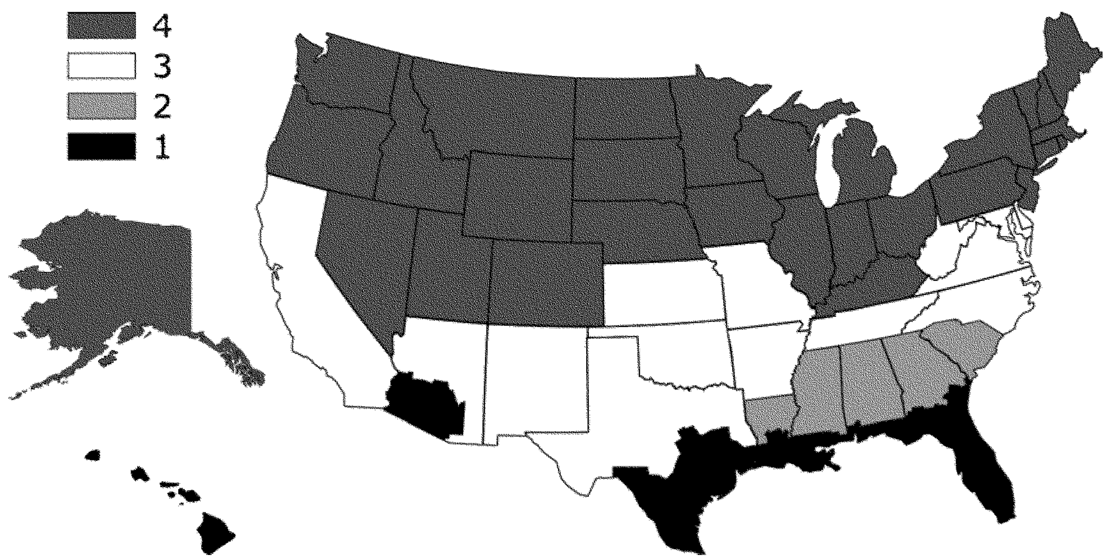

**Figure III.2 Climate Zones in the 2015 IECC**




The 2015 IECC includes climate zone-specific prescriptive energy conservation specifications for the building thermal envelope. In accounting for the design and factory construction techniques for manufactured homes, the MH working group recommended that DOE perform a LCC analysis on various cities located in each of the 2015 IECC climate zones. The MH working group also recommended that DOE incorporate into its LCC analysis several alternatives to certain 2015 IECC prescriptive specifications, including alternative levels of insulation in ceilings, walls, and floors.

DOE calculated the LCC for various alternatives to the 2015 IECC prescriptive specifications for 19 cities, representing a geographically diverse set of climates, with at least one city in each of the 2015 IECC climate zones. As discussed in greater detail in section III.B.2.b of this document and chapters 6 and 8 of the TSD, DOE's LCC analysis demonstrated that common building thermal envelope requirements for multiple groups of cities proved to be most cost-effective. After reviewing DOE's LCC analysis, the MH working group recommended that DOE establish four climate zones that placed cities with the same set of most-cost-effective building thermal envelope requirements in the same climate zone. The MH working group found that a four climate zone approach would improve upon the HUD Code climate zones with regard to energy conservation by more accurately distinguishing among regions with similar climates while simultaneously minimizing the extensive subdivisions of states found in the 2015 IECC. Consistent with the recommendations of the MH working group [4] and as illustrated in Figure III.3, § 460.101 would establish a new climate zone arrangement that reflects the advantages of both the HUD Code and the 2015 IECC climate zones. *See* Term Sheet at 2.

**Figure III.3 Proposed Climate Zones**




If DOE's proposed energy conservation standards adopted the eight climate zones established in the 2015 IECC, 40 states would be divided into two or more climate zones. Although the 2015 IECC climate zones more precisely account for climatic conditions that affect energy use in the United States, any loss of accuracy in addressing climatic differences is negligible compared to the impracticality to the manufactured housing industry of designing and constructing manufactured homes that comply with eight different sets of climate zone requirements and planning home shipments based on individual states with multiple climate zones. A large number of climate zones, particularly within a state, would burden the manufactured housing industry because manufacturers are not always certain of the eventual destination of a home during the manufacturing process. That is, although some manufactured homes are custom orders where the destination is known prior to manufacture, many other manufactured homes are stocked as inventory with manufactured housing dealers. In particular, manufactured housing dealers and installers in states with multiple climate zones would encounter increased complexities associated with ordering, stocking, selling, installing, and servicing manufactured homes.

Although DOE generally prioritized establishment of a single climate zone per state where appropriate, the size or varied climate of certain states necessitated two climate zones in some instances. DOE's proposed climate zones bifurcate Texas, Louisiana, Alabama, Mississippi, Georgia, and Arizona. Data indicates that the inland climate of Texas, Louisiana, Alabama, Mississippi, and Georgia varies significantly from these states' coastal climates along the borders of the Gulf of Mexico. Similarly, southwestern Arizona exhibits different weather patterns from the rest of the state.

DOE requests comment on the proposal to establish four climate zones as well as input with regard to categorization of states and counties that comprise each climate zone. To the extent that a particular approach is advocated, commenters also should provide analyses and data on the potential impact to the costs and benefits of the proposed rule. DOE also requests comment on the need for additional training of state and local building officials who must be familiar with the requirements of two rather than one climate zone.

[4] The term sheet named the four climate zones 1A, 1B, 2, and 3. DOE proposes to rename these climate zones as 1 (former climate zone 1A), 2, (former climate zone 1B), 3 (former climate zone 2), and 4 (former climate zone 3).

(b) § 460.102 Building Thermal Envelope Requirements

Section 460.102 would establish requirements related to the building thermal envelope, which includes the materials within a manufactured home that separate the interior conditioned space from the exterior of the building or interior spaces that are not conditioned space. As discussed in this preamble, § 460.102(a) would establish two approaches to ensure that the building thermal envelope would meet more stringent energy conservation levels: A prescriptive option and a maximum $U_o$ option.

In developing recommendations under this section, the MH working group carefully considered section R402.1 of the 2015 IECC, which sets forth two primary compliance pathways. First, sections R402.1.2 and R402.1.4 of the 2015 IECC contain climate zone-specific prescriptive building thermal envelope component *R*-value requirements, prescriptive fenestration *U*-factor requirements, and prescriptive SHGC requirements. Second, section R402.1.5 of the 2015 IECC provides an alternate pathway to compliance, which allows for a home to be constructed using a variety of materials as long as the entire building thermal envelope has a singular total *UA* value [5] that is less than or equal to the sum of the component *U*-factor requirements under section R402.1.4 multiplied by the surface area of the building thermal envelope components. The first option is referred to as a ''prescriptive-based approach'' and the second option is referred to as a ''performance-based approach.''

DOE considered developing proposed requirements in line with either a prescriptive-based approach or a performance-based approach for specific assemblies that comprise the building thermal envelope. Ultimately, however, and consistent with the recommendation of the MH working group, DOE determined that allowing manufacturers to choose between two pathways for compliance would realize cost-effective energy savings for homeowners while providing for flexibility within the manufactured housing industry. *See* Term Sheet at 3–4.

The prescriptive approach would establish specific component *R*-value, *U*-factor, and SHGC requirements, providing a straightforward option for construction planning. This pathway would facilitate the ease of compliance but would restrict manufacturer flexibility in making trade-offs, such as increasing insulation levels in some building thermal envelope components while decreasing insulation levels in other building thermal envelope components.

In contrast, the performance-based approach would allow a manufactured home to be constructed using a variety of different materials with varying thermal properties so long as the building thermal envelope achieved a required level of overall thermal performance. The performance-based approach thus would provide manufacturers with greater flexibility in identifying and implementing cost-effective approaches to building thermal envelope design. The performance-based approach is familiar to the manufactured housing industry, as this approach is the basis for the building thermal envelope requirements under the HUD Code. The proposed performance-based requirements would be intended to be functionally equivalent to the prescriptive-based requirements in that both options would result in manufactured homes with approximately the same amount of energy use.

DOE requests comment on the proposal to set forth prescriptive and performance options for the purpose of compliance with the proposed building thermal envelope requirements. In particular, DOE requests comment on the requirements of each pathway as well as their equivalency in terms of overall thermal performance.

The proposed prescriptive building thermal envelope requirements under § 460.102(b) are stated in terms of minimum *R*-value and maximum *U*-factor and SHGC requirements. The MH working group recommended the prescriptive values set forth in Table III.3 that DOE has adopted in this rulemaking by assessing and revising the 2015 IECC specifications to ensure cost-effectiveness based on the impact on the purchase price of manufactured homes and on total lifecycle construction and operating costs. *See* Term Sheet at 3.

TABLE III.1—PROPOSED BUILDING THERMAL ENVELOPE PRESCRIPTIVE REQUIREMENTS

| Climate zone | Ceiling *R*-value | Wall *R*-value | Floor *R*-value | Window *U*-factor | Skylight *U*-factor | Door *U*-factor | Glazed fenestration SHGC |
|---|---|---|---|---|---|---|---|
| 1 | 30 | 13 | 13 | 0.35 | 0.75 | 0.40 | 0.25. |
| 2 | 30 | 13 | 13 | 0.35 | 0.75 | 0.40 | 0.33. |
| 3 | 30 | 21 | 19 | 0.35 | 0.55 | 0.40 | 0.33. |
| 4 | 38 | 21 | 30 | 0.32 | 0.55 | 0.40 | No Rating. |

As discussed in greater detail in chapter 6 of the TSD, DOE developed the requirements included in § 460.102(b), as illustrated in Table III.1, by evaluating the cost-effectiveness of the 2015 IECC building thermal envelope specifications and alternatives to these specifications. DOE performed LCC analysis for all alternatives to the 2015 IECC specifications that were recommended by the MH working group, in order to assist in the development of cost-effective standards under this rule.

The MH working group requested that DOE evaluate variations in the *R*-value requirement for ceilings, walls, and floors, and the *U*-factor requirement for windows, to determine the impact on cost-effectiveness relative to the 2015 IECC requirements. Upon analyzing a range of ceiling insulation requirements from *R*-22 to *R*-38, wall insulation requirements from *R*-13 to *R*-21, floor insulation requirements from *R*-13 to *R*-38, and window U-factor requirements from 0.40 to 0.31, DOE has proposed the most cost-effective energy conservation requirement for each climate zone, as included in Table III.1.

The MH working group also requested that DOE conduct sensitivity analyses of window SHGC. *See* Term Sheet at 3. In climate zone 1, DOE analyzed a range of window SHGC from 0.25 to 0.40. DOE is proposing the most cost-effective

[5] Total *UA* is a metric that is very similar to $U_o$ that typically is used in the context of site-built construction. Section R402.1.5 of the 2015 IECC uses the metric ''total *UA*,'' which denotes the sum of each building thermal envelope component's *U*-factor multiplied by the assembly area of the component. This metric is referred to as ''$U_o$'' in the manufactured housing industry and serves the same function as ''total *UA*.''

SHGC requirement for climate zone 1, as included in Table III.1. In climate zone 4, the MH working group requested that DOE not run sensitivity analyses for different SHGC options for most cities found in climate zone 4. SHGC has a smaller impact on energy use in regions dominated by heating rather than cooling loads. In these locations, more stringent SHGC requirements can lead to increased energy consumption by blocking the solar heating effects of sunlight. For these reasons, the MH working group proposed to not modify the 2015 IECC specification of no requirement, and DOE is incorporating the 2015 IECC specification of no SHGC requirement for proposed climate zone 4. Please see chapter 6 of the TSD for additional detail on DOE's SHGC sensitivity analyses.

The MH working group also recommended that DOE perform a sensitivity analysis of the total cost of ownership to determine the most cost-effective SHGC for climate zones 2 and 3. *See* Term Sheet at 3. DOE recognizes that many variables affecting the selection of recommended SHGC values were discussed by the MH working group over the course of multiple public meetings. At the recommendation of the MH working group, DOE studied the potential economic impacts of several SHGC values with the intent of proposing prescriptive SHGC requirements that provide the greatest economic benefit. Economic impact was the primary decision tool used in proposing prescriptive SHGC values, and DOE has prepared an economic analysis that supports different SHGC requirements for climate zones 2 and 3. DOE specifically found that an SHGC of 0.30 was the most cost-effective SHGC value based on a 10-year cost of ownership savings calculation. *See* 80 FR 7550. In arriving at this value, DOE placed all windows on one side of the manufactured home, with the windows facing west. DOE used this window orientation in its sensitivity analysis in order to arrive at SHGC values that would have the greatest impact on energy savings. DOE sought public input on this methodology and analysis in the 2015 RFI. *See* 80 FR 7550.

In response to the 2015 RFI, several commenters stated that factors other than total cost of ownership should be considered when proposing a prescriptive SHGC requirement. One commenter suggested that the total cost of ownership analysis should not be the sole consideration for choosing the SHGC requirement and that DOE should consider the 2015 IECC SHGC specifications, lifecycle costs, potential impacts on the purchase price of manufactured housing, air conditioner down-sizing and cost savings opportunities, reductions in peak electric loads, and manufacturer benefits in harmonizing SHGC across climate zones. Another commenter suggested that equipment downsizing, reduction in peak demand, improved occupant comfort leading to behavioral changes in adjusting a thermostat, synchronizing with the 2015 IECC, and lifecycle costs should be considered as a basis for the proposed SHGC requirements. The commenter also recommended that an SHGC of 0.25 in climate zones 1, 2, and 3 would be beneficial, as doing so would establish only two window requirements (SHGC of 0.25 in climate zones 1, 2, and 3; and no SHGC requirement for climate zone 4) and would simplify and streamline the purchasing of windows for manufacturers of manufactured homes.

Other commenters noted that placing all windows on one side of a manufactured home with the assumption that all windows face west was an atypical assumption. The commenters suggested that window orientation should follow the same ''industry average'' convention used in all other assumptions used in DOE's SHGC analysis. The commenters presented analysis based on their assessment of industry averages to demonstrate that such assumptions would support an SHGC requirement of 0.33; however, this analysis included assumptions that differed from those agreed upon by the MH working group, including window-to-floor area, window shading, and window cost. The commenters also noted that a group of windows with a weighted SHGC of 0.30 would require a mixture of window products of dissimilar aesthetic. Finally, the commenters believed that the likely industry response to a 0.30 SHGC requirement would be to assemble manufactured homes with a single window product SHGC value closer to 0.25. DOE also received a comment that supported the window orientation that DOE employed in its analysis, recommending that the analysis properly based SHGC assumptions on window orientation that would experience the highest energy use.

In response to the aforementioned comments, DOE determined that the window orientation assumption used in its SHGC analysis was inconsistent with other analytical assumptions under the proposed rule, as a more representative SHGC analysis would place windows uniformly on all sides of a manufactured home. Although the assumption of all windows facing west represents the highest energy use window orientation, manufactured homes with other window orientations would not experience as large an economic benefit. DOE also found no reason to deviate from the other assumptions in the submitted analysis (window-to-floor area, window shading, and window cost) that formed the basis of the MH working group's deliberations and recommendations. Finally, DOE notes that factors such as lifecycle costs, potential impacts on the purchase price of manufactured housing are included in its analysis.

DOE did not include air conditioner down-sizing and cost savings opportunities in its SHGC analysis. Although in some instances a manufacturer may be able to install a smaller air conditioner, for example, leading to reduced energy costs and a lower purchase price, this is not always possible. DOE did not prioritize peak electric load reduction over lifecycle cost savings to individual manufactured homeowners under its analysis. Finally, while equivalent SHGC requirements across climate zones could simplify window procurement for manufacturers, DOE notes that manufacturers could elect to use the same window types for manufactured homes shipped to any climate zone in accordance with the proposed rule.

DOE repeated its SHGC sensitivity analysis of climate zones 2 and 3 using a uniform window orientation to study the economic impacts of SHGC values of 0.25, 0.30, and 0.33. This analysis indicated SHGC of 0.33 had the greatest total cost of ownership savings; therefore, DOE proposes requiring SHGC of 0.33 in climate zones 2 and 3. Because the sensitivity analysis performed for climate zone 1 during the negotiated consensus process used the original assumption of uniform window distribution, this analysis was not repeated for climate zone 1.

For skylight *U*-factor requirements, the MH working group did not request that DOE evaluate the effect of variations of the 2015 IECC requirements on cost-effectiveness. Because there were LCC savings associated with the 2015 IECC requirements, DOE is proposing to adopt the 2015 IECC *U*-factor requirements for skylights into the proposed rule. This proposal is consistent with the recommendation of the MH working group. *See* Term Sheet at 3.

For door *U*-factor requirements, DOE found that a manufactured home with a *U*-factor of 0.40 was cost-effective. Therefore, DOE proposes a prescriptive door *U*-factor requirement of 0.40 in all climate zones for the proposed rule.

This proposal is consistent with the recommendation of the MH working group. *See* Term Sheet at 3.

Section 460.102(b)(2) as proposed would require the truss heel height to be a minimum of 5.5 inches at the outside face of each exterior wall for the purpose of compliance with the prescriptive ceiling insulation *R*-value requirement established under § 460.102(b)(1). This minimum heel height requirement would ensure that a minimum space is available in the eaves of the ceiling, allowing for adequate insulation coverage near the eaves. This proposal is also consistent with the recommendation of the MH working group. *See* Term Sheet at 3.

Section 460.102(b)(3) would authorize manufacturers to install ceiling insulation with either a uniform thickness or a uniform density. In many cases, a ceiling may need to be filled with loose blown insulation to a greater height at the center of the ceiling relative to the edges near the eaves to meet average overall *R*-value requirements. Although uniform insulation thickness is not required under the proposed standard, the 5.5-inch minimum truss heel height encourages a minimum insulation thickness at the eaves. This proposal is also consistent with the recommendations of the MH working group. *See* Term Sheet at 3.

Section 460.102(b)(4) would authorize manufacturers to use a combination of *R*-21 batt insulation and *R*-14 blanket insulation in lieu of *R*-30 insulation for the purpose of compliance with the climate zone 4 floor insulation *R*-value requirement under paragraph (b)(1) of this section. This requirement would reflect industry practice in which manufactured homes often do not have space in the floor to accommodate *R*-30 insulation without compression. DOE thus proposes that *R*-21 batt insulation plus *R*-14 blanket insulation would be deemed compliant with the *R*-30 requirement in order to provide a prescriptive alternative for space-constrained floors. This proposal is also consistent with the recommendation of the MH working group. *See* Term Sheet at 3.

Section 460.102(b)(5) would authorize manufacturers to exclude from the SHGC requirements under § 460.102(a) any individual skylight with an SHGC that is less than or equal to 0.30. This requirement effectively would establish an exception for skylights to the SHGC requirements in climate zone 1, setting forth a maximum skylight SHGC requirement of 0.30. This exception is set forth in the 2015 IECC in footnote ''b'' to Table R402.1.2. The MH working group recommended that DOE retain this requirement, and DOE agrees with including this exception in the proposed rule. *See* Term Sheet at 3.

DOE also considered the potential impact of adopting sections R402.3.3 and R402.3.4 of the 2015 IECC in this rulemaking. Section R402.3.3 specifies that 15 square feet of glazed fenestration may be exempt from SHGC and *U*-factor requirements. DOE proposes not to adopt this requirement because the prescriptive fenestration SHGC and *U*-factor requirements would apply to all fenestration. Given that 15 square feet represents a large portion of the overall fenestration area that comprises a manufactured home, adoption of this requirement potentially would exclude from these requirements a significant source of energy conservation. Section R402.3.4 of the 2015 IECC exempts one side-hinged opaque door of up to 24 square feet in surface area from the 2015 IECC *U*-factor requirements. DOE has not adopted section R402.3.4 of the 2015 IECC, as excluding these types of doors from this proposed rulemaking also would represent the loss of a significant source of home energy conservation.

Section R402.5 of the 2015 IECC specifies maximum *U*-factor requirements for sunroom fenestration. Because sunrooms are not commonly offered in manufactured housing, DOE determined this section was not applicable to manufactured housing and proposes not to include sunroom fenestration requirements in this proposed rule.

Section 460.102(b)(6) would establish maximum *U*-factor values as alternatives to the minimum *R*-value requirements established under § 460.102(a). *See* Term Sheet at 5. DOE determined each proposed *U*-factor alternative by calculating the *U*-factor corresponding to a building component (*e.g.,* wall) with typical dimensions and construction using the insulation material *R*-value specified in Table III.1. More detail on establishing the proposed *U*-factor alternatives is provided in chapter 7 of the TSD. DOE notes that the proposed *U*-factor alternatives are based on a representative single-section manufactured home, which are an average of 4.2 percent higher than the corresponding calculations of *U*-factor alternatives using the dimensions of a representative multi-section manufactured home.

DOE requests comment on the *U*-factor alternatives and their equivalency with the *R*-value requirements for ceiling, wall, and floor insulation. Specifically, DOE invites comment on the use of *U*-factor alternatives for ceiling insulation based on a conversion calculation using a representative single-section manufactured home.

Section 460.102(b)(7) would establish a maximum ratio of 12 percent for glazed fenestration area to floor area. As discussed in further detail in chapter 7 of the TSD, DOE used this ratio as a typical housing characteristic in its analyses for determining the prescriptive requirements. Manufactured homes with window to floor area greater than 12 percent would use more energy (all else held equal), because glazed fenestration generally has a greater *U*-factor than other building components (such as walls). Although this requirement limits the amount of glazed fenestration in a manufactured home when a manufacturer is using the prescriptive requirements for compliance with the proposed rule, a manufacturer may instead follow the performance-based requirements for compliance if they wish to increase the area of glazed fenestration (in exchange for increasing the performance of other building thermal envelope components).

The proposed performance-based requirements under § 460.102(c) are stated in terms of maximum $U_o$ of the entire building thermal envelope as a function of climate zone. The $U_o$ requirements proposed in § 460.102(c) were determined by applying the proposed prescriptive building thermal envelope requirements under § 460.102(b) to manufactured homes using typical dimensions and construction techniques and then calculating the resultant $U_o$. See chapter 7 of the TSD for more detailed information on the typical dimensions of manufactured homes and the Battelle Method for more detailed information on the calculation of $U_o$.

As discussed in chapter 7 of the TSD, the proposed maximum $U_o$ for a multi-section manufactured home was calculated by assuming a 1,568-square-foot double-section manufactured home. The proposed maximum $U_o$ for a single-section manufactured home was calculated by assuming a 924-square-foot single-section manufactured home. Both multi- and single-section home $U_o$ values were calculated assuming manufactured homes built with wood framing and a window area equal to 12 percent of the floor area. DOE's proposed approach to determining $U_o$ is consistent with HUD's approach to determining $U_o$ under the HUD Code (*see* 24 CFR 3280.507(a)), and is very similar to the ICC's approach to determining total *UA* under section R402.1.5 of the 2015 IECC. DOE believes that its approach to determining $U_o$ would reduce the compliance burden on manufacturers by avoiding the need for manufacturers to perform two separate calculations under both the HUD Code and the DOE requirements.

Section R402.5 of the 2015 IECC includes specifications for maximum allowable fenestration *U*-factors when following the performance-based approach. The 2015 IECC specifies a maximum area-weighted average *U*-factor of 0.48 in IECC climate zones 4 and 5 for vertical fenestration, a maximum area-weighted average *U*-factor of 0.40 for IECC climate zones 6 through 8 for vertical fenestration, and a maximum area-weighted average *U*-factor of 0.75 for skylights in IECC climate zones 4 through 8. Consistent with the recommendations of the MH working group (*see* Term Sheet at 1), DOE proposes to adopt these requirements under §§ 460.102(c)(2) and 460.102(c)(3) by limiting area-weighted vertical fenestration *U*-factor to 0.48 in climate zone 3, limiting area-weighted vertical fenestration *U*-factor to 0.40 in climate zone 4, and limiting area-weighted skylight *U*-factor to 0.75 in climate zones 3 and 4. Sections 460.102(c)(2) and 460.102(c)(3) would serve the purpose of limiting the extent to which window performance can be traded off for improved performance in other components of a manufactured home and would prevent areas of a manufactured home that are located in close proximity to vertical fenestration and skylights from being subject to excessive rates of heat loss.

Finally, § 460.102(c)(4) would require windows, skylights, and doors containing more than 50 percent glazing by area to satisfy the SHGC requirements under § 460.102(a) on the basis of an area-weighted average and seeks to ensure flexibility among manufacturers that choose to use unique glazed fenestration products that otherwise would not meet the SHGC requirement individually. This proposal is also consistent with the recommendations of the MH working group. *See* Term Sheet at 4.

DOE invites comment on proposal to include an area-weighted average calculation of SHGC for compliance with § 460.102(c). DOE also requests comment on all other prescriptive and performance requirements proposed in this section. To the extent that a commenter supports the proposed requirements or suggests alternative building thermal envelope criteria, DOE is specifically interested in data and calculations that would support the commenter's position.

Section 460.102(d) would establish procedures for ensuring compliance with the prescriptive building thermal envelope standards under § 460.102(b). As discussed in this preamble, however, the MH working group did not address options for systems of compliance and enforcement, and DOE has not included proposed compliance and enforcement provisions in rule. In the event that DOE addresses compliance assurance in a future rulemaking, paragraphs (d)(1), (d)(2), (d)(4), (d)(5), and (d)(7) would be reserved to provide a methodology for calculating the *R*-value of insulation; the *R*-value of non-insulating materials; fenestration *U*-factor; the *U*-factor of walls, ceilings, and floors; and glazed fenestration SHGC that would provide for an accurate and repeatable procedure to determine compliance with the standards proposed under § 460.102(b).

Section 460.102(d)(3) would establish that the total *R*-value of a component is the sum of the *R*-values of each layer of insulation that compose the component. This proposed requirement is consistent with section R402.1.3 of the 2015 IECC, which specifies that component insulation materials installed in layers has a total *R*-value equal to the sum of the *R*-values of each layer.

Sections 460.102(d)(6) and 460.102(d)(8) would authorize manufacturers to determine *U*-factor or SHGC for certain fenestration products and doors in accordance with the prescriptive default values set forth in Tables 460.102–4, 460.102–5, and 460.102–6. DOE anticipates that a manufacturer could rely on these prescriptive default *U*-factor values to facilitate the ease of compliance with this proposed rule. DOE has designed proposed § 460.102(d)(6) for consistency with Tables R303.1.3(1), R303.1.3(2), and R303.1.3(3) of the 2015 IECC and in accordance with the MH working group's recommendations. DOE has proposed conservative prescriptive default values to provide an incentive to manufacturers to determine the actual performance value of the windows, doors, or skylights installed in a manufactured home. DOE expects the default tables would be used primarily in instances in which the actual performance value of a window, door, or skylight is unavailable or unknown.

Section 460.102(e) would establish procedures for ensuring compliance with the building thermal envelope $U_o$ standards under § 460.102(c). As discussed in this preamble, the MH working group did not address options for systems of compliance and enforcement, and DOE has not included proposed compliance and enforcement provisions in this proposed rule. In the event that DOE addresses compliance assurance in a future rulemaking, paragraphs (e)(1)(i), (e)(1)(ii), and (e)(2) would be reserved to provide a methodology for calculating the *R*-value of insulation, the *R*-value of non-insulating materials, and glazed fenestration SHGC that would provide for an accurate and repeatable procedure to determine compliance with the standards proposed under § 460.102(c).

The MH working group recommended, however, that $U_o$ be determined in accordance with the ''Battelle Method.'' The Battelle Method is an industry standard methodology for determining $U_o$ and is commonly utilized in the manufactured home industry. The Battelle Method's methodology is based on recommendations in the ASHRAE Handbook of Fundamentals but provides more specificity to determining $U_o$ for manufactured housing. The Battelle Method provides a step-by-step process for calculating $U_o$ by calculating the *U*-value of each unique area of the building thermal envelope and by calculating a weighted average. Both of these references serve as the basis for calculating overall thermal transmittance under the HUD Code (*see* 24 CFR 3280.508) while only the ASHRAE Handbook of Fundamentals is referenced in section R402.1.5 of the 2015 IECC.

Finally, § 460.102(e)(3) would authorize manufacturers to determine the SHGC of certain glazed fenestration products in accordance with the prescriptive default values set forth in Table 460.102–6 for consistency with the rationale accompanying § 460.102(d)(8) of this section. Table 460.102–6 differentiates between single- and double-pane windows, glazed block windows, as well as clear and tinted glass. Single- and double-pane windows refer to the number of panes of glass that are in the window assembly. A single-pane window consists of one pane of glass while a double-pane window consists of two panes of glass separated within the window assembly at a fixed distance. The space between the two panes of glass serves to reduce heat transfer through the window. A glazed block window refers to a window assembly that consists of glass blocks that are arranged or laid out like bricks. These types of windows cannot be opened and are typically used in ground level or basement floors for security purposes. The terms ''clear'' and ''tinted'' glass characterize the light transmission properties of the glass. Clear glass is uncoated and transparent, admitting all light through its body. Tinted glass instead has an altered chemical composition or surface coating that affects light transmission and color. Different types of tinted glass block and reflect different quantities and types of light. Table 460.102–6 provides proposed default SHGC values for these different types of windows.

(c) § 460.103 Installation of Insulation

Section 460.103(a) would require manufacturers to install insulation according to both the insulation manufacturer's installation instructions and the instructions set forth in Table 460.103. DOE proposes to require manufacturers to comply with the insulation manufacturer's installation instructions both for consistency with section R303.2 of the 2015 IECC and to ensure that the intended performance of the insulation is achieved. Unlike section R303.2 of the 2015 IECC, however, § 460.103 would not require insulation to be installed in accordance with the International Building Code or the International Residential Code, as the HUD Code already sets forth requirements in this regard. DOE also proposes additional insulation requirements under § 460.103(a) that are based in part on section R402.4.1.1 of the 2015 IECC, with clarifications to account for the unique design of manufactured homes, to ensure that insulation is able to achieve its intended thermal performance.

Table 460.103 would include a general requirement that air-permeable insulation must not be used as a material to establish the air barrier. This proposed requirement is consistent with Table R402.4.1.1 of the 2015 IECC, which the MH working group recommended that DOE include this in the proposed rule. *See* Term Sheet at 1. DOE proposes to adopt this requirement to improve energy conservation in manufactured housing through the reduction of natural air infiltration through the building thermal envelope.

Proposed Table 460.103 also includes insulation requirements for access hatches, panels, and doors between conditioned space and unconditioned space. Section 460.103(a) would require each access hatch, panel, and door leading from conditioned space to unconditioned space to be insulated to a level equivalent to the level of insulation immediately adjacent to the access hatch, panel, and door. This requirement would ensure that the thermal performance of the access hatch, panel, or door would be identical to the surrounding ceiling and would ensure that the ceiling insulation achieves the same level of performance as ceiling insulation without an access hatch, panel, or door. Section 460.103(a) also would require each access hatch, panel, and door to provide access to all equipment without damaging or compressing the insulation. Damaging or compressing the insulation would reduce the performance of the insulation and increase the energy losses associated with the ceiling. Finally, each access hatch, panel, and door must be equipped with a wood-framed or equivalent baffle or retainer when loose fill insulation is installed within a ceiling assembly to retain the insulation on the access hatch, panel, or door. That is, an access hatch, panel, or door must use baffles or a retainer to prevent loose-fill insulation installed within a ceiling assembly from spilling into the living space upon use of the access hatch, panel, or door. Each of these requirements have been adopted from section R402.2.4 of the 2015 IECC are consistent with the recommendations of the MH working group, and seek to preserve the performance of insulation within a manufactured home. *See* Term Sheet at 1.

Section R402.2.4 of the 2015 IECC also includes a specification for vertical doors that provide access from conditioned to unconditioned spaces to meet certain fenestration insulation requirements. The MH working group recommended not adopting this specification in the proposed rule because vertical doors that separate conditioned and unconditioned spaces typically are not installed in manufactured homes. Consistent with the recommendation of the MH working group, DOE proposes not to include this requirement in this proposed rule. *See* Term Sheet at 1.

Proposed Table 460.103 includes requirements for installing insulation adjacent to baffles. Baffles must be constructed using a solid material, maintain an opening equal or greater than the size of the eave vent, and extend over the top of the attic insulation. Baffles allow for air circulation from the exterior of the manufactured home to the attic space between the ceiling insulation and the top of the roof. The installation requirement would ensure proper attic ventilation and that insulation would not interfere with a baffle's ability to facilitate air circulation. The proposed requirements would be consistent with section R402.2.3 of the 2015 IECC and the MH working group's recommendations, and would help ensure proper ventilation in attic spaces. *See* Term Sheet at 1.

Table 460.103 as proposed includes a requirement for installing insulation in ceilings or attics. Specifically, the requirement states that insulation installed in any dropped ceiling or dropped soffit must be aligned with the air barrier. The requirement would ensure that there would not be excessive air infiltration through the building thermal envelope if a dropped ceiling or dropped soffit is present in a manufactured home. This requirement is consistent with Table R402.4.1.1 in the 2015 IECC, and the MH working group recommended that DOE include this requirement in the proposed rule. *See* Term Sheet at 1.

To address the unique practice of HVAC duct installation in manufactured homes, Table 460.103 would require insulation to be installed to maintain permanent contact with the underside of the rough floor decking over which the finished floor, flooring material, or carpet is laid, except where air ducts directly contact the underside of the rough floor decking. This requirement is generally consistent with section R402.2.8 of the 2015 IECC, which specifies that floor insulation be installed in direct contact with the underside of the subfloor decking. Given that HVAC ducts in manufactured homes generally are located in the floor space between the insulation and the underside of the subfloor decking, DOE would require the same floor insulation requirements as the 2015 IECC while recognizing the need to insulate around HVAC ducts. DOE requests comment on the proposed floor insulation requirement and whether it would be consistent with industry practice.

Table 460.103 as proposed includes an insulation installation requirement associated with narrow cavities such that batts installed in narrow cavities must be cut to fit or filled by insulation that upon installation readily conforms to the available cavity space. This requirement would ensure that all wall cavities are properly insulated, even if they have a non-standard width. This type of narrow cavity could occur in a wall area adjacent to a window frame. This requirement would be consistent with Table R402.4.1.1 of the 2015 IECC, which the MH working group recommended that DOE adopt in the proposed rule. *See* Term Sheet at 1. DOE proposes to include this requirement in the proposed rule because it ensures that all cavities are properly insulated to achieve the expected thermal performance.

Table 460.103 also would require rim joists to be insulated. This requirement would ensure that the entire floor assembly of a manufactured home achieves the desired thermal performance. The requirement is consistent with Table R402.4.1.1 of the 2015 IECC, and the MH working group recommended that DOE include this requirement in the proposed rule. *See* Term Sheet at 1.

Table 460.103 includes an insulation installation requirement that would require exterior walls adjacent to showers and tubs to be insulated. This proposed requirement is consistent with Table R402.4.1.1 of the 2015 IECC, which the MH working group recommended that DOE adopt in the proposed rule. *See* Term Sheet at 1. DOE proposes to include this requirement in the proposed rule because it would ensure that all wall assemblies with showers and tubs would achieve the expected thermal performance requirements established under § 460.102.

Table 460.103 also would require air permeable exterior building thermal envelope insulation for framed walls to completely fill the wall cavity, including cavities within stud bays caused by blocking lay flats or headers. The requirement clarifies the 2015 IECC requirement for wall insulation installation found in Table R402.4.1.1. The MH working group recommended that DOE modify the language of the 2015 IECC requirement to account for the unique design of manufactured housing. *See* 9/23 Working Group Transcript, EERE–2009–BT–BC–0021–0122 at p. 315. DOE proposes to adopt this requirement, along with the recommended modifications from the MH working group, to ensure that wall assemblies in manufactured homes achieve the proposed thermal performance requirements set forth under § 460.102.

Finally, the 2015 IECC contemplates additional specifications for insulating areas associated with the building thermal envelope that DOE has not included in this proposed rule. For example, section R402.1.1 of the 2015 IECC specifies that wall assemblies in the building thermal envelope comply with the vapor retarder requirements of section R702.7 of the International Residential Code or section 1405.3 of the International Building Code. DOE has not incorporated this requirement into this proposed rule, as this specification is a construction requirement that was not addressed by the MH working group.

Section R402.2.13 of the 2015 IECC establishes sunroom insulation specifications. Sunrooms typically are not commonly installed in manufactured homes; accordingly, DOE has not incorporated this provision of the 2015 IECC into this proposed rule. Similarly, section R402.2.12 of the 2015 IECC specifies that insulation is not required on the horizontal portion of the foundation that supports a masonry veneer. Given that masonry veneers typically are not used in manufactured homes, DOE has not incorporated this provision of the 2015 IECC into this proposed rule

The 2015 IECC also includes building thermal envelope specifications for mass walls, steel-framed buildings, walls with partial structural sheathing, basement and below-grade walls, slab-on grade construction, and crawl space walls in sections R402.2.5, R402.2.6, R402.2.7, R402.2.9, R402.2.10, R402.2.11, respectively. DOE has not included these requirements in the proposed rule because they are not directly relevant to manufactured housing.

### (d) § 460.104 Building Thermal Envelope Air Leakage

Section 460.104 would require manufacturers to seal manufactured homes against air leakage in order to ensure the conservation of energy within a manufactured home. Section 460.104 would establish both general and specific requirements for sealing a manufactured home to prevent air leakage, all of which are based on Table 402.4.1.1 of the 2015 IECC and related recommendations from the MH working group. *See* Term Sheet at 5. Unlike the 2015 IECC, the proposed rule would not establish maximum building thermal envelope air leakage rate requirements. The MH working group recommended sealing requirements that would ensure that a home can be tightly sealed with techniques that can be visually inspected, thus minimizing the compliance burden on manufacturers. The MH working group also recommended the adoption of air leakage sealing requirements designed to achieve an overall air exchange rate of 5 ACH within a manufactured home. *See* Term Sheet at 5.

The general requirements in § 460.104 require that manufacturers properly seal all joints, seams, and penetrations in the building thermal envelope to establish a continuous air barrier and use appropriate sealing materials to allow for differential expansion and contraction of dissimilar materials. These requirements would ensure that there would not be excessive air infiltration through the building thermal envelope and that air seals would be durable through seasonal changes in temperature. Because these requirements would result in reduced energy use through proper air sealing in a manufactured home, DOE proposes to adopt the MH working group's recommendations in the proposed rule. DOE requests comment on the effectiveness of the proposed prescriptive criteria of § 460.104 for the purpose of sealing the building thermal envelope to limit air leakage.

Table 460.104 also would include requirements for establishing an air barrier for specific building components. The proposed requirements included in Table 460.104 for ceilings or attics, duct system register boots, recessed lighting, and windows, skylights, and exterior doors are all consistent with Table R402.4.1.1 of the 2015 IECC. The MH working group recommended that these 2015 IECC-based requirements also be included in the proposed rule. *See* Term Sheet at 1. Because these specifications reduce energy use by helping to ensure proper installation of an air barrier for the applicable building components, DOE proposes to adopt the 2015 IECC specifications as requirements in the proposed rule.

The requirements of Table 460.104 for walls, floors, and electrical boxes or phone boxes on exterior walls are based on specifications included in Table R402.4.1.1 of the 2015 IECC with modifications based on the recommendation of the MH working group. *See* Term Sheet at 1. The 2015 IECC specifications save energy by helping to ensure proper installation of an air barrier, and the MH working group recommended modifications to the specifications based on the unique nature of the manufactured housing industry. Rather than use the term ''air sealed boxes'' from the 2015 IECC, the MH working group described directly how this could be achieved using the phrasing ''the air barrier must be sealed around the box penetration.'' DOE thus proposes to adopt the 2015 IECC specifications, as amended, in the proposed rule.

Table 460.104 also would establish requirements for mating line surfaces, as recommended by the MH working group. *See* Term Sheet at 5. The proposed requirements would ensure proper sealing of the mating line surface between the two sections of a multi-section manufactured home and would reduce energy use by ensuring that multi-section manufactured homes have a continuous air barrier.

The proposed requirements of Table 460.104 for rim joists, and showers or tubs adjacent to exterior walls are consistent with the specifications of Table R402.4.1.1 of the 2015 IECC. The MH working group recommended that DOE adopt the 2015 IECC specifications in the proposed rule given that they would result in additional energy conservation within a manufactured home by helping to ensure a continuous air barrier. *See* Term Sheet at 1.

Table R402.4.1.1 of the 2015 IECC also contains specifications for air leakage sealing in crawl space walls, garage separation, plumbing and wiring, and concealed sprinklers. The MH working group recommended that DOE not propose these specifications in the proposed rule. *See* Term Sheet at 1. Given that these requirements are not directly applicable to manufactured home construction, DOE is not proposing to include these requirements in the proposed rule.

The 2015 IECC includes specifications for air leakage of fenestration and recessed luminaires that DOE has not included in this proposed rule. In section R402.4.3 of the 2015 IECC, windows, skylights, and sliding glass doors have a specified maximum air leakage rate of 0.3 cubic feet per minute (cfm) and swinging doors have a specified maximum air leakage rate of 0.5 cfm. Section R402.4.5 of the 2015 IECC specifies air leakage around recessed luminaires most be no greater than 2.0 cfm when tested at a 75 pascal pressure differential. The MH working group recommended not to include these requirements for fenestration and recessed luminaire air leakage in order to reduce the testing burden on manufacturers. *See* Term Sheet at 1. DOE agrees with the MH working group's recommendation and has not proposed to include air leakage requirements for fenestration and recessed luminaires, as air leakage standards already are addressed generally at the building thermal envelope level. Nevertheless, DOE has designed its proposed prescriptive building thermal envelope air leakage standards, which include requirements to seal the space between fenestration and framing and between recessed luminaires and drywall, to achieve an air leakage rate of five ACH.

DOE also reviewed section R402.4.4 of the 2015 IECC regarding rooms containing fuel-burning appliances. Section R402.4.4 includes specifications for the placement of fuel-burning appliances (outside of conditioned space), for sealing of the room enclosing the appliance, and for insulation of ducts and waterlines. Although these provisions have potential to save energy, the HUD Code already specifies that the combustion system for fuel burning devices must be completely separated from the interior atmosphere of the manufactured home. *See* 24 CFR 3280.709(d). Therefore, DOE is not including these requirements in this proposed rulemaking. However, DOE may consider the merits of including R402.4.4 in future revisions of energy conservation standards for manufactured housing. DOE requests comment on the fireplace requirements based on section R402.4.2 of the 2015 IECC and the proposal not to include insulation and air sealing requirements pertaining to rooms containing fuel-burning appliances.

3. Subpart C: HVAC, Service Water Heating, and Equipment Sizing

(a) § 460.201 Duct Sealing

Section 460.201(a) would require manufacturers to equip each manufactured home with a duct system designed to limit total air leakage to less than or equal to four cubic feet per minute per 100 square feet of conditioned floor area, when tested in accordance with § 460.201(b). Section R403.3.4 of the 2015 IECC specifies that the total air leakage of duct systems is to be less than or equal to four cubic feet per minute per 100 square feet of conditioned floor area under a post-construction test. The 2015 IECC also includes specifications for a rough-in test performed with or without an air handler. The MH working group recommended that DOE consider only the post-construction test 2015 IECC specifications in developing the proposed standards given the unique nature of manufactured homes relative to site-built housing. *See* 9/10 Working Group Transcript, EERE–2009–BT–BC–0021–0133 at 227. DOE proposes to adopt the post-construction test specifications of the 2015 IECC as it would be more cost-effective to the manufactured housing industry.

Section R403.3.5 of the 2015 IECC specifies that building framing cavities must not be used as plenums. A plenum is a space within a building that facilitates the circulation of air. Building framing cavities are typically not tightly sealed and do not provide an adequate barrier to foreign bodies for air quality reasons. The use of building framing cavities as ducts and plenums is generally considered to be poor practice and is not a typical practice in the manufactured housing industry. Therefore, consistent with the 2015 IECC and the recommendation of the MH working group (*see* Term Sheet at p. 1), DOE proposes to require that building framing cavities not be used as ducts or plenums under § 460.201(a).

Section 460.201(b) would establish procedures for ensuring compliance with the duct system air leakage standard under § 460.201(a). As discussed in this preamble, the MH working group did not address options for systems of compliance and enforcement, and DOE has not included proposed compliance and enforcement provisions in this rule. In the event that DOE addresses compliance assurance in a future rulemaking, paragraph (b) would be reserved to provide a methodology for determining compliance with this standard that would provide for an accurate and repeatable procedure.

The 2015 IECC also includes specifications associated with duct systems that DOE has not included in this proposed rule. Section R403.3.1 of the 2015 IECC specifies that supply ducts in attics shall be insulated to a minimum of *R*-8 while all other ducts shall be insulated to a minimum of *R*-6. The MH working group did not discuss this section of the 2015 IECC. Because ducts are typically located within the building thermal envelope in manufactured homes, DOE did not include this IECC requirement. DOE requests comment on this proposal.

DOE also would not incorporate sections R403.3.2 and R403.3.2.1 of the 2015 IECC, which specify that sealing of ducts, air handlers, and filter boxes must be in accordance with the International Mechanical Code or the International Residential Code. DOE believes that additional sealing requirements are not needed in conjunction with the proposed quantitative sealing requirements in § 460.201(a). DOE recognizes, however, that some manufacturers may choose to meet the requirements of § 460.201(a) in part by voluntarily following the requirements of the International Mechanical Code or the International Residential Code.

(b) § 460.202 Thermostats and Controls

Section R403.1 of the 2015 IECC specifies that at least one thermostat shall be provided for each separate heating and cooling system. Section R403.1.1 of the 2015 IECC also specifies that the thermostat controlling the primary heating or cooling system must be capable of controlling the heating and cooling system on a daily schedule to maintain different temperature set points at different times of the day. The 2015 IECC further specifies that where the primary heating system is a forced-air furnace, at least one thermostat per dwelling unit must be capable of controlling the heating and cooling system on a daily schedule to maintain different temperature set points at different times of the day. The 2015 IECC also specifies that this thermostat to have the capability of setting back, or temporarily operating, the system to maintain zone temperatures as low as 55 °F or as high as 85 °F.

DOE has adopted section R403.1 of the 2015 IECC into § 460.202(a) without revision. DOE also has incorporated section R403.1.1 of the 2015 IECC into § 460.202(b). As proposed, § 460.202 would apply to any thermostat and controls installed by the manufacturer. A thermostat is a necessary interface for establishing desired temperature levels within a home, and already standard practice currently. Programmable thermostats help consumers save energy by providing the capability reduce energy use automatically during predetermined times (generally times the home is not occupied). This is also consistent with recommendations of the MH working group. *See* Term Sheet at 1.

Moreover, section R403.1.2 of the 2015 IECC specifies that heat pumps having supplementary electric-resistance heat to have controls that, except during defrost, prevent supplemental heat operation when the heat pump compressor can meet the heating load. Supplementary electric-resistance heating equipment is less efficient and less cost-effective as a heating method than heat-pump heating equipment. Therefore, preventing supplementary electric-resistance heating except for during defrost would reduce energy usage and manufactured home energy bills. DOE notes that § 3280.714(a)(1)(ii) of the HUD Code establishes requirements for heat pumps. DOE is not aware of any instances in which the proposed requirement, which provides that the heating system be provided with controls that, except during defrost, prevent supplemental heat operation when the heat pump compressor can meet the heating load, would conflict with § 3280.714(a)(1)(ii). DOE thus proposes to include this requirement in this rule, as recommended by the MH working group. *See* Term Sheet at 1.

DOE requests comment on the proposed requirements contained in § 460.202. Specifically, DOE requests comment and information on the potential interaction between proposed § 460.202(c) and § 3280.714(a)(1)(ii) of the HUD Code.

### (c) § 460.203 Service Hot Water Systems

Section 460.203(a) would require manufacturers to install service water heating systems according to the service water heating system manufacturer's installation instructions. As proposed, § 460.203 would apply to any service water heating system installed by a manufacturer. In addition, § 460.203 would require manufacturers to provide maintenance instructions for the service water heating system with the manufactured home. These requirements would promote the correct installation and maintenance of service water heating equipment and help to ensure that such equipment performs at its intended level of efficiency.

Section 403.5.1 of the 2015 IECC specifies that automatic controls, temperature sensors, and pumps related to service water heating must be accessible and that manual controls be ''readily accessible.'' § 460.203(b) would require any automatic and manual controls, temperature sensors, pumps associated with service water heating systems to be similarly accessible. This requirement would ensure that manufactured homeowners would have adequate control over service water heating equipment in order to achieve the intended level of efficiency contemplated under part 460. This is also consistent with the recommendation of the MH working group. *See* Term Sheet at 1.

Section 403.5.1.1 of the 2015 IECC specifies that (1) heated water circulation systems be provided with a circulation pump, and the system return pipe be a dedicated return pipe or cold water supply pipe; (2) gravity and thermosyphon circulation systems are prohibited; (3) controls for circulating hot water system pumps must start the pump based on the identification of a demand for hot water within the occupancy; and (4) the controls must automatically turn off the pump when the water in the circulation loop is at the desired temperature and when there is no demand for hot water. Heated water circulation systems must have a circulation pump (if they are not of the gravity or thermosyphon variety) to function properly. Moreover, gravity or thermosyphon circulation systems are less efficient than those that use a pump. Manufactured homeowners would benefit from the energy savings associated with controls used to operate the circulation pump based on demand from a user and that automatically turn off the pump when there is no demand for hot water. Finally, controls that automatically turn off the pump once the desired temperature is reached reduce energy use relative to a system that runs the pump continuously. Accordingly, DOE has incorporated each of these specifications into proposed § 460.203(c) without change to ensure heated water circulation systems are designed in an energy efficient manner.

Section R403.5.2 of the 2015 IECC includes specifications that are related to demand recirculation systems. Conventional hot water systems send cold water (hot water that has cooled) standing in the hot water pipe down the drain when hot water is demanded by the home owner. After the cold water is flushed out, hot water from the water heater reaches the point of use. Demand recirculation systems differ from conventional hot water systems in that any cold water standing in hot water pipes at the time hot water is demanded is sent back to the hot water system rather than being dumped down the drain. Given that these systems, while technically feasible to install in manufactured housing, are not currently in use by the industry, DOE proposes not to include any requirements relating to demand recirculation systems in this proposed rule; however, DOE requests comment on the potential benefits and burdens of including demand recirculation system standards for consideration in development of a final rule.

Section R403.5.4 of the 2015 IECC specifies standards and test procedures for drain water heat recovery units. Given that these devices typically are not used in manufactured homes, DOE proposes not to include any requirements related to drain water heat recovery units in this proposed rule; however, DOE requests comment on the potential benefits and burdens of drain water heat recovery unit procedures for consideration in development of a final rule.

DOE proposes that all hot water pipes outside conditioned space would be required to be insulated to at least *R*-3, and that all hot water pipes from a water heater to a distribution manifold would be required to be insulated to at least *R*-3. Section R403.5.3 of the 2015 IECC specifies seven categories of hot water pipe (such as piping outside the conditioned space) that must be insulated to at least *R*-3. Section 460.203(e) has incorporated each of the categories of piping listed under section R403.5.3 of the 2015 IECC that are relevant to manufactured housing. Accordingly, DOE has not adopted specifications related to piping under a floor slab, buried-in piping, and supply and return piping in recirculation system other than demand recirculation systems. Any piping located within conditioned space is unlikely to affect energy use dramatically, as hot water eventually will reach room temperature regardless of whether *R*-3 insulation is in place. Hot water piping outside of conditioned space is exposed to a larger temperature gradient and therefore piping insulation would have a greater opportunity for energy conservation within a manufactured home. This is also consistent with the recommendations of the MH working group. *See* Term Sheet at 6.

(d) § 460.204 Mechanical Ventilation Fan Efficacy

Table 403.6.1 of the 2015 IECC includes requirements for mechanical ventilation system fan efficacy. Consistent with the recommendations of the MH working group, and because DOE considers that there would be significant potential energy savings benefits associated with fan efficacy, DOE proposes to incorporate these specifications, without change, into Table 460.204. *See* Term Sheet at 1.

Section 403.6.1 of the 2015 IECC specifies that if mechanical ventilation fans are integral to tested and listed HVAC equipment, then they must be powered with an electronically commutated motor. The MH working group (*see* Term Sheet at 1) recommended that DOE include this requirement in the proposed rule without change. Since electronically commutated motors offer substantially increased energy conservation over conventional induction motors, DOE proposes to include this requirement in the proposed rule.

Section 3280.103(b) of the HUD Code establishes whole-house ventilation requirements, including that a manufactured home must be capable of providing 0.035 cubic feet (air volume) per minute per square foot (floor area) of mechanical ventilation. Section 3280.103(b) also requires that the flow rate of the system must be between 50 and 90 cubic feet per minute. In contrast, § 460.204 would establish requirements for the electrical efficiency of the fans providing the ventilation. These regulations would not conflict, as HUD regulates the ''size'' of the ventilation system while DOE would regulate the efficiency of the fans that provide ventilation.

(e) § 460.205 Equipment Sizing

Section R403.7 of the 2015 IECC sets forth specifications on the appropriate sizing of heating and cooling equipment within a manufactured home, which the MH working group recommended for inclusion in the proposed rule. *See* Term Sheet at 1. This section of the 2015 IECC requires the use of ACCA Manual S to select appropriately sized heating and cooling equipment based on building loads calculated using ACCA Manual J. The 2015 IECC also includes the option to use ''other approved'' calculation methodologies and requires that new or replacement heating and cooling equipment meet minimum energy efficiency requirements as required by federal law. Section 460.205 would set forth specific requirements for the utilization of ACCA Manuals S and Manual J for the purposes of selecting equipment size and calculating building load. The ACCA manuals are industry standards that DOE has determined are adequate for these calculations. DOE has not approved any other calculation methodologies because no other applicable, widely-used methodologies are currently available. DOE requests comment on the applicability of ACCA Manual S and ACCA Manual J for the purposes of heating and cooling equipment sizing.

Section R403.7 of the 2015 IECC also specifies that any replacement heating or cooling equipment be compliant with federal law. DOE would not adopt section R403.7 as there would be no need to remind manufacturers of the requirement to comply with existing federal law.

*C. Other 2015 IECC Specifications*

The following section discusses certain specifications included in the 2015 IECC that DOE has not included in the development of its proposed energy conservation standards. DOE requests comment with regard to each of these specifications, including whether DOE should incorporate any of the specifications in development of a final rule.

1. Section R302

Section R302 of the 2015 IECC specifies interior design temperatures that are to be used for heating and cooling load calculations when using energy use modeling. Given that the proposed rule does not include an option for compliance with the building thermal envelope requirements that makes use of simulated performance (*see* section R405 of the 2105 IECC), DOE has not included this requirement in the proposed rule. DOE requests comment on the practicality and functionality of using a simulated performance alternative that contemplates the adoption of sections R302 and R405 of the 2015 IECC.

2. Section R303.1

Section R303.1 of the 2015 IECC specifies how materials, systems, and equipment are to be identified. DOE has not incorporated these specifications in the proposed rule as the underlying statutory authority provides no direction for DOE to impose requirements on component manufacturers.

3. Section R401.3

Section R401.3 of the 2015 IECC specifies that a permanent certificate be posted in a utility room that gives the performance values of major building components and systems. Provisions related to enforcement and compliance of the proposed DOE standards were not contemplated by the MH working group and therefore are not included in this proposed rule.

4. Section R402.4

Section R402.4.2 of the 2015 IECC specifies that wood-burning fireplaces shall have tight fitting doors and outdoor combustion air. The IECC also requires that the fireplace and tight fitting doors must be listed and labeled in accordance with certain referenced standards. DOE is proposing not to include these requirements in this rule because they were not specifically addressed by the MH working group.

Section R402.4.5 of the 2015 IECC also specifies that recessed luminaires must be IC-rated. DOE has not adopted section R402.4.5 as fire safety was not contemplated by the MH working group.

5. Section R403

Section R403.2 of the 2015 IECC includes specifications for hot water boiler outdoor temperature setback. Given that hot water boilers used to supply building heat are not used in manufactured homes, DOE has not adopted requirements based on section R403.2 of the 2015 IECC under this proposed rule.

Section R403.5.1.2 of the 2015 IECC includes specifications for electric heat trace systems. The IECC requires that these systems comply with certain referenced standards. DOE is proposing not to include this requirement because electric heat trace systems are not commonly used in manufactured housing.

Section R403.4 of the 2015 IECC specifies a minimum of *R*-3 insulation on mechanical system piping capable of carrying fluids above 105 °F or below 55 °F. Section R403.4.1 of the 2015 IECC specifies that mechanical system piping insulation exposed to weather must be protected to prevent insulation degradation. These specifications are intended to reduce heat loss or gain and improve the energy efficiency of the piping delivery system. Mechanical systems that require piping holding fluids in this temperature range are unusual for manufactured housing. *See* Cavco, EERE–2009–BT–BC–0021–0133 at p. 63. Furthermore, DOE expects that the manufacturer of the mechanical system would require piping insulation of at least *R*-3 for proper installation. For the aforementioned reasons, DOE is not proposing to include the requirements of section R403.4 and R403.4.1 of the 2015 IECC. DOE requests comment on this proposal.

Section R403.8 of the 2015 IECC includes specifications for systems serving as multiple dwelling units. Consistent with the recommendation of the MH working group (*see* Term Sheet at 1), and because a manufactured home typically functions only as a single dwelling unit, DOE has not adopted requirements related to section R403.8 of the 2015 IECC under this proposed rule.

Section R403.9 of the 2015 IECC includes specifications for pavement snow- and ice-melting controls. Consistent with the recommendation of the MH working group (*see* Term Sheet at 1), and because the factory assembly of manufactured homes does not contemplate driveway conditions, DOE has not adopted requirements related to section R403.9 of the 2015 IECC in this proposed rule.

Sections R403.10, R403.11, and R403.12 of the 2015 IECC include specifications associated with the energy consumption of pools, permanent spas, and portable spas. Consistent with the recommendation of the MH working group (*see* Term Sheet at 1), and because the factory assembly of manufactured homes does not include pools and spas, DOE has not adopted requirements related to these sections of the 2015 IECC in this proposed rule.

6. Section R404

Section R404.1 of the 2015 IECC specifies either that a minimum of 75 percent of the lamps within each permanently installed lighting fixture be high-efficacy lamps or that a minimum of 75 percent of the permanently installed lighting fixtures contain only high-efficacy lamps. The 2015 IECC defines high-efficacy lighting as (1) compact fluorescent lamps; (2) T8 or smaller diameter linear fluorescent lamps; or (3) lamps with a minimum efficacy of 60 lumens per watt for lamps greater than 40 watts, 50 lumens per watt for lamps greater than 15 watts and less than or equal to 40 watts, and 40 lumens per watt for lamps less than or equal to 15 watts. Consumer adoption of high-efficacy lighting has increased over the past decade, as evidenced by section 3.4.5 of the preliminary TSD associated with the DOE general service lamp energy conservation standard. *See* 79 FR 73503 (Dec. 11, 2014). This ongoing rulemaking for general service lamps studies the benefits and burdens of establishing nationwide minimum lamp efficacy standards. DOE also completed a final rule adopting revised lamp efficacy standards for general service fluorescent lamps on January 26, 2015. *See* 80 FR 4041. Given DOE's ongoing efforts in this regard, DOE has not adopted requirements related to lighting in the proposed rule and requests comment on whether DOE's other rulemaking efforts would be insufficient to achieve lighting efficiency in manufactured housing.

Section R404.1.1 of the 2015 IECC includes specifications for fuel gas lighting systems. Given that manufactured homes do not utilize fuel gas lighting systems, DOE has not adopted requirements related to section R404.1.1 of the 2015 IECC in this proposed rule.

7. Section R405

Section R405 of the 2015 IECC establishes criteria for compliance using a simulated energy performance analysis, which involves calculating expected building energy use and comparing that value to the energy use of a standard reference building that complies with the minimum specifications of the 2015 IECC. Although DOE believes that simulated performance is a valid and technically feasible option, such an option does not appear to offer additional flexibility in the design of a manufactured home relative to the performance-based approach for the building thermal envelope. Accordingly, DOE has not adopted requirements associated with alternative performance under the proposed rule. DOE requests comment on the practicality and functionality of using a simulated performance alternative that contemplates the adoption of sections R302 and R405 of the 2015 IECC.

8. Section R406

Section R406 of the 2015 IECC establishes criteria for compliance using an energy rating index (ERI) that contemplates the use of software to calculate the energy use of a building. Although DOE believes that ERI analysis is a valid and technically feasible option, such an option does not appear to offer additional flexibility in the design of a manufactured home relative to the performance-based approach for the building thermal envelope. Accordingly, DOE has not adopted requirements associated with alternative performance under the proposed rule. DOE requests comment on the practicality and functionality of adopting an ERI alternative that contemplates the adoption of section R406 of the 2015 IECC.

9. Chapter 5

Chapter 5 of the 2015 IECC includes specifications related to the alteration, repair, addition, and change of occupancy of existing buildings and structures. Given that the proposed rule contemplates the energy conservation of newly constructed manufactured homes, DOE has not adopted any of the specifications included in chapter 5 of the 2015 IECC.

10. Chapter 6

Chapter 6 of the 2015 IECC lists the industry standards referenced in the 2015 IECC. Section 460.3 incorporates by reference only the industry standards relevant to the proposals included in this proposed rule, with specific modifications as applicable to manufactured housing. Accordingly, DOE has not adopted the industry standards as referenced in chapter 6 of the 2015 IECC.

*D. Crosswalk of Proposed Standards With the HUD Code*

As discussed in this preamble, DOE's intention in proposing energy conservation standards for manufactured homes is that, if finalized, there would be no conflict between the proposed requirements and the construction and safety standards for manufactured homes as established by HUD. That is, compliance with the proposed requirements would not prohibit a manufacturer from complying with the HUD Code. Table III.2 lists the proposed energy conservation standards and discusses their relationship to similar requirements contained in the HUD Code. As this proposed approach requires careful analysis of all aspects of energy conservation contained in both the proposed rule and in the HUD Code, DOE requests comment on any inconsistencies that would result from this proposed approach.

TABLE III.2—CROSSWALK OF PROPOSED STANDARDS WITH THE HUD CODE

| DOE Proposed rule (10 CFR part 460) | HUD Code (24 CFR part 3280) | Notes |
|---|---|---|
| § 460.101 would establish four climate zones, which would be delineated by home size and both state and county boundaries. | § 3280.506 establishes three climate zones delineated by state boundaries. The HUD Code establishes one standard for homes of all sizes within a climate zone. | HUD Code climate zone 3 and the northern portion of HUD Code climate zone 2 cover a similar region to climate zones 3 and 4 of the proposed rule. HUD Code climate zones 1 and the southern portion of HUD Code climate zone 2 cover a similar region to climate zones 1, 2, and 3 of the proposed rule. |
| § 460.102(a) would establish building thermal envelope prescriptive and performance compliance options. | § 3280.506 establishes a performance approach. | |
| § 460.102(b) would set forth the prescriptive option for compliance with the building thermal envelope requirements. | § 3280.506 establishes a performance approach only. | |
| § 460.102(b)(2) would establish a minimum truss heel height. | No corresponding requirement. | |
| § 460.102(b)(3) would require ceiling insulation to have uniform thickness and density. | No corresponding requirement. | |
| § 460.102(b)(4) would establish an acceptable batt and blanket insulation combination for compliance with the floor insulation requirement in climate zone 4. | No corresponding requirement. | |
| § 460.102(b)(5) would identify certain skylights not subject to SHGC requirements. | No corresponding requirements. | |
| § 460.102(b)(6) would establish *U*-factor alternatives for the *R*-value requirements under § 460.102(b)(1). | No corresponding requirements. | |
| § 460.102(b)(7) would establish a maximum ratio of 12 percent for glazed fenestration area to floor area under the prescriptive option. | No corresponding requirements. | |
| § 460.102(c)(1) would establish maximum building thermal envelope $U_o$ requirements by home size and climate zone. | § 3280.506(a) establishes maximum building thermal envelope $U_o$ requirements by climate zone. | The proposed maximum building thermal envelope $U_o$ requirements would be lower than the corresponding maximum $U_o$ requirements under § 3280.506(a). Compliance with the proposed $U_o$ requirements would achieve compliance with the $U_o$ requirements under the HUD Code. |
| § 460.102(c)(2) would establish maximum area-weighted vertical fenestration *U*-factor requirements in climate zones 3 and 4. | No corresponding requirements. | |
| § 460.102(c)(3) would establish maximum area-weighted average skylight *U*-factor requirements in climate zones 3 and 4. | No corresponding requirements. | |
| § 460.102(c)(4) would authorize windows, skylights and doors containing more than 50 percent glazing by area to satisfy the SHGC requirements of § 460.102(a) on the basis of an area-weighted average. | No corresponding requirements. | |
| § 460.102(d)(1) | | [Reserved]. |
| § 460.102(d)(2) | | [Reserved]. |
| § 460.102(d)(3) would establish a method of determining total *R*-value where multiple layers comprise a component. | § 3280.508(a) and (b) reference the Overall *U*-values and Heating/Cooling Loads—Manufactured Homes method and the 1997 ASHRAE Handbook of Fundamentals. | |
| § 460.102(d)(4) | | [Reserved]. |
| § 460.102(d)(5) | | [Reserved]. |
| § 460.102(d)(6) would establish prescriptive default *U*-factor values. | § 3280.508(a) and (b) reference the Overall *U*-values and Heating/Cooling Loads—Manufactured Homes method and the 1997 ASHRAE Handbook of Fundamentals. | |
| § 460.102(d)(7) | | [Reserved]. |
| § 460.102(d)(8) would establish prescriptive default *U*-factor values. | No corresponding requirements. | |
| § 460.102(e)(1) would establish a method of determining $U_o$. | § 3280.508(a) and (b) reference the Overall *U*-values and Heating/Cooling Loads—Manufactured Homes method and the 1997 ASHRAE Handbook of Fundamentals. | |
| § 460.102(e)(2) | | [Reserved]. |

TABLE III.2—CROSSWALK OF PROPOSED STANDARDS WITH THE HUD CODE—Continued

| DOE Proposed rule (10 CFR part 460) | HUD Code (24 CFR part 3280) | Notes |
|---|---|---|
| § 460.102(e)(3) would establish default fenestration and door *U*-factor and fenestration SHGC values. | § 3280.508(a) and (b) reference the Overall *U*-values and Heating/Cooling Loads—Manufactured Homes method and the 1997 ASHRAE Handbook of Fundamentals. These references contain default values. | DOE's proposed default values originate from the 2015 IECC. These default values generally result in lower performance than the HUD Code values. DOE expects compliance with the proposed rule to result in compliance with the HUD Code. |
| § 460.103(a) would require insulating materials to be installed according to the manufacturer installation instructions and the prescriptive requirements of Table 460.103. | No corresponding requirements. | |
| § 460.103(b) would establish requirements for the installation of batt, blanket, loose fill, and sprayed insulation materials. | No corresponding requirements. | |
| § 460.104 would require manufactured homes to be sealed against air leakage at all joints, seams, and penetrations associated with the building thermal envelope in accordance with the manufacturer's installation instructions and the requirements set forth in Table 460.104. | § 3280.505 establishes air sealing requirements of building thermal envelope penetrations and joints. | |
| § 460.201(a) would require each manufactured home to be equipped with a duct system that must be sealed to limit total air leakage to less than or equal to 4 cfm per 100 square feet of floor area when tested according to § 460.201(b) and specifies that building framing cavities are not to be used as ducts or plenums. | § 3280.715(a)(4) establishes requirements for airtightness of supply duct systems. | |
| § 460.201(b) ........................................................ | .......................................................................... | [Reserved]. |
| § 460.202(a) would require at least one thermostat to be provided for each separate heating and cooling system installed by the manufacturer. | § 3280.707(e) requires that each space heating, cooling, or combination heating and cooling system be provided with at least one adjustable automatic control for regulation of living space temperature. | Both the proposed rule and the HUD Code would require the installation of at least one thermostat that is capable of maintaining zone temperatures. |
| § 460.202(b) would require that installed thermostats controlling the primary heating or cooling system be capable of maintaining different set temperatures at different times of day. | No corresponding requirements. | |
| § 460.202(c) would require heat pumps with supplementary electric resistance heat to be provided with controls that, except during defrost, prevent supplemental heat operation when the pump compressor can meet the heating load. | § 3280.714(a)(1)(ii) requires heat pumps to be certified to comply with ARI Standard 210/240–89, heat pumps with supplemental electrical resistance heat to be sized to provide by compression at least 60 percent of the calculated annual heating requirements of the manufactured home, and that a control be provided and set to prevent operation of supplemental electrical resistance heat at outdoor temperatures above 40 °F. | Both the proposed rule and the HUD Code would require heat pumps with supplemental electric resistance heat to prevent supplemental heat operation when the heat pump compressor can meet the heating load of the manufactured home. |
| § 460.203(a) would establish requirements for the installation of service water heating systems. | No corresponding requirements. | |
| § 460.203(b) would require any automatic and manual controls, temperature sensors, pumps associated with service water heating systems to be accessible. | No corresponding requirement. | |
| § 460.203(c) would establish requirements for heated water circulation systems. | No corresponding requirements. | |
| § 460.203(d) would establish requirement for the insulation of hot water pipes. | No corresponding requirements. | |
| § 460.204 would establish requirements for mechanical ventilation system fan efficacy. | No corresponding requirements ...................... | HUD requirements at § 3280.103(b) do not overlap with DOE's proposal. DOE's proposal is for fan electrical efficiency, while HUD requirements specify minimum and maximum air flow rates. |
| § 460.205 would establish requirements for heating and cooling equipment sizing. | No corresponding requirements. | |

*E. Compliance and Enforcement*

Although DOE is not considering compliance and enforcement in this proposed rule, DOE anticipates assessing compliance and enforcement mechanisms in a future rulemaking. As a result, the costs and benefits resulting from any compliance and enforcement mechanism are not included in the economic impact analysis that is included in this rulemaking. DOE anticipates it will provide a detailed analysis of the costs and benefits resulting from compliance and enforcement activities in its future rulemaking. A variety of possibilities may be considered in that rulemaking process including, but not limited to, the three options described in this paragraph. First, HUD could directly administer a compliance and enforcement program for DOE's manufactured housing regulations via the existing HUD system outlined at 24 CFR 3282. This option would require that HUD adopt the energy conservation standards resulting from this rulemaking into its Manufactured Home Construction and Safety Standards. Second, DOE could implement a compliance and enforcement program mirroring HUD's system codified at 24 CFR 3282. Third, manufacturers could self-certify compliance to DOE by submitting documentation attesting that manufactured homes are compliant with DOE regulations. This third compliance option could be paired with a variety of enforcement mechanisms ranging from unannounced inspections and audits to a system mirroring HUD's enforcement system at 24 CFR 3282.

By way of background, under HUD's compliance and enforcement system, manufacturers are required to: (1) Contract for services with a HUD accepted Design Approval Primary Inspection Agency (DAPIA) to evaluate their designs and quality assurance manual for conformance with the Standards and Regulations; and (2) contract for services with a HUD accepted Production Inspection Primary Inspection Agency (IPIA) to evaluate, through on-going surveillance of the production process, that each plant is continuing to follow its DAPIA approved quality assurance manual and quality control procedures and to verify that each factory is continuing to produce homes in conformance with the Standards. In addition, the actions of all primary inspection agencies (DAPIAs, IPIAs) and State Administrative Agencies (SAAs) are monitored to determine whether they are fulfilling their responsibilities under HUD's regulatory system. In addition, manufacturers are also subject to system of notification and correction procedures whenever they produce homes that contain imminent safety hazards or failures to conform to the HUD standards.

DOE seeks comment on potential options for compliance and enforcement to be considered in a future rulemaking, including information regarding the rationale for any recommended option. DOE also seeks comment on the estimated costs (only direct compliance and enforcement costs, not engineering costs for redesign) and time (design review validation, inspection frequency and duration, administrative procedures) associated with the potential options.

## IV. Economic Impacts and Energy Savings

*A. Economic Impacts on Individual Purchasers of Manufactured Homes*

DOE used the LCC and payback period (PBP) analyses developed during the MH working group negotiations to inform the development of the proposed rule based on the economic impacts on individual purchasers of manufactured homes. The LCC of a manufactured home refers to the total homeowner expense over the life of the manufactured home, consisting of purchase expenses (*i.e.,* mortgage or cash purchase) and operating costs (*i.e.,* energy costs). To compute the operating costs, DOE discounted future operating costs to the time of purchase and summed them over the 30-year lifetime of the home used for the purpose of analysis in this rulemaking. The PBP refers to the estimated amount of time (in years) for manufactured homeowners to recover the increased purchase cost (including installation) of their homes through lower operating costs. DOE calculates the PBP by dividing the incremental increase in purchase cost by the reduction in average annual operating costs that would result from this proposed rule.

The LCC analysis demonstrates that increased purchase prices would be offset by the benefits manufactured homeowners would experience in operating cost savings under the proposed rule. DOE has evaluated these projected impacts on individual manufactured homeowners by analyzing the potential impacts to LCC, energy savings, and purchase price of manufactured homes under the proposed rule. For the purpose of this economic analysis, DOE compared the purchase price and LCC for manufactured homes built in accordance with the proposed rule relative to a baseline manufactured home built in compliance with the minimum requirements of the HUD Code. Specifically, DOE performed energy simulations on manufactured homes located in 19 geographically diverse locations across the United States, accounting for five common heating fuel/system types and two typical industry sizes of manufactured homes (single-section and double-section[6] manufactured homes). Further information on how DOE calculated LCC impacts and energy savings for the alternative efficiency levels discussed here is included in chapter 8 of the TSD. DOE requests comment on the methodology and results of the LCC analysis.

Table IV.1 provides the preliminary average purchase price increases to manufactured homes associated with the proposed rule under each of the proposed climate zones. These costs are based on estimates for the increased costs associated with more energy efficient components, as provided by the MH working group. *See* EERE–2009–BT–BC–0021–0091. These costs are discussed in further detail in chapter 5 and chapter 9 of the TSD.

TABLE IV.1—AVERAGE MANUFACTURED HOME PURCHASE PRICE AND PERCENTAGE INCREASES UNDER THE PROPOSED RULE BY CLIMATE ZONE

| | Single-section | | Multi-section | |
|---|---|---|---|---|
| | $ | % | $ | % |
| Climate Zone 1 | 2,422 | 5.3 | 3,748 | 4.5 |
| Climate Zone 2 | 2,348 | 5.1 | 3,668 | 4.4 |

[6] Double-section manufactured homes were used to represent all multi-section homes. Double-section manufactured homes have the largest market share by shipments (about 98 percent) of all multi-section homes.

TABLE IV.1—AVERAGE MANUFACTURED HOME PURCHASE PRICE AND PERCENTAGE INCREASES UNDER THE PROPOSED RULE BY CLIMATE ZONE—Continued

| | Single-section | | Multi-section | |
|---|---|---|---|---|
| | $ | % | $ | % |
| Climate Zone 3 | 2,041 | 4.5 | 2,655 | 3.2 |
| Climate Zone 4 | 2,208 | 4.8 | 2,877 | 3.4 |
| National Average | 2,226 | 4.9 | 3,109 | 3.7 |

Although DOE preliminarily has determined that the proposed standards would result in increased purchase prices of manufactured homes, manufactured homeowners, on average, would realize significant LCC savings and energy savings as a result of the proposed rule. DOE requests comment on affordability with respect to the projected average increase in purchase cost (see Table IV.1 below) on the ability of low-income consumers to obtain credit and financing to purchase a manufactured home. DOE also requests comments on affordability in context of the potential for reduced operating costs (energy bills) and total LCC.

Figure IV.1 illustrates the average annual energy cost savings for space heating and air conditioning for the first year of occupation by geographic location under the proposed rule based on the estimated fuel costs provided in chapter 8 of the TSD. Heating cost savings are generally higher than cooling cost savings, so locations with cold climates would have higher amounts of energy cost savings because of the reduced heating energy use.

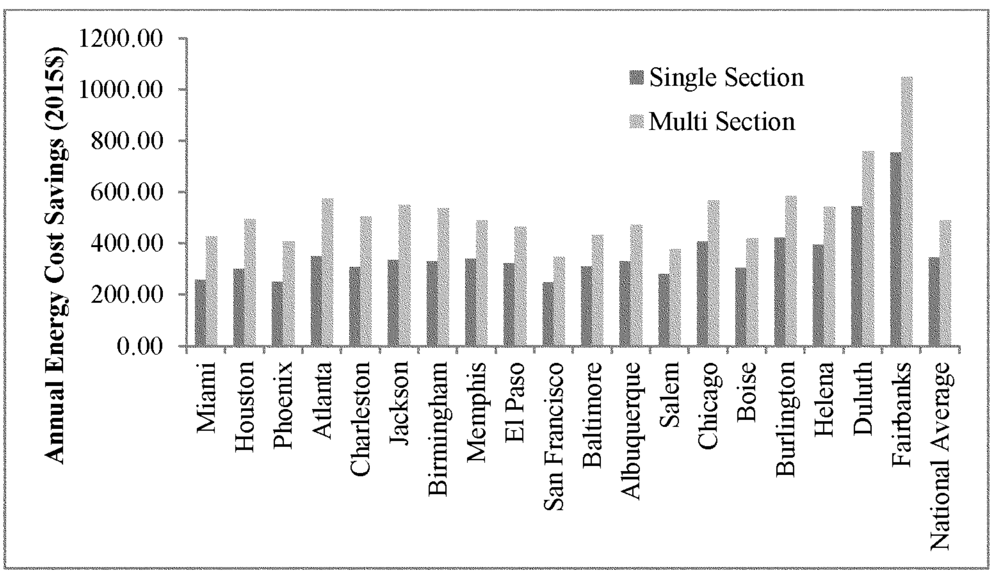



**Figure IV.1. Annual Energy Cost Savings under the Proposed Rule**

Figure IV.2 illustrates the average 30-year LCC savings by geographic location (averaged across the five different heating fuel/system types) associated with the proposed rule for both single-section and multi-section manufactured homes. As discussed in detail in chapter 9 of the TSD, Figure IV.2 accounts for LCC savings and impacts over a 30-year period of analysis, including energy cost savings and mortgage payment increases discounted to a present value using the discount rates discussed in chapter 4 of the TSD. These preliminary results also are based on the costs associated with energy conservation improvements, as discussed in chapter 5 of the TSD.

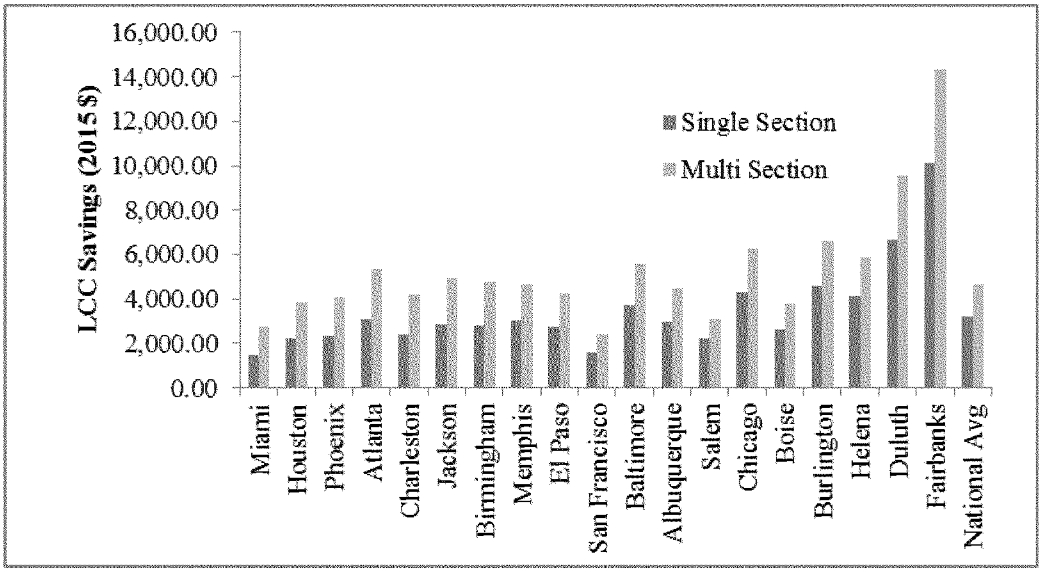



**Figure IV.2. Thirty-Year Lifecycle Cost Savings under the Proposed Rule**

The estimated LCC impacts under Figure IV.2 vary by location for three primary reasons. First, each geographic location analyzed is situated in one of four proposed climate zones and therefore would be subject to different energy conservation requirements. Second, geographic locations within the same climate zone would experience different levels of energy savings. For example, both El Paso and Baltimore would be situated in climate zone 3. However, a manufactured home in Baltimore that meets the proposed climate zone 3 requirements would experience greater savings than a manufactured home in El Paso that meets the proposed climate zone 3 requirements because cooler climates would have greater energy cost savings as a result of greater reductions in heating costs. Finally, the level of energy cost savings depends on the type of heating system installed and fuel type used in a manufactured home. As discussed in chapter 8 of the TSD, DOE has accounted for regional differences in heating systems and fuel types commonly installed in manufactured housing.

Table IV.2 provides the preliminary national average LCC savings under the proposed rule and annual energy cost savings associated with the proposed rule for space heating and air conditioning (and percent reduction in space heating and cooling costs), both of which are measured against a baseline manufactured home constructed in accordance with the HUD Code. As discussed in further detail in chapter 9 of the TSD, each geographic location preliminary has been determined to result in LCC savings and energy savings, on average.

TABLE IV.2—NATIONAL AVERAGE PER-HOME SAVINGS UNDER THE PROPOSED RULE

| | Single-section | Multi-section |
|---|---|---|
| Lifecycle Cost Savings (30 Years) | $3,211 | $4,625 |
| Annual Energy Cost Savings | 345 | 490 |

Table IV.3 shows the benefits and costs to the manufactured homeowner associated with the proposed rule, expressed in terms of annualized values.

TABLE IV.3—ANNUALIZED BENEFITS AND COSTS TO MANUFACTURED HOMEOWNERS UNDER THE PROPOSED RULE

| | Discount Rate (%) | Monetized (million 2015$/year) | | |
|---|---|---|---|---|
| | | Primary estimate ** | Low estimate ** | High estimate ** |
| **Benefits** * | | | | |
| Operating (Energy) Cost Savings | 7<br>3 | 516<br>843 | 400<br>617 | 688<br>1,191 |
| **Costs** * | | | | |
| Incremental Purchase Price Increase | 7<br>3 | 220<br>277 | 165<br>192 | 285<br>378 |
| **Net Benefits/Costs** * | | | | |
| | 7<br>3 | 296<br>566 | 235<br>425 | 403<br>813 |

* The benefits and costs are calculated for homes shipped in 2017–2046.
** The Primary, Low, and High Estimates utilize forecasts of energy prices from the 2015 AEO Reference case, Low Economic Growth case, and High Economic Growth case, respectively.

Figure IV.3 illustrates the nationwide average simple payback period (purchase price increase divided by first year energy cost savings) under the proposed rule. The estimated simple payback periods under Figure IV.3 vary by geographic location based on the different climate zone requirements for manufactured housing, geographic climatic differences within climate zones, and the type of heating system installed and fuel type used in a manufactured home.

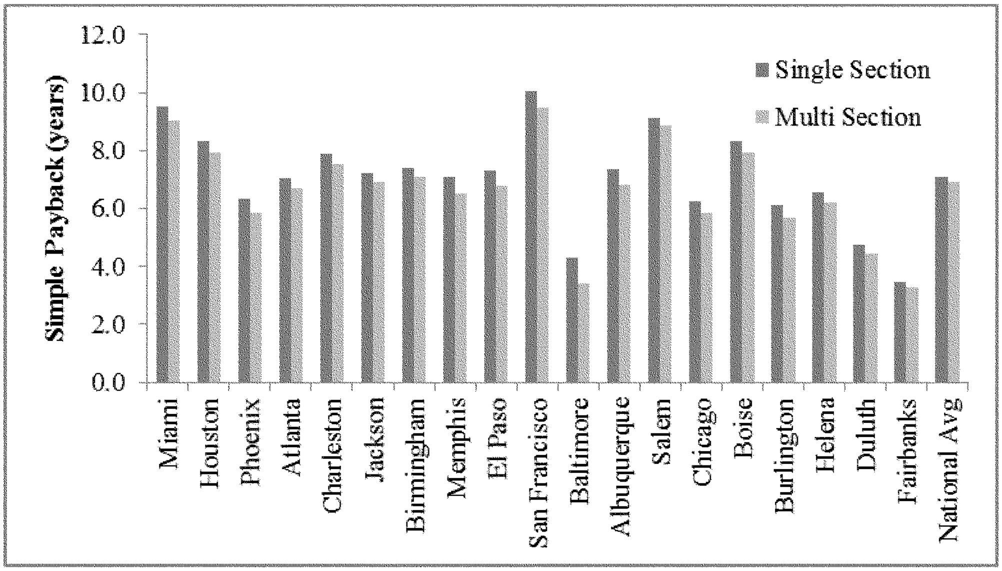



**Figure IV.3. Simple Payback Period of the Proposed Rule**

*B. Manufacturer Impacts*

DOE performed a manufacturer impact analysis (MIA) to estimate the potential financial impact of energy conservation standards on manufacturers of manufactured homes. The MIA relied on the Government Regulatory Impact Model (GRIM), an industry cash-flow model used to estimate changes in industry value as a result of energy conservation standards. The key GRIM inputs are data on: Industry financial metrics, manufacturer production cost estimates, shipments forecasts, conversion expenditures estimates, and assumptions about manufacturer markups. The primary output of the GRIM is industry net present value (INPV), which is the sum of industry annual cash flows over the analysis period (2016–2046), discounted using the industry weighted average cost of capital. The GRIM has a slightly different analysis period than the NIA and LCC because it takes into account the conversion period, the time between the announcement of the standard and the effective date of the standard, since manufacturers may need to make upfront investments to bring their covered products ahead of the standard going into effect. The GRIM estimates the impacts of more-stringent energy conservation standards on a given industry by comparing changes in INPV and domestic manufacturing employment between a base case and the standards case. To capture the uncertainty relating to manufacturer pricing strategy following new standards, the GRIM estimates a range of possible impacts under different markup scenarios. Each of the inputs and output is discussed in chapter 12 of the NOPR TSD. DOE used the GRIM to calculate cash flows using standard accounting principles and to compare changes in INPV between a base case and a standards case. The percent change in INPV between the base and standards cases represents the financial impact of new energy conservation standards on manufacturers of manufactured homes. Additional detail on the GRIM can be found in Appendix 12A.

DOE conducted the MIA analysis in three phases. In Phase 1 of the MIA, DOE analyzed the upfront investments, conversation costs, manufacturers would need to make to bring their products into compliance with the new energy conservation standards. These upfront investments include product conversion costs and capital conversion costs. Product conversion costs are one-time investments in research, development, labeling updates, and other costs necessary to make product designs comply with energy conservation standards. Capital conversion costs are one-time investments in property, plant and equipment to adapt or change existing production lines to fabricate and assemble new product designs that comply with the energy conservation standards.

DOE calculated that the proposed rule would result in an average upfront investment, or conversion cost, of $37,500 per manufacturer. This figure includes $32,500 per manufacturer for product conversion costs and $5,000 per manufacturer for capital conversion costs. DOE assumed in its analysis that manufacturers would incur all upfront costs in the year following publication of the final rule. Additional detail on the conversion costs can be found in chapter 12 of the TSD.

In Phase 2 of the MIA, DOE analyzed the effect the proposed standards would have on manufacturer production costs. To be conservative in its analysis, DOE assumed that all units sold are at the HUD minimum. Thus, the analysis does not account for the reduced impact on units sold that may exceed the HUD minimum. Based on this analysis, DOE estimates average manufacturer production costs would increase by $1,321 for each single-section unit and by $1,840 for each multi-section unit. The estimated increases in manufacturer production costs are derived from the estimated increases in purchase price, the retail markup and the manufacturer markup on these units. As a starting point, DOE used the retail prices of manufactured homes in 19 cities that include all four proposed climate zones. The retail prices were for the base case in each city and the standard case in each city. Using public sources of information, including company SEC 10–K filings [7] and corporate annual reports, DOE applied a consistent manufacturer markup of 1.25 and a retail markup of 1.30 for the base cases and standards cases. DOE used these two markups, and along with a sales tax multiplier, to back-calculate the manufacturer production cost for each city. Details on the derivation of the sales tax multiplier, retail markup, manufacturer markup, and manufacturer production cost for each city can be found in chapter 12 of the NOPR TSD. DOE requests comments on whether other manufacturer and retailer markups for base case and standards cases should be considered (*e.g.,* a combined mark-up of 2.30 has historically been used in the past by HUD to assess combined manufacturer and retailer mark-ups to determine potential first cost impacts on consumers).

In Phase 3 of the MIA, DOE modeled two scenarios that reflect changes in the manufacturer's ability to pass on their upfront investments and increases in production costs to the customers. As manufacturer production costs increase, manufacturers may need to adjust their markup structure. For the MIA, DOE modeled two standards case markup scenarios for manufactured homes to represent the uncertainty regarding the potential impacts on prices and profitability for manufactured home manufacturers following the implementation of the proposed rule. DOE modeled a high and a low scenario for a manufacturer to pass on their upfront investments and increases in production costs to the customer: (1) A preservation of gross margin percentage markup scenario; and (2) a preservation of operating profit markup scenario. These scenarios lead to different markup values that, when applied to the inputted manufacturer production costs, result in varying revenue and cash flow impacts on the manufacturer.

Under the preservation of gross margin percentage markup scenario, manufacturers maintain their current average markup of 1.25 even as production costs increase. Manufacturers are able to maintain the same amount of profit as a percentage of revenues, suggesting that they are able to pass on the costs of compliance to their customers. DOE considers this scenario the upper bound to industry profitability.

In the preservation of per unit operating profit scenario, manufacturer markups are set so that operating profit one year after the compliance date of the amended energy conservation standard is the same as in the base case on a per unit basis. Under this scenario, as the costs of production increase under a standards case, manufacturers are generally required to reduce their markups. The implicit assumption behind this markup scenario is that the industry can only maintain its operating profit in absolute dollars per unit after compliance with the new standard is required. Therefore, operating margin is reduced between the base case and standards case. This markup scenario represents a lower bound to industry profitability under an amended energy conservation standard.

DOE calculated an industry average discount rate of 9.2% based on SEC filings for public manufacturers of manufactured homes. This discount rate was used to estimate the time-value of money when discounting future cash flows. The INPV is the sum of the discounted cash flows over the analysis period, which begins in 2016 and ends in 2046. When applying the two different markup scenarios, DOE is able to estimate a range of potential impacts to INPV and the industry. DOE compares the INPV of the base case to that of the proposed level. The difference between INPV in the base case and INPV at the proposed level is an estimate of the economic impacts on the industry.

TABLE IV.4—INPV RESULTS: PRESERVATION OF GROSS MARGIN PERCENTAGE SCENARIO *

| | Single-section | Multi-section | Total industry |
|---|---|---|---|
| Base Case INPV (million 2015$) | 229.0 | 487.8 | 716.7 |
| Standards Case INPV (million 2015$) | 227.9 | 485.8 | 713.6 |
| Change in INPV (million 2015$) | (1.1) | (2.0) | (3.1) |
| Change in INPV (%) | −0.5% | −0.4% | −0.4% |
| Total Conversion Costs (million 2015$) | 0.5 | 1.1 | 1.6 |

* Values in parentheses are negative values.

TABLE IV.5—INPV RESULTS: PRESERVATION OF OPERATING PROFIT MARKUP SCENARIO *

| | Single-section | Multi-section | Total industry |
|---|---|---|---|
| Base Case INPV (million 2015$) | 229.0 | 487.8 | 716.7 |
| Standards Case INPV (million 2015$) | 215.0 | 465.0 | 680.0 |
| Change in INPV (million 2015$) | (14.0) | (22.8) | (36.8) |
| Change in INPV (%) | −6.1% | −4.7% | −5.1% |
| Total Conversion Costs (million 2015$) | 0.5 | 1.1 | 1.6 |

* Values in parentheses are negative values.

For single-section units, the base case INPV is $229.0 million. The proposed standard could result in a drop of industry value ranging from −0.5 percent to −6.1 percent, or a loss of $1.1 million to $14.0 million. For multi-section units, the base case INPV is $487.8 million. The proposed standard could result in a drop of industry value

[7] U.S. Securities and Exchange Commission. Annual 10–K Reports. Various Years. <*http://sec.gov*>.

ranging from −0.4 percent to −4.7 percent, or a loss of $2.0 million to $22.8 million. For the industry as a whole, the base case INPV is $716.7 million. The proposed standard could result in a drop in INPV of −0.4 percent to −5.1 percent, or a loss of $3.1 million to $36.8 million. Industry conversion costs total $1.6 million at the proposed level.

Though DOE's analysis assumes all manufactured homes are sold at the HUD minimum level (analyzed as the baseline in this rulemaking), select manufactured homes are available in the market at higher efficiencies. If a manufacturer currently produces homes that are more efficient than the HUD minimum level, the impacts associated with that manufacturer will be reduced. For example, the incremental manufacturer production cost would be smaller for a manufacturer already producing homes above the minimum level. If a manufacturer already produces homes compliant with the proposed level, then the manufacturer would experience no conversion costs or increases in production costs for those models.

DOE requests comment on the conversion costs for proposed standard. DOE welcomes additional data regarding the cost to redesign model plans to meet the proposed standard and the capital expenditures that the proposed standard would require.

DOE also requests comment on the average manufacturer markup for single-section and multi-section homes, including any differences in markup between minimally compliant homes and homes with upgrades that improve energy performance. Additionally, DOE requests comment on the average retail markup in the industry.

*C. Nationwide Impacts*

DOE's NIA projects a net benefit to the nation as a whole as a result of the proposed rule in terms of NES and the NPV of total customer costs and savings that would be expected as a result of the proposed rule in comparison with the minimum requirements of the HUD Code. DOE calculated the NES and NPV based on annual energy consumption and total construction and lifecycle cost data from the LCC analysis (developed during the MH working group negotiation process) described in section IV.A of this SUPPLEMENTARY INFORMATION and shipment projections. DOE projected the energy savings, operating cost savings, equipment costs, and NPV of customer benefits sold in a 30-year period from 2017 through 2046. The analysis also accounts for costs and savings for a manufactured home lifetime of 30 years. A detailed description of the NIA methodology is provided in chapter 11 of the TSD. DOE requests comment on the methodology and initial findings of the NIA.

DOE developed a shipments model to forecast the shipments of manufactured homes during the analysis period. DOE first gathered historical shipments spanning 1990–2013 from a report developed and written by the Institute for Building Technology and Safety and published by the Manufactured Housing Institute.[8] Then, using the growth rate (1.8 percent) in new residential housing starts from the *AEO 2015,* DOE projected the number of manufactured housing shipments from 2014 through 2046 in the base case (no new standards adopted by DOE). For the standards case shipments, DOE used this same growth rate estimate (1.8 percent), but also applied an estimate for price elasticity of demand. Price elasticity of demand (price elasticity) is an economic concept that describes the change of the quantity demanded in response to a change in price. DOE used the price elasticity value of −0.48 (a 10-percent price increase would translate to a 4.8-percent reduction in manufactured home shipment) based on a study published in the *Journal of Housing Economics*[9] for estimating standards case shipments.

In a second sensitivity analysis, DOE also considered a standards case shipment scenario in which the price elasticity is −2.4 (instead of −0.48) This would project a 2.4 percent reduction in shipments based on the projected cost increases in the proposed rule. DOE based this sensitivity case on previous HUD estimates of −2.4 price elasticity based on a 1992 paper written by Carol Meeks.[11] This would translate to a 12 percent reduction in shipments based on a 5 percent increase in price as forecasted in the proposed rule.

A detailed description of the shipments methodology is provided in chapter 10 of the TSD. DOE requests comment on the methodology and initial findings of the shipments analysis.

Table IV.6 and Table IV.7 reflect the NES results over a 30-year analysis period under the proposed rule on a primary energy savings basis. Primary energy savings apply a factor to account for losses associated with generation, transmission, and distribution of electricity. Primary energy savings differ among the different climate zones because of differing energy conservation requirements in each climate zone and different shipment projections in each climate zone.

TABLE IV.6—CUMULATIVE NATIONAL ENERGY SAVINGS OF MANUFACTURED HOMES PURCHASED 2017–2046 WITH A 30-YEAR LIFETIME

| | Single-section (quads) | Multi-section (quads) |
|---|---|---|
| Climate Zone 1 | 0.171 | 0.281 |
| Climate Zone 2 | 0.124 | 0.234 |
| Climate Zone 3 | 0.259 | 0.449 |
| Climate Zone 4 | 0.279 | 0.382 |
| Total | 0.833 | 1.346 |

[8] See *Manufactured Home Shipments by Product Mix (1990–2013),* Manufactured Housing Institute (2014).

[9] See Marshall, M.I. & Marsh, T.L. Consumer and investment demand for manufactured housing units. *J. Hous. Econ.* 16, 59–71 (2007).

[11] Meeks, C., 1992, Price Elasticity of Demand for Manufactured Homes: 1961–1989.

TABLE IV.7—CUMULATIVE NATIONAL ENERGY SAVINGS OF MANUFACTURED HOMES PURCHASED 2017–2046 WITH A 30-YEAR LIFETIME

| | Single-section (%) | Multi-section (%) |
|---|---|---|
| Climate Zone 1 | 25.3 | 29.9 |
| Climate Zone 2 | 25.4 | 30.6 |
| Climate Zone 3 | 26.0 | 28.1 |
| Climate Zone 4 | 25.4 | 26.5 |
| Total | 25.6 | 28.4 |

Table IV.8 and Table IV.9 illustrate the cumulative NES over the 30-year analysis period under the proposed rule on a FFC energy savings basis. FFC energy savings apply a factor to account for losses associated with generation, transmission, and distribution of electricity, and the energy consumed in extracting, processing, and transporting or distributing primary fuels. NES differ amongst the different climate zones because of differing energy efficiency requirements in each climate zone and different shipment projections in each climate zone.

TABLE IV.8—CUMULATIVE NATIONAL ENERGY SAVINGS, INCLUDING FULL-FUEL-CYCLE OF MANUFACTURED HOMES PURCHASED 2017–2046 WITH A 30-YEAR LIFETIME

| | Single-section (quads) | Multi-section (quads) |
|---|---|---|
| Climate Zone 1 | 0.179 | 0.294 |
| Climate Zone 2 | 0.130 | 0.245 |
| Climate Zone 3 | 0.272 | 0.474 |
| Climate Zone 4 | 0.303 | 0.416 |
| Total | 0.884 | 1.428 |

TABLE IV.9—CUMULATIVE NATIONAL ENERGY SAVINGS, INCLUDING FULL-FUEL-CYCLE OF MANUFACTURED HOMES PURCHASED 2017–2046 WITH A 30-YEAR LIFETIME

| | Single-section (%) | Multi-section (%) |
|---|---|---|
| Climate Zone 1 | 25.3 | 29.9 |
| Climate Zone 2 | 25.4 | 30.6 |
| Climate Zone 3 | 26.0 | 28.1 |
| Climate Zone 4 | 25.4 | 26.6 |
| Total | 25.6 | 28.3 |

Table IV.10 and Table IV.11 illustrate the NPV of customer benefits over the 30-year analysis period under the proposed rule for a discount rate of 7 percent and 3 percent respectively. The NPV of manufactured homeowner benefits differ among the different climate zones because there are different up-front costs and operating cost savings associated with each climate zone and different shipment projections in each climate zone. All climate zones have a positive NPV for both discount rates under this proposed rule.

TABLE IV.10—NET PRESENT VALUE OF MANUFACTURED HOMES PURCHASED 2017–2046 WITH A 30-YEAR LIFETIME AT A 7% DISCOUNT RATE

| | Single-section (billion 2015$) | Multi-section (billion 2015$) |
|---|---|---|
| Climate Zone 1 | 0.19 | 0.34 |
| Climate Zone 2 | 0.16 | 0.35 |
| Climate Zone 3 | 0.39 | 0.74 |
| Climate Zone 4 | 0.52 | 0.74 |
| Total | 1.26 | 2.18 |

TABLE IV.11—NET PRESENT VALUE OF MANUFACTURED HOMES PURCHASED 2017–2046 WITH A 30-YEAR LIFETIME AT A 3% DISCOUNT RATE

| | Single-section (billion 2015$) | Multi-section (billion 2015$) |
|---|---|---|
| Climate Zone 1 | 0.66 | 1.16 |
| Climate Zone 2 | 0.54 | 1.10 |
| Climate Zone 3 | 1.22 | 2.26 |
| Climate Zone 4 | 1.60 | 2.24 |
| Total | 4.03 | 6.75 |

DOE considered two sensitivity analyses relating to shipments. First, DOE considered a shipment scenario in which the growth rate is 6.5 percent (instead of 1.8 percent) based on the trend in actual manufactured home shipments from 2011 to 2014. This growth rate applies to both the base case and standards case shipments. DOE's primary scenario is based on the residential housing start data from *AEO 2015.* The sensitivity analysis calculates the increase in NES and NPV associated with a much larger future market for manufactured homes. See Table IV.12 for results of the sensitivity analysis. A detailed description of the sensitivity analysis is provided in appendix 11A of the TSD. DOE requests comment on the shipment growth rate assumption used in the shipments analysis.

TABLE IV.12—SHIPMENTS GROWTH RATE SENSITIVITY ANALYSIS NES AND NPV RESULTS

| | National energy savings (full fuel cycle quads) | Net present value 3% discount rate (billion 2015$) | Net present value 7% discount rate (billion 2015$) |
|---|---|---|---|
| 1.8% Shipment Growth (primary scenario) | 2.3 | 10.93 | 3.47 |
| 6.5% Shipment Growth | 5.8 | 26.19 | 7.38 |

In a second sensitivity analysis, DOE considered a standards case shipment scenario in which the price elasticity is −2.4 (instead of −0.48). HUD has used an estimate of −2.4 in analysis of revisions to its regulations[10] promulgated at 24 CFR 3282 based on a 1992 paper written by Carol Meeks.[11] DOE's primary scenario is based on a study published in 2007 in the *Journal of Housing Economics.* The sensitivity analysis calculates the decrease in NES and NPV associated with a larger decrease in shipments resulting from the more negative price elasticity value. Price elasticity of −2.4 would translate to a 12 percent reduction in shipments based on a 5 percent increase in price as projected by the proposed rule. Price elasticity of −0.48 would project a 2.4 percent reduction in shipments based on the projected cost increases in this proposed rule. See Table IV.13 for results of the sensitivity analysis. A detailed description of the sensitivity analysis is provided in appendix 11A of the TSD. DOE requests comment on the price elasticity assumption used in the standards case shipments analysis.

TABLE IV.13—PRICE ELASTICITY OF DEMAND SENSITIVITY ANALYSIS NES AND NPV RESULTS

| | National energy savings (full fuel cycle quads) | Net present value 3% discount rate (billion 2015$) | Net present value 7% discount rate (billion 2015$) |
|---|---|---|---|
| −0.48 Price Elasticity (primary scenario) | 2.3 | 10.93 | 3.47 |
| −2.4 Price Elasticity | 2.1 | 10.04 | 3.19 |

### *D. Nationwide Environmental Benefits*

DOE's analyses indicate that this proposed rule would reduce overall demand for energy in manufactured housing. The proposed rule also would produce environmental benefits in the form of reduced emissions of air pollutants and greenhouse gases associated with electricity production. Emissions avoided under the proposed rule would be directly proportional to energy savings that would be achieved. DOE has based these estimates on a 30-year analysis period of manufactured home shipments, accounting for a 30-year home lifetime. DOE's analysis estimates reductions in emissions of six pollutants associated with energy savings: Carbon dioxide ($CO_2$), mercury (Hg), nitric oxide and nitrogen dioxide ($NO_X$), sulfur dioxide ($SO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$). These reductions are referred to as "site" emissions reductions. Furthermore, DOE estimated reductions in emissions associated with the production of these fuels (extracting, processing, transporting to power plants or homes). Such reductions are referred to as

[10] For example, see *http://www.regulations.gov/#!documentDetail;D=HUD-2014-0033-0001.*

[11] Meeks, C., 1992, Price Elasticity of Demand for Manufactured Homes: 1961 to 1989.

"upstream" emissions reductions. Together, site emissions reductions and upstream emissions reductions account for the FFC. In accordance with DOE's FFC Statement of Policy (*see* 76 FR 51282 (Aug. 18, 2011), 77 FR 49701 (Aug. 17, 2012)), the FFC analysis includes impacts on emissions of $CH_4$ and $N_2O$, both of which are recognized as greenhouse gases (GHGs).

The emissions reduction estimates are based on emission intensity factors for each pollutant, which depend on the type of fuel associated with energy savings (electricity, natural gas, liquefied petroleum gas, fuel oil). These emission intensity factors were derived from data in the *AEO 2015* [12] and from the EPA GHG Emissions Factors Hub.[13] Full details of this methodology are described in chapter 13 of the TSD. Table IV.14 reflects the emissions reductions for both single-section and multi-section manufactured homes. DOE requests comment on the methodology and initial findings of the emissions analysis.

TABLE IV.14—EMISSIONS REDUCTIONS AS A RESULT OF THE PROPOSED RULE

| Pollutant | Single-section | Multi-section |
|---|---|---|
| **Site Emissions Reductions** | | |
| $CO_2$ (million metric tons) | 56.5 | 91.1 |
| Hg (metric tons) | 0.0904 | 0.146 |
| $NO_X$ (thousand metric tons) | 223 | 356 |
| $SO_2$ (thousand metric tons) | 27.6 | 44.4 |
| $CH_4$ (thousand metric tons) | 3.78 | 6.09 |
| $N_2O$ (thousand metric tons) | 0.632 | 1.02 |
| **Upstream Emissions Reductions** | | |
| $CO_2$ (million metric tons) | 4.01 | 6.45 |
| Hg (metric tons) | 0.000944 | 0.00153 |
| $NO_X$ (thousand metric tons) | 51.8 | 83.2 |
| $SO_2$ (thousand metric tons) | 0.615 | 0.991 |
| $CH_4$ (thousand metric tons) | 239 | 385 |
| $N_2O$ (thousand metric tons) | 0.0294 | 0.0474 |
| **Total Emissions Reductions** | | |
| $CO_2$ (million metric tons) | 60.5 | 97.6 |
| Hg (metric tons) | 0.0913 | 0.148 |
| $NO_X$ (thousand metric tons) | 275 | 439 |
| $SO_2$ (thousand metric tons) | 28.2 | 45.4 |
| $CH_4$ (thousand metric tons) | 243 | 391 |
| $N_2O$ (thousand metric tons) | 0.661 | 1.07 |

Additionally, DOE considered the estimated monetary benefits likely to result from the reduced emissions of $CO_2$ and $NO_X$ that would be expected to result from the proposed rule. In order to make this calculation similar to the calculation of the net present value of consumer benefit, DOE considered the reduced emissions expected to result over the lifetime of products shipped in the analysis period (2017–2046) under the proposed rule. DOE has calculated the monetary values for each of these emissions using the social cost of carbon (SCC) methodology, which estimates the monetized damages associated with an incremental increase in carbon emissions within a given year. The SCC is intended to account for, but is not limited to, changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services. SCC estimates are given in terms of dollars per metric ton of $CO_2$ emitted.

The SCC is comprised of monetization estimate results from three different integrated assessment models, which have different methodologies for calculating the damages associated with $CO_2$ emissions. The SCC values used for this rulemaking were generated using the most recent versions of the three integrated assessment models that have been published in peer-reviewed literature.[14] As a result, four SCC estimates of emitted $CO_2$ value are available, representing different aggregation of these three models and utilization of a variety of discount rates. Three sets of the monetization factors utilize the average impacts projected by the three assessment models that comprise the SCC. The fourth set of monetization factors utilizes the 95th percentile impacts of the three assessment models and is intended to capture higher than expected impacts. For the purposes of capturing the uncertainty of emitted $CO_2$ value, the interagency group recommends including all four sets of available SCC values. Full details of this methodology are described in chapter 14 of the TSD. These estimates have been developed by an interagency process and are presented with an acknowledgement of uncertainty. These results should be treated as revisable, as the estimates of emitted $CO_2$ monetary value evolve with improved scientific and economic understanding.

DOE also has estimated monetary benefits for $NO_X$ emissions under the proposed rule. Estimates of the monetary value of reducing $NO_X$ from stationary sources range from $489 to $5,023 per metric ton (2015$). DOE calculated monetary benefits using an intermediate value for $NO_X$ emissions of $2,755 per metric ton (in 2015$), and real discount rates of 3 and 7 percent. DOE is evaluating appropriate monetization of avoided $SO_2$ and Hg emissions in energy conservation standards rulemakings and has not included such monetization in the current analysis. DOE has similarly not included monetization of reductions in emissions of $CH_4$ or $N_2O$. DOE requests comments on the methodology and results of the monetization of emissions reductions benefits analysis. Table IV.15 provides the NPVs from the savings of reduced $CO_2$ and $NO_X$ emissions resulting from manufactured homes built in accordance with the proposed rule.

[12] *See* Energy Information Administration, *Annual Energy Outlook 2015 with Projections to 2040* (2015), available at *http://www.eia.gov/forecasts/aeo/pdf/0383(2015).pdf.*

[13] *See* U.S. Environmental Protection Agency, *Emissions Factors for Greenhouse Gas Inventories* (2014), available at *http://www.epa.gov/climateleadership/documents/emission-factors.pdf.*

[14] *See* Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866, Interagency Working Group on Social Cost of Carbon, United States Government. May 2013; (revised November 2013), *available at www.whitehouse.gov/sites/default/files/omb/assets/inforeg/technical-update-social-cost-of-carbon-for-regulator-impact-analysis.pdf.*

TABLE IV.15—NET PRESENT VALUE OF MONETIZED BENEFITS FROM $CO_2$ AND $NO_X$ EMISSIONS REDUCTIONS UNDER THE PROPOSED RULE

| | Discount rate (%) | Net present value (million 2015$) | |
|---|---|---|---|
| | | Single-section | Multi-section |
| **Monetary Benefits** | | | |
| $CO_2$, Average SCC Case | 5 | 368.2 | 593.7 |
| $CO_2$, Average SCC Case | 3 | 1,810.9 | 2,920.5 |
| $CO_2$, Average SCC Case | 2.5 | 2,925.0 | 4,717.3 |
| $CO_2$, 95th Percentile SCC Case | 3 | 5,581.5 | 9,001.5 |
| $NO_X$ Reduction | 3 | 311.5 | 498.6 |
| | 7 | 119.8 | 191.9 |

*E. Total Benefits and Costs*

As explained in greater detail in section IV of this **SUPPLEMENTARY INFORMATION** and in chapter 15 of the TSD, Table IV.16 reflects the total benefits and costs (from the manufactured homeowner's perspective) associated with the proposed rule, expressed in terms of annualized values.[15]

TABLE IV.16—TOTAL ANNUALIZED BENEFITS AND COSTS TO MANUFACTURED HOMEOWNERS UNDER THE PROPOSED RULE

| | Monetized (million 2015$/year) | | | |
|---|---|---|---|---|
| | Discount rate (%) | Primary estimate** | Low estimate** | High estimate** |
| **Benefits*** | | | | |
| Operating (Energy) Cost Savings | 7 | 516 | 400 | 688. |
| | 3 | 843 | 617 | 1,191. |
| $CO_2$, Average SCC Case*** | 5 | 63 | 46 | 85. |
| $CO_2$, Average SCC Case*** | 3 | 241 | 176 | 331. |
| $CO_2$, Average SCC Case*** | 2.5 | 365 | 266 | 503. |
| $CO_2$, 95th Percentile SCC Case*** | 3 | 744 | 543 | 1,022. |
| $NO_X$ Reduction at $2,773/metric ton*** | 7 | 25 | 20 | 32. |
| | 3 | 41 | 31 | 56. |
| Total (Operating Cost Savings, $CO_2$ Reduction and $NO_X$ Reduction). | 7 plus $CO_2$ range | 604 to 1,285 | 466 to 962 | 805 to 1,742. |
| | 7 | 783 | 596 | 1,052. |
| | | 1,126 | 824 | 1,578. |
| | 2 | 947 to 1,628 | 694 to 1,191 | 1,332 to 2,269. |
| | 3 plus $CO_2$ range. | | | |
| **Costs*** | | | | |
| Incremental Purchase Price Increase | 7 | 220 | 165 | 285. |
| | 3 | 277 | 192 | 378. |
| **Net Benefits/Costs*** | | | | |
| Total (Operating Cost Savings, $CO_2$ Reduction and $NO_X$ Reduction, Minus Incremental Cost Increase to Homes). | 7 plus $CO_2$ range | 384 to 1,065 | 301 to 797 | 520 to 1,457. |
| | 7 | 563 | 431 | 767. |
| | | 849 | 632 | 1,200. |
| | 3 | 670 to 1,351 | 502 to 999 | 954 to 1,891. |
| | 3 plus $CO_2$ range. | | | |

* The benefits and costs are calculated for homes shipped 2017–2046.

** The Primary, Low, and High Estimates utilize forecasts of energy prices from the 2015_AEO Reference case, Low Economic Growth case, and High Economic Growth case, respectively.

*** The $CO_2$ values represent global monetized values (in 2015$) of the social cost of $CO_2$ emissions reductions over the analysis period under several different scenarios of the SCC model. The ''average SCC case'' refers to average predicted monetary savings as predicted by the SCC model. The ''95th percentile case'' refers to values calculated using the 95th percentile impacts of the SCC model, which accounts for greater than expected environmental damages. The value for $NO_X$ (in 2015$) is the average of the low and high values used in DOE's analysis.

[15] As stated above, DOE used a two-step calculation process to convert the time-series of costs and benefits into annualized values. First, DOE calculated a present value in 2015, the year used for discounting the net present value of total consumer costs and savings, for the time-series of costs and benefits using discount rates of three and seven percent for all costs and benefits except for the value of $CO_2$ reductions. For the latter, DOE used a range of discount rates, as shown in Table IV.16. From the present value, DOE then calculated the fixed annual payment over a 30-year period, starting in 2017 that yields the same present value. The fixed annual payment is the annualized value. Although DOE calculated annualized values, this does not imply that the time-series of cost and benefits from which the annualized values were determined would be a steady stream of payments.

DOE is well aware that scientific and economic knowledge about the contribution of $CO_2$ and other GHG emissions to changes in the future global climate and the potential resulting damages to the world economy continues to evolve rapidly. Thus, any value placed in this proposed rulemaking on reducing $CO_2$ emissions is subject to change. DOE, together with other federal agencies, will continue to review various methodologies for estimating the monetary value of reductions in $CO_2$ and other GHG emissions. This ongoing review will consider any comments on this subject that are part of the public record for this and other rulemakings, as well as other methodological assumptions and issues. However, consistent with DOE's legal obligations, and taking into account the uncertainty involved with this particular issue, DOE has included in this proposed rulemaking the most recent values and analyses resulting from the ongoing interagency review process.

Although adding the value of consumer savings to the values of emission reductions provides a valuable perspective, two issues should be considered. First, the national operating savings are domestic U.S. consumer monetary savings that would occur as a result of market transactions, while the value of $CO_2$ reductions is based on a global value. Second, the assessments of operating cost savings and $CO_2$ savings are performed with different methods that use quite different time frames for analysis. The national operating cost savings is measured for the lifetime of manufactured homes shipped in the 30-year period after the compliance date. The SCC values, on the other hand, reflect the present value of future climate-related impacts resulting from the emission of one ton of $CO_2$ in each year. These impacts would go well beyond 2100.

## V. Regulatory Review

### *A. Executive Order 12866*

Section 1(b)(1) of Executive Order 12866, ''Regulatory Planning and Review,'' 58 FR 51735 (Oct. 4, 1993), requires each agency to identify the problem that it intends to address, including, where applicable, the failures of private markets or public institutions that warrant new agency action, as well as to assess the significance of that problem. The problems that this proposed standards address are as follows:

(1) Under current federal standards, manufactured homes typically conserve less energy than comparably built site-built and modular homes, and.

(2) There are external benefits resulting from improved energy conservation in manufactured housing. These benefits include externalities related to environmental protection and energy security that are not reflected in energy prices, such as reduced emissions of greenhouse gases.

DOE has determined that this regulatory action is an ''economically significant regulatory action'' under section 3(f)(1) of Executive Order 12866. Accordingly, section 6(a)(3) of the Executive Order requires that DOE prepare a regulatory impact analysis (RIA) on this proposed rule and that the Office of Information and Regulatory Affairs (OIRA) in OMB review this proposed rule. DOE has presented the proposed rule and supporting documents, including the RIA, to OIRA for review and has included these documents in the rulemaking record. The assessments prepared pursuant to Executive Order 12866 can be found in chapter 11 of the TSD for this rulemaking. They are available for public review in the Resource Room of DOE's Building Technologies Program, 950 L'Enfant Plaza SW., Suite 600, Washington, DC 20024, (202) 586–2945, between 9:00 a.m. and 4:00 p.m., Monday through Friday, except federal holidays.

DOE also has reviewed this regulation pursuant to Executive Order 13563, issued on January 18, 2011 (76 FR 3281, Jan. 21, 2011). Executive Order 13563 is supplemental to and reaffirms the principles, structures, and definitions governing regulatory review established in Executive Order 12866. To the extent permitted by law, federal agencies are required by these Executive Orders to, among other things:

(1) Propose or adopt a regulation only upon a reasoned determination that its benefits justify its costs (recognizing that some benefits and costs are difficult to quantify);

(2) Tailor regulations to impose the least burden on society, consistent with obtaining regulatory objectives, taking into account, among other things, and to the extent practicable, the costs of cumulative regulations;

(3) Select, in choosing among alternative regulatory approaches, those approaches that maximize net benefits (including potential economic, environmental, public health and safety, and other advantages; distributive impacts; and equity);

(4) To the extent feasible, specify performance objectives, rather than specifying the behavior or manner of compliance that regulated entities must adopt; and

(5) Identify and assess available alternatives to direct regulation, including providing economic incentives to encourage the desired behavior, such as user fees or marketable permits, or providing information upon which choices can be made by the public.

For the reasons stated in the chapter 11 of the TSD and in section III of the document, DOE believes that this proposed rule is consistent with these principles.

### *B. Executive Order 13563*

DOE has also reviewed this regulation pursuant to Executive Order 13563 (*see* 76 FR 3281, Jan. 21, 2011), which is supplemental to, and explicitly reaffirms the principles, structures, and definitions governing regulatory review established in Executive Order 12866. To the extent permitted by law, agencies are required by Executive Order 13563 to: (1) Propose or adopt a regulation only upon a reasoned determination that its benefits justify its costs (recognizing that some benefits and costs are difficult to quantify); (2) tailor regulations to impose the least burden on society, consistent with obtaining regulatory objectives, taking into account, among other things, and to the extent practicable, the costs of cumulative regulations; (3) select, in choosing among alternative regulatory approaches, those approaches that maximize net benefits (including potential economic, environmental, public health and safety, and other advantages; distributive impacts; and equity); (4) to the extent feasible, specify performance objectives, rather than specifying the behavior or manner of compliance that regulated entities must adopt; and (5) identify and assess available alternatives to direct regulation, including providing economic incentives to encourage the desired behavior, such as user fees or marketable permits, or providing information upon which choices can be made by the public.

DOE emphasizes that Executive Order 13563 requires agencies ''to use the best available techniques to quantify anticipated present and future benefits and costs as accurately as possible.'' In its guidance, the Office of Information and Regulatory Affairs has emphasized that such techniques may include ''identifying changing future compliance costs that might result from technological innovation or anticipated behavioral changes.'' This proposed rule is consistent with these principles, including that, to the extent permitted by law, agencies adopt a regulation only upon a reasoned determination that its benefits justify its costs and select, in choosing among alternative regulatory approaches, those approaches that maximize net benefits.

*C. Regulatory Flexibility Act*

The Regulatory Flexibility Act (5 U.S.C. 601 *et seq.*) requires preparation of an initial regulatory flexibility analysis (IRFA) for any rule that by law must be proposed for public comment, unless the agency certifies that the rule, if promulgated, will not have a significant economic impact on a substantial number of small entities. As required by Executive Order 13272, ''Proper Consideration of Small Entities in Agency Rulemaking,'' 67 FR 53461 (Aug. 16, 2002), DOE published procedures and policies on February 19, 2003, to ensure that the potential impacts of its rules on small entities are properly considered during the rulemaking process. 68 FR 7990. DOE has made its procedures and policies available on the Office of the General Counsel's Web site (*www.energy.gov/gc/office-general-counsel*). DOE has prepared the following IRFA for small manufacturers of manufactured homes that are the subject of this proposed rulemaking.

For the manufacturers of manufactured homes, the Small Business Administration (SBA) has set a size threshold, which defines those entities classified as ''small businesses'' for the purposes of the statute. DOE used the SBA's small business size standards to determine whether any small entities would be subject to the requirements of the rule. 65 FR 30836, 30848 (May 15, 2000), as amended at 65 FR 53533, 53544 (Sept. 5, 2000) and codified at 13 CFR part 121. The size standards are listed by NAICS code and industry description and are available at *http://www.sba.gov/content/table-small-business-size-standards*. The covered manufacturers are classified under NAICS 321991, ''Manufactured Home (Mobile Home) Manufacturing.'' The SBA sets a threshold of 500 employees or less for an entity to be considered as a small business for this category.

DOE reviewed the potential standards considered in this NOPR under the provisions of the Regulatory Flexibility Act and the procedures and policies published on February 19, 2003. To better assess the potential impacts of this rulemaking on small entities, DOE conducted a more focused inquiry of the companies that could be small business manufacturers of manufactured homes. During its market survey, DOE used available public information to identify potential small manufacturers. DOE's research involved industry trade association membership directories, information from previous rulemakings, individual company Web sites, and market research tools (*e.g.,* Hoover's reports) to create a list of companies that manufacture or sell manufactured homes covered by this rulemaking.

To assess the potential impacts of this rulemaking on small entities, DOE conducted a focused inquiry of the companies that could be small business manufacturers of manufactured homes. During its market survey, DOE used available public information to identify potential small manufacturers. DOE's research involved individual company Web sites and market research tools (*e.g.,* Hoovers reports [16]) to create a list of companies that manufacture homes covered by this rulemaking. DOE also asked stakeholders and industry representatives if they were aware of any other small manufacturers.

DOE identified forty-six manufacturers of manufactured homes. Of the forty-six, DOE identified twenty-five manufacturers that qualified as small businesses. All small manufacturers identified are domestic manufacturers. DOE contacted all 25 identified manufactured home manufacturers for interviews. DOE spoke with two small manufacturers.

During discussions with small manufacturers, DOE asked participating companies to describe their major concerns with regard to the rulemaking. The primary concern cited by small manufacturers was the potential for an energy conservation standard to result in a shrinking market for manufactured homes. Manufacturers noted two possible reasons. First, they were concerned that the standard would be set at a level where the economics do not make sense for the home purchaser. One manufacturer specifically requested the Department perform an analysis that showed the proposed level would result in cost-savings for the home owner. Second, the manufacturers noted the possibility that cost increases for the baseline homes could potentially price out some consumers, specifically lower income consumers. One of the small manufacturers noted that the market for the minimally compliant homes is dominated by much larger manufacturers. In particular, they noted Clayton Homes is the biggest player in that market with roughly half of the overall market for manufactured homes.

Based on HUD data, research reports, and SEC filings, as described in section IV.C and chapter 12 of the TSD, DOE understands the retail prices, markups, and manufacturer production costs used in its manufacturer impact analysis are representative of the industry. DOE estimates that the proposed rule would reduce INPV by 0.4 to 5.1 percent. DOE did not receive sufficient quantitative data to conclude that small manufacturer would experience impacts that are substantially different from the industry-at-large.

Since the proposed standards could cause competitive concerns for small manufacturers, DOE cannot certify that the proposed standards would not have a significant impact on a substantial number of small businesses. DOE requests additional information and data regarding the number and market share of domestic small manufacturers of manufactured homes. DOE also requested information on the conversion costs small manufacturers would face and on other potential small business impacts related to the proposed energy conservation standards.

*D. Paperwork Reduction Act*

This rulemaking does not include any information collection requirements subject to the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 *et seq.*).

*E. National Environmental Policy Act*

DOE is preparing a draft Environmental Assessment (EA) pursuant to the Council on Environmental Quality's Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act (40 CFR parts 1500–1508), the National Environmental Policy Act of 1969, as amended (42 U.S.C. 4321 *et seq.*), DOE's National Environmental Policy Act (NEPA) Implementing Procedures (10 CFR part 1021), and DOE Order 451.1B. DOE is preparing the draft EA in parallel with this rulemaking, and it will be posted to the DOE Web site separately. Reduced emissions of air pollutants and greenhouse gases associated with electricity production and fuel usage are discussed in section IV.D of this **SUPPLEMENTARY INFORMATION.**

*F. Executive Order 13132*

Executive Order 13132, ''Federalism,'' 64 FR 43255 (August 4, 1999), imposes certain requirements on agencies formulating and implementing policies or regulations that preempt state law or that have federalism implications. The Executive Order requires agencies to examine the constitutional and statutory authority supporting any action that would limit the policymaking discretion of the states and to carefully assess the necessity for such actions. The

[16] Hoovers. *http://www.hoovers.com/*.

Executive Order also requires agencies to have a process to ensure meaningful and timely input by state and local officials in the development of regulatory policies that have federalism implications. On March 14, 2000, DOE published a statement of policy describing the intergovernmental consultation process it will follow in the development of such regulations (65 FR 13735).

DOE has examined this action and has determined that it will not pre-empt State law. This action impacts energy efficiency requirements for manufacturers of manufactured homes. Accordingly, no further action is required by Executive Order 13132.

*G. Executive Order 12988*

With respect to the review of existing regulations and the promulgation of new regulations, section 3(a) of Executive Order 12988, ''Civil Justice Reform,'' 61 FR 4729 (February 7, 1996), imposes on Executive agencies the general duty to adhere to the following requirements: (1) Eliminate drafting errors and ambiguity; (2) write regulations to minimize litigation; and (3) provide a clear legal standard for affected conduct, rather than a general standard, and promote simplification and burden reduction. Regarding the review required by section 3(a), section 3(b) of Executive Order 12988 specifically requires that Executive agencies make every reasonable effort to ensure that the regulation: (1) Clearly specifies the preemptive effect, if any; (2) clearly specifies any effect on existing federal law or regulation; (3) provides a clear legal standard for affected conduct, while promoting simplification and burden reduction; (4) specifies the retroactive effect, if any; (5) adequately defines key terms; and (6) addresses other important issues affecting clarity and general draftsmanship under any guidelines issued by the Attorney General. Section 3(c) of Executive Order 12988 requires Executive agencies to review regulations in light of applicable standards in sections 3(a) and 3(b) to determine either that those standards are met or it is unreasonable to meet one or more of them. DOE has completed the required review and preliminarily has determined that, to the extent permitted by law, this proposed rule meets the relevant standards of Executive Order 12988.

*H. Unfunded Mandates Reform Act*

Title II of the Unfunded Mandates Reform Act of 1995 (UMRA) requires each federal agency to assess the effects of federal regulatory actions on state, local, and Tribal governments and the private sector. Public Law 104–4, sec. 201 (codified at 2 U.S.C. 1531). For an amended regulatory action likely to result in a rule that may cause the expenditure by state, local, and Tribal governments, in the aggregate, or by the private sector of $100 million or more in any one year (adjusted annually for inflation), section 202 of UMRA requires a federal agency to publish a written statement that estimates the resulting costs, benefits, and other effects on the national economy. *See* 2 U.S.C. 1532(a), (b). The UMRA also requires a federal agency to develop an effective process to permit timely input by elected officers of state, local, and Tribal governments on a ''significant intergovernmental mandate,'' and requires an agency plan for giving notice and opportunity for timely input to potentially affected small governments before establishing any requirements that might significantly or uniquely affect small governments. On March 18, 1997, DOE published a statement of policy on its process for intergovernmental consultation under UMRA. *See* 62 FR 12820. DOE's policy statement is also available at *http://energy.gov/gc/office-general-counsel*.

This proposed rule does not contain a federal intergovernmental or private sector mandate, as those terms are defined in UMRA.

*I. Family and General Government Appropriations Act*

Section 654 of the Family and General Government Appropriations Act of 1999 (Pub. L. 105–277) requires federal agencies to issue a Family Policymaking Assessment for any proposed rule that may affect family well-being. This proposed rule would not have any impact on the autonomy or integrity of the family as an institution. Accordingly, DOE has preliminarily concluded that it is not necessary to prepare a Family Policymaking Assessment.

*J. Executive Order 12630*

DOE has determined, under Executive Order 12630, ''Governmental Actions and Interference with Constitutionally Protected Property Rights,'' 53 FR 8859 (March 18, 1988), that this proposed rule would not result in any takings that might require compensation under the Fifth Amendment to the U.S. Constitution.

*K. Treasury and General Government Appropriations Act*

Section 515 of the Treasury and General Government Appropriations Act of 2001 (44 U.S.C. 3516, note) provides for agencies to review most disseminations of information to the public under guidelines established by each agency pursuant to general guidelines issued by OMB. OMB's guidelines were published at 67 FR 8452 (February 22, 2002), and DOE's guidelines were published at 67 FR 62446 (October 7, 2002). DOE has reviewed this proposed rule under the OMB and DOE guidelines and preliminarily has concluded that it is consistent with applicable policies in those guidelines.

*L. Executive Order 13211*

Executive Order 13211, ''Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution, or Use,'' 66 FR 28355 (May 22, 2001), requires federal agencies to prepare and submit to OIRA a Statement of Energy Effects for any proposed significant energy action. A ''significant energy action'' is defined as any action by an agency that promulgates or is expected to lead to promulgation of a final rule or regulation, and that: (1) Is a significant regulatory action under Executive Order 12866, or any successor order; and (2) is likely to have a significant adverse effect on the supply, distribution, or use of energy; or (3) is designated by the Administrator of OIRA as a significant energy action. For any proposed significant energy action, the agency must give a detailed statement of any adverse effects on energy supply, distribution, or use should the proposal be implemented, and of reasonable alternatives to the action and their expected benefits on energy supply, distribution, and use.

DOE preliminarily has concluded that this regulatory action, which sets forth energy conservation standards for manufactured homes, is not a significant energy action because the proposed standards are not likely to have a significant adverse effect on the supply, distribution, or use of energy, nor has it been designated as such by the Administrator at OIRA. Accordingly, DOE has not prepared a Statement of Energy Effects for this proposed rule.

*M. Section 32 of the Federal Energy Administration Act of 1974*

Under section 301 of the Department of Energy Organization Act (Pub. L. 95–91), DOE must comply with section 32 of the Federal Energy Administration Act of 1974, as amended by the Federal Energy Administration Authorization Act of 1977 (15 U.S.C. 788). Section 32 provides in part that, where a proposed rule contains or involves use of commercial standards, the rulemaking must inform the public of the use and background of such standards.

The rule proposed in this notice incorporates testing methods contained in the following commercial standards: The ACCA ''Manual J—Residential Load Calculation (8th Edition)'' (ACCA Manual J); the ACCA ''Manual S—Residential Equipment Selection (2nd Edition)'' (ACCA Manual S); and the PNNL ''Overall *U*-Values and Heating/Cooling Loads—Manufactured Homes'' (Overall *U*-Values and Heating/Cooling Loads—Manufactured Homes).

DOE has evaluated these standards and is unable to conclude whether they fully comply with the requirements of section 32(b) of the Federal Energy Administration Act of 1974, as amended. DOE will consult with the Attorney General and the Chairman of the Federal Trade Commission before prescribing a final rule concerning the impact on competition of requiring manufacturers to use the methods contained in these standards to test various components of manufactured homes.

*N. Materials Incorporated by Reference*

In this NOPR, DOE proposes to incorporate by reference the test standard published by ACCA, titled ''*Manual J—Residential Load Calculation (8th Edition).*'' ACCA Manual J is an industry accepted standard for calculating the heating and cooling load associated with a building. DOE proposes requiring building heating and cooling loads to be calculated (for purposes of equipment sizing) in accordance with ACCA Manual J. ACCA Manual J is readily available on ACCA's Web site at *http://www.acca.org/*.

DOE also proposes to incorporate by reference the test standard published by ACCA, titled ''*Manual S—Residential Equipment Selection (2nd Edition).*'' ACCA Manual S is an industry accepted standard for calculating the appropriate heating and cooling equipment size for a building. DOE proposes requiring building heating and cooling equipment to be sized in accordance with ACCA Manual S. ACCA Manual S is readily available on ACCA's Web site at *http://www.acca.org/*.

DOE also proposes to incorporate by reference the test standard titled ''*Overall U-Values and Heating/Cooling Loads—Manufactured Homes*'' *written by* Conner C.C., Taylor, Z.T. of Pacific Northwest Laboratory. This test standard (often referred to as the Battelle Method) is an industry accepted method for calculating the overall thermal transmittance of a manufactured home. DOE proposes requiring manufactured housing manufacturers to calculate the overall thermal transmittance of a manufactured home in accordance with this test standard. This test standard is readily available on the U.S. Department of Housing and Urban Development's Web site at *http://www.huduser.org/portal/publications/manufhsg/uvalue.html*.

**VI. Public Participation**

*A. Attendance at Public Meeting*

The time, date, and location of the public meeting are listed in the **DATES** and **ADDRESSES** sections at the beginning of this document. If you plan to attend the public meeting, please notify Ms. Brenda Edwards at (202) 586–2945 or *Brenda.Edwards@ee.doe.gov*. As explained in the **ADDRESSES** section, foreign nationals visiting DOE Headquarters are subject to advance security screening procedures.

*B. Procedure for Submitting Prepared General Statements for Distribution*

Any person who has plans to present a prepared general statement may request that copies of his or her statement be made available at the public meeting. Such persons may submit requests, along with an advance electronic copy of their statement in PDF (preferred), Microsoft Word or Excel, WordPerfect, or text (ASCII) file format, to the appropriate address shown in the **ADDRESSES** section at the beginning of this notice. The request and advance copy of statements must be received at least one week before the public meeting and may be emailed, hand-delivered, or sent by U.S. mail. DOE prefers to receive requests and advance copies via email. Please include a telephone number to enable DOE staff to make follow-up contact, if needed.

*C. Conduct of Public Meeting*

DOE will designate a DOE official to preside at the public meeting and may also use a professional facilitator to aid discussion. A court reporter will be present to record the proceedings and prepare a transcript. DOE reserves the right to schedule the order of presentations and to establish the procedures governing the conduct of the public meeting. After the public meeting, interested parties may submit further comments on the proceedings as well as on any aspect of the rulemaking until the end of the comment period.

The public meeting will be conducted in an informal, conference style. DOE will present summaries of comments received before the public meeting, allow time for prepared general statements by participants, and encourage all interested parties to share their views on issues affecting this rulemaking. Each participant will be allowed to make a general statement (within time limits determined by DOE), before the discussion of specific topics. DOE will permit, as time permits, other participants to comment briefly on any general statements.

At the end of all prepared statements on a topic, DOE will permit participants to clarify their statements briefly and comment on statements made by others. Participants should be prepared to answer questions by DOE and by other participants concerning these issues. DOE representatives also may ask questions of participants concerning other matters relevant to this rulemaking. The official conducting the public meeting will accept additional comments or questions from those attending, as time permits. The presiding official will announce any further procedural rules or modification of the above procedures that may be needed for the proper conduct of the public meeting.

A transcript of the public meeting will be included in the docket, which can be viewed as described in the DOCKET section at the beginning of this proposed rulemaking. In addition, any person may buy a copy of the transcript from the transcribing reporter.

*D. Submission of Comments*

DOE will accept comments, data, and information regarding this proposed rule before or after the public meeting, but no later than the date provided in the **DATES** section at the beginning of this proposed rule. Interested parties may submit comments using any of the methods described in the **ADDRESSES** section at the beginning of this proposed rule.

1. Submitting Comments via *Regulations.gov*

The *regulations.gov* Web page will require you to provide your name and contact information. Your contact information will be viewable to DOE Building Technologies staff only. Your contact information will not be publicly viewable except for your first and last names, organization name (if any), and submitter representative name (if any). If your comment is not processed properly because of technical difficulties, DOE will use this information to contact you. If DOE cannot read your comment due to technical difficulties and cannot contact you for clarification, DOE may not be able to consider your comment.

However, your contact information will be publicly viewable if you include it in the comment or in any documents attached to your comment. Any information that you do not want to be publicly viewable should not be included in your comment, nor in any document attached to your comment. Persons viewing comments will see only first and last names, organization names, correspondence containing comments, and any documents submitted with the comments.

Do not submit to regulations.gov information for which disclosure is restricted by statute, such as trade secrets and commercial or financial information (hereinafter referred to as Confidential Business Information (CBI)). Comments submitted through *regulations.gov* cannot be claimed as CBI. Comments received through the Web site will waive any CBI claims for the information submitted. For information on submitting CBI, see the Confidential Business Information section below.

DOE processes submissions made through regulations.gov before posting. Normally, comments will be posted within a few days of being submitted. However, if large volumes of comments are being processed simultaneously, your comment may not be viewable for up to several weeks. Please keep the comment tracking number that regulations.gov provides after you have successfully uploaded your comment.

2. Submitting Comments via Email, Hand Delivery, or Mail

Comments and documents submitted via email, hand delivery, or mail also will be posted to *regulations.gov*. If you do not want your personal contact information to be publicly viewable, do not include it in your comment or any accompanying documents. Instead, provide your contact information on a cover letter. Include your first and last names, email address, telephone number, and optional mailing address. The cover letter will not be publicly viewable as long as it does not include any comments.

Include contact information each time you submit comments, data, documents, and other information to DOE. Email submissions are preferred. If you submit via mail or hand delivery, please provide all items on a CD, if feasible. It is not necessary to submit printed copies. No facsimiles (faxes) will be accepted.

Comments, data, and other information submitted to DOE electronically should be provided in PDF (preferred), Microsoft Word or Excel, WordPerfect, or text (ASCII) file format. Provide documents that are not secured, written in English, and are free of any defects or viruses. Documents should not contain special characters or any form of encryption and, if possible, they should carry the electronic signature of the author.

Campaign Form Letters

Please submit campaign form letters by the originating organization in batches of between 50 to 500 form letters per PDF or as one form letter with a list of supporters' names compiled into one or more PDFs. This reduces comment processing and posting time.

Confidential Business Information

According to 10 CFR 1004.11, any person submitting information that he or she believes to be confidential and exempt by law from public disclosure should submit via email, postal mail, or hand delivery two well-marked copies: one copy of the document marked confidential including all the information believed to be confidential, and one copy of the document marked non-confidential with the information believed to be confidential deleted. Submit these documents via email or on a CD, if feasible. DOE will make its own determination about the confidential status of the information and treat it according to its determination.

Factors of interest to DOE when evaluating requests to treat submitted information as confidential include: (1) A description of the items, (2) whether and why such items are customarily treated as confidential within the industry, (3) whether the information is generally known by or available from other sources, (4) whether the information has previously been made available to others without obligation concerning its confidentiality, (5) an explanation of the competitive injury to the submitting person which would result from public disclosure, (6) when such information might lose its confidential character due to the passage of time, and (7) why disclosure of the information would be contrary to the public interest.

It is DOE's policy that all comments may be included in the public docket, without change and as received, including any personal information provided in the comments (except information deemed to be exempt from public disclosure).

*E. Issues on Which DOE Seeks Comment*

Although DOE welcomes comments on any aspect of this proposal, DOE is particularly interested in receiving comments and views of interested parties concerning the following issues:

1. Relationship With the HUD Code

Potential inconsistencies or conflicts between the proposed rule and the HUD Code, as discussed in detail in section II.B.1 of this document.

2. Scope and Effective Date

The scope and effective date of the proposed rule, as discussed in section III.B.1.a) of the document. DOE requests comment on whether a one-year compliance period would be sufficient for manufacturers to transition their designs, materials, and factory operations and processes in order to comply with the finalized DOE energy conservation standards and for DOE to develop and implement regulations to enforce its standards. DOE also requests comments on what additional lead time should be allowed if it elects to use HUD's existing enforcement system, which would require HUD to adopt the energy standards resulting from this rulemaking. The agency also requests comment on whether there are any particular timing considerations that the agency should consider due to manufacturers choosing to comply with either the prescriptive or thermal envelope compliance paths.

3. Definitions

Proposed additions, exclusions, modifications, and potential inconsistencies among the definitions proposed under this rule, the HUD Code, and the 2015 IECC, as discussed in section III.B.1.b) of this document.

4. Air Barrier

Potential clarification on the meaning of the term ''air barrier,'' as discussed in section III.B.1.b) of this document.

5. Tubular Daylighting Devices

Whether to include tubular daylighting devices in the definition of the term ''fenestration,'' as discussed in section III.B.1.b) of this document.

6. Climate Zones

The proposal to establish four climate zones and the specific categorization of states and counties included in each climate zone, as discussed in section III.B.2.a) of this **SUPPLEMENTARY INFORMATION** and chapter 4 of the TSD. DOE also requests comment on the proposed use of four climate zones relative to adopting the three HUD climate zones and whether there are any potential impacts on manufacturing costs, compliance costs, or other impacts, in particular in Arizona, Texas, Louisiana, Mississippi, Alabama, and

Georgia, where the agency has proposed two different energy efficiency standards within the same state.

7. Home Size

The proposal to establish separate requirements for single- and multi-section manufactured homes, as discussed in section III.B.2.a) of this document.

8. Paths for Compliance With the Building Thermal Envelope Standards

The proposal to establish prescriptive and performance options for achieving compliance with the proposed building thermal envelope requirements, the requirements of each option, and their equivalency in terms of overall thermal performance, as discussed in section III.B.2.b) of this SUPPLEMENTARY INFORMATION and chapter 6 of the TSD.

9. Insulated Siding

The proposal to include a requirement similar to section R402.1.3 of the 2015 IECC while excluding the insulated siding specification, as discussed in section III.B.2.b) of this document.

10. U-Factor Alternatives

11. The proposed *U*-factor alternatives and their equivalency with the prescriptive *R*-value requirements for ceiling, wall, and floor insulation, as discussed in section III.B.2.b) of this document.

12. Calculation of Average SHGC

The proposal to include an area-weighted average calculation of SHGC for compliance with § 460.102(c), as discussed in section III.B.2.b) of this document.

13. Insulation Installation Requirements for Floors

Whether the insulation installation requirements in § 460.103, including installation of insulation in floors, may be readily implemented by the manufactured housing industry, as discussed in section III.B.2.c) of this document.

14. Design Criteria for Envelope Sealing

The effectiveness of the prescriptive building thermal envelope sealing requirements, as discussed in section III.B.2.d) of this SUPPLEMENTARY INFORMATION.

15. Impact of Envelope Sealing on Indoor Air Quality

The potential impacts associated with the reduction in levels of natural air infiltration (through sealing leaks in the building thermal envelope), if any, relative to the minimum requirements of the HUD Code on reduced indoor air quality, the importance of natural air infiltration for whole-house ventilation strategies in manufactured housing, the relationship between the proposed standards and the mechanical ventilation requirements under the HUD Code, the basis by which the ICC determines a whole-house ventilation strategy is safe, and the minimum total air flow (in ACH units) through a manufactured home that is required to adequately protect public health and safety, as discussed in section V.E of this document.

16. Duct Sealing

The proposed duct sealing and duct leakage requirements, as discussed in section III.B.3.a) of this document.

17. Thermostats and Controls

The proposed requirements for thermostats and controls, and any potential inconsistencies with the HUD Code, as discussed in III.B.3.b) of this document.

18. Demand Recirculation Systems

The initial decision not to propose requirements related to demand recirculation systems in this rule, as discussed in section III.B.3.c) of this document.

19. Drain Water Heat Recovery Units

The initial decision not to propose requirements related to drain water heat recovery units, as discussed in section III.B.3.c) of this document.

20. Equipment Sizing

The proposed requirements for equipment sizing and the applicability of ACCA Manuals S and J, as discussed in section III.B.3.e) of this document.

21. Lighting Equipment Standards

The initial determination not to propose lighting equipment standards specific to manufactured housing, as discussed in section III.C.6 of this document.

22. Simulated Performance Alternative

The exclusion of a simulated performance alternative as a pathway to compliance, as discussed in section III.C.7 of this document.

23. Waivers and Exception Relief

A process for authorizing manufacturers to obtain waivers or exception relief from the energy conservation requirements, as discussed in section II.B.3 of this document.

24. Compliance and Enforcement Program Options

The potential options DOE may consider in a future rulemaking regarding compliance and enforcement, as discussed in section III.E of this document.

25. Compliance and Enforcement Program Costs and Time Requirements

The estimated costs (only direct compliance and enforcement costs, not engineering costs for redesign) and time (design compliance review, inspection frequency and duration, administrative procedures) associated with the potential compliance and enforcement options, as discussed in section III.E of this document.

26. Increased Costs of Components

The assumptions underlying DOE's analyses associated with the increased costs of manufactured home components, as discussed in section IV.A of this document.

27. Lifecycle Cost Analysis

The methodology and initial findings of the lifecycle cost analysis, as discussed in IV.A of this SUPPLEMENTARY INFORMATION and chapter 8 of the TSD.

28. Affordability

The affordability of the proposed rule, with respect to the increased purchase cost, reduced operating costs (energy bills), and total lifecycle cost, as discussed in IV.A of this SUPPLEMENTARY INFORMATION and chapter 8 of the TSD.

29. Manufacturer Impacts Analysis—Markups

Whether manufacturer and retailer mark-ups for the base-case and standards case other than the primary estimate should be considered. (*e.g.,* a combined mark-up of 2.30 has historically been used in the past to assess combined manufacturer and retailer mark-ups to determine potential first cost impacts on consumers), as discussed in IV.B of this SUPPLEMENTARY INFORMATION and chapter 12 of the TSD.

30. Shipments Analysis

The methodology and initial findings of the shipments analysis, as discussed in section IV.B of this SUPPLEMENTARY INFORMATION and chapter 10 of the TSD.

31. Shipment Growth Rate

The estimate of the future growth rate of manufactured home shipments, as discussed in section IV.C of this SUPPLEMENTARY INFORMATION and chapter 10 and appendix 11A of the TSD.

32. Price Elasticity

The estimate of the price elasticity of demand of manufactured homes, as discussed in section IV.C of this SUPPLEMENTARY INFORMATION and chapter 10 and appendix 11A of the TSD.

33. National Impacts Analysis

The methodology and initial findings of the national impacts analysis, as discussed in section IV.C of this SUPPLEMENTARY INFORMATION and chapter 11 of the TSD.

34. Emissions Analysis

The methodology and results of the emissions analysis and the proper monetization of emissions, as discussed in section IV.D of this SUPPLEMENTARY INFORMATION and chapter 13 of the TSD.

## VII. Approval of the Office of the Secretary

The Secretary of Energy has approved publication of this notice of proposed rulemaking.

### List of Subjects in 10 CFR Part 460

Administrative practice and procedure, Buildings and facilities, Energy conservation, Housing standards, Incorporation by reference, Reporting and recordkeeping requirements.

Issued in Washington, DC, on May 20, 2016.

**David Friedman,**

*Principal Deputy Assistant Secretary, Energy Efficiency and Renewable Energy.*

For the reasons stated in the preamble, DOE proposes to add part 460 of title 10 of the Code of Federal Regulations as set forth below:

## PART 460—ENERGY CONSERVATION STANDARDS FOR MANUFACTURED HOMES

### Subpart A—General



### Subpart B—Building Thermal Envelope



### Subpart C—HVAC, Service Water Heating, and Equipment Sizing



**Authority:** 42 U.S.C. 17071; 42 U.S.C. 7101 *et seq.*

### Subpart A—General

#### § 460.1 Scope.

This subpart establishes energy conservation standards for manufactured homes. A manufactured home that is manufactured on or after the date one year following issuance of the final rule must comply with all applicable requirements of this part.

#### § 460.2 Definitions.

As used in this part—

*Accessible* means admitting close approach as a result of not being guarded by locked doors, elevation, or other effective means.

*Air barrier* means material or materials assembled and joined together to provide a barrier to air leakage through the building thermal envelope.

*Automatic* means self-acting or operating by its own mechanism when actuated by some impersonal influence.

*Building thermal envelope* means exterior walls, floor, ceiling or roof, and any other building elements that enclose conditioned space or provide a boundary between conditioned space and unconditioned space.

*Ceiling* means an assembly that supports and forms the overhead interior surface of a building or room that covers its upper limit and is horizontal or tilted at an angle less than 60 degrees (1.05 rad) from horizontal.

*Circulating hot water system* means a water distribution system in which one or more pumps are operated in the service hot water piping to circulate heated water from the water heating equipment to fixtures and back to the water heating equipment.

*Climate zone* means a geographical region identified in § 460.101.

*Conditioned space* means an area, room, or space that is enclosed within the building thermal envelope and that is directly heated or cooled, or an area, room, or space that has a fixed opening directly into an adjacent area, room, or space that is enclosed within the building thermal envelope and that is directly heated or cooled.

*Continuous air barrier* means a combination of materials and assemblies that restrict or prevent the passage of air from conditioned space to unconditioned space.

*Door* means an operable barrier used to block or allow access to an entrance of a manufactured home.

*Dropped ceiling* means a secondary nonstructural ceiling, hung below the main ceiling.

*Dropped soffit* means a secondary nonstructural ceiling that is hung below the ceiling and that covers only a portion of the ceiling.

*Duct* means a tube or conduit, except an air passage within a self-contained system, utilized for conveying air to or from heating, cooling, or ventilating equipment.

*Duct system* means a continuous passageway for the transmission of air that, in addition to ducts, includes duct fittings, dampers, plenums, fans, and accessory air-handling equipment and appliances.

*Eave* means the edge of the roof that overhangs the face of a wall and normally projects beyond the side of the manufactured home.

*Equipment* includes material, appliances, devices, fixtures, fittings, or accessories both in the construction of, and in the plumbing, heating, cooling, and electrical systems of, a manufactured home.

*Exterior wall* means a wall that separates conditioned space from unconditioned space.

*Fenestration* means vertical fenestration and skylights.

*Floor* means a horizontal assembly that supports and forms the lower interior surface of a building or room upon which occupants can walk.

*Glazed or glazing* means an infill material, including glass, plastic, or other transparent or translucent material, used in fenestration.

*Infiltration* means the uncontrolled air leakage into a manufactured home caused by the pressure effects of wind and/or the effect of differences in the indoor and outdoor air density.

*Insulation* means material deemed to be insulation under 16 CFR 460.2.

*Manufactured home* means a structure, transportable in one or more sections, which in the traveling mode is 8 body feet or more in width or 40 body feet or more in length or which when erected on-site is 320 or more square feet, and which is built on a permanent chassis and designed to be used as a dwelling with or without a permanent foundation when connected to the required utilities, and includes the plumbing, heating, air conditioning, and electrical systems contained in the structure. This term includes all structures that meet the above requirements except the size requirements and with respect to which the manufacturer voluntarily files a certification pursuant to 24 CFR 3282.13 and complies with the construction and safety standards set forth in 24 CFR part 3280. The term does not include any self-propelled recreational vehicle. Calculations used to determine the number of square feet in a structure will be based on the structure's exterior dimensions, measured at the largest horizontal projections when erected on site. These dimensions will include all expandable rooms, cabinets, and other projections containing interior space, but do not include bay windows. Nothing in this definition should be interpreted to mean that a manufactured home necessarily meets the requirements of the U.S. Department of Housing and Urban Development Minimum Property Standards (HUD Handbook 4900.1) or that it is automatically eligible for financing under 12 U.S.C. 1709(b).

*Manufacturer* means any person engaged in the factory construction or assembly of a manufactured home, including any person engaged in importing manufactured homes for resale.

*Manual* means capable of being operated by personal intervention.

*R-value (thermal resistance)* means the inverse of the time rate of heat flow through a body from one of its bounding surfaces to the other surface for a unit temperature difference between the two surfaces, under steady state conditions, per unit area (h · ft² · °F/Btu).

*Rough opening* means an opening in the wall or roof, sized for installation of fenestration.

*Service hot water* means supply of hot water for purposes other than comfort heating.

*Skylight* means glass or other transparent or translucent glazing material, including framing materials, installed at an angle less than 60 degrees (1.05 rad) from horizontal.

*Solar heat gain coefficient (SHGC)* means the ratio of the solar heat gain entering a space through a fenestration assembly to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation that is then reradiated, conducted, or convected into the space.

*State* means each of the 50 states, the District of Columbia, the Commonwealth of Puerto Rico, Guam, the U.S. Virgin Islands, and American Samoa.

*Thermostat* means an automatic control device used to maintain temperature at a fixed or adjustable set point.

*U-factor (thermal transmittance)* means the coefficient of heat transmission (air to air) through a building component or assembly, equal to the time rate of heat flow per unit area and unit temperature difference between the warm side and cold side air films (Btu/h · ft² · °F).

*$U_o$ (overall thermal transmittance)* means the coefficient of heat transmission (air to air) through the building thermal envelope, equal to the time rate of heat flow per unit area and unit temperature difference between the warm side and cold side air films (Btu/h · ft² ·; °F).

*Ventilation* means the natural or mechanical process of supplying conditioned or unconditioned air to, or removing such air from, any space.

*Vertical fenestration* means windows (fixed or moveable), opaque doors, glazed doors, glazed block and combination opaque and glazed doors composed of glass or other transparent or translucent glazing materials and installed at a slope of greater than or equal to 60 degrees (1.05 rad) from horizontal.

*Wall* means an assembly that is vertical or tilted at an angle equal to greater than 60 degrees (1.05 rad) from horizontal that encloses or divides an area of a building or room.

*Whole-house mechanical ventilation system* means an exhaust system, supply system, or combination thereof that is designed to mechanically exchange indoor air with outdoor air when operating continuously or through a programmed intermittent schedule.

*Window* means glass or other transparent or translucent glazing material, including framing materials, installed at an angle greater than 60 degrees (1.05 rad) from horizontal.

*Zone* means a space or group of spaces within a manufactured home with heating or cooling requirements that are sufficiently similar so that desired conditions can be maintained using a single controlling device.

### § 460.3 Materials incorporated by reference.

(a) *General.* We incorporate by reference the following standards into part 460. The material listed has been approved for incorporation by reference by the Director of the Federal Register in accordance with 5 U.S.C. 552(a) and 1 CFR part 51. Any subsequent amendment to a standard by the standard-setting organization will not affect the DOE regulations unless and until amended by DOE. Material is incorporated as it exists on the date of the approval and a notice of any change in the material will be published in the Federal Register. All approved material is available for inspection at the National Archives and Records Administration (NARA). For information on the availability of this material at NARA, call 202–741–6030 or go to *http://www.archives.gov/federal_register/code_of_federal_regulations/ibr_locations.html.* This material also is available for inspection at U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Building Technologies Office, 6th Floor, 950 L'Enfant Plaza SW., Washington, DC 20024, 202–586–2945, between 9 a.m. and 4 p.m., Monday through Friday, except Federal holidays. Standards can be obtained from the sources listed.

(b) *ACCA.* Air Conditioning Contractors of America, Inc., 2800 S. Shirlington Road, Suite 300, Arlington, VA 22206, 703–575–4477, *http://www.acca.org/.*

(1) *Manual J—Residential Load Calculation (8th Edition).* IBR approved for § 460.205 of subpart C.

(2) *Manual S—Residential Equipment Selection (2nd Edition).* IBR approved for § 460.205 of subpart C.

(c) *HUD.* U.S. Department of Housing and Urban Development, *http://www.huduser.org/portal/publications/manufhsg/uvalue.html*, 800–245–2691.

(1) *Overall U-Values and Heating/Cooling Loads—Manufactured Homes.* Conner C.C., Taylor, Z.T., Pacific Northwest Laboratory, published February 1, 1992, IBR approved for § 460.102 of subpart B.

(2) Reserved.

## Subpart B—Building Thermal Envelope

### § 460.101 Climate zones.

Manufactured homes must comply with the requirements applicable to one or more of the climate zones set forth in Figure 460.101 and Tables 460.101–1 and 460.101–2 of this section.

**Figure 460.101 Climate Zones**

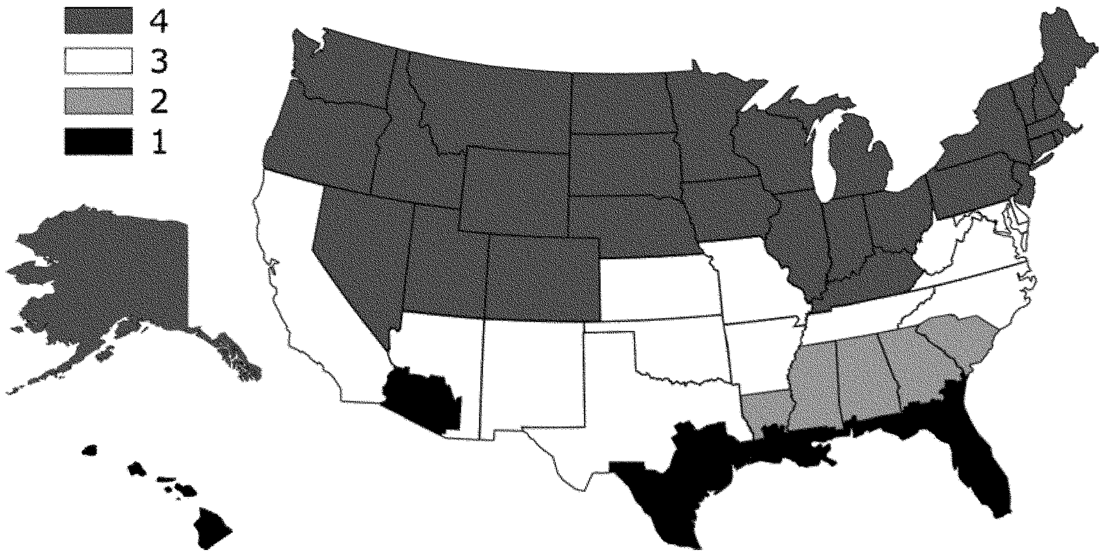



TABLE 460.101–1—U.S. STATES AND TERRITORIES WITH ONE CLIMATE ZONE

| Zone 1 | Zone 2 | Zone 3 | Zone 4 |
|---|---|---|---|
| Florida | South Carolina | Arkansas | Alaska. |
| Hawaii | | Delaware | Colorado. |
| American Samoa | | District of Columbia | Connecticut. |
| Guam | | Kansas | Idaho. |
| The Commonwealth of Puerto Rico | | Kentucky | Illinois. |
| U.S. Virgin Islands | | Maryland | Indiana. |
| | | Missouri | Iowa. |
| | | New Mexico | Maine. |
| | | North Carolina | Massachusetts. |
| | | Oklahoma | Michigan. |
| | | Tennessee | Minnesota. |
| | | Virginia | Montana. |
| | | West Virginia | Nebraska. |
| | | | Nevada. |
| | | | New Hampshire. |
| | | | New Jersey. |
| | | | New York. |
| | | | North Dakota. |
| | | | Ohio. |
| | | | Oregon. |
| | | | Pennsylvania. |
| | | | Rhode Island. |
| | | | South Dakota. |
| | | | Utah. |
| | | | Vermont. |
| | | | Washington. |
| | | | Wisconsin. |
| | | | Wyoming. |

TABLE 460.101–2—U.S. STATES WITH MORE THAN ONE CLIMATE ZONE

| State | Zone | Counties | Counties | Counties | Counties | Counties |
|---|---|---|---|---|---|---|
| Alabama | 1 | Baldwin | Mobile. | | | |
| | 2 | Autauga | Barbour | Bibb | Blount | Bullock. |
| | | Butler | Calhoun | Chambers | Cherokee | Chilton. |
| | | Choctaw | Clarke | Clay | Cleburne | Coffee. |
| | | Colbert | Conecuh | Coosa | Covington | Crenshaw. |
| | | Cullman | Dale | Dallas | DeKalb | Elmore. |
| | | Escambia | Etowah | Fayette | Franklin | Geneva. |
| | | Greene | Hale | Henry | Houston | Jackson. |
| | | Jefferson | Lamar | Lauderdale | Lawrence | Lee. |
| | | Limestone | Lowndes | Macon | Madison | Marengo. |
| | | Marion | Marshall | Monroe | Montgomery | Morgan. |
| | | Perry | Pickens | Pike | Randolph | Russell. |

TABLE 460.101–2—U.S. STATES WITH MORE THAN ONE CLIMATE ZONE—Continued

| State | Zone | Counties | Counties | Counties | Counties | Counties |
|---|---|---|---|---|---|---|
| | | St. Clair | Shelby | Sumter | Talladega | Tallapoosa. |
| | | Tuscaloosa | Walker | Washington | Wilcox | Winston. |
| Arizona | 1 | La Paz | Maricopa | Pima | Pinal | Yuma. |
| | 3 | Apache | Cochise | Coconino | Graham | Greenlee. |
| | | Mohave | Navajo | Santa Cruz | Yavapai. | |
| Georgia | 1 | Appling | Atkinson | Bacon | Baker | Berrien. |
| | | Brantley | Brooks | Bryan | Camden | Charlton. |
| | | Chatham | Clinch | Colquitt | Cook | Decatur. |
| | | Echols | Effingham | Evans | Glynn | Grady. |
| | | Jeff Davis | Lanier | Liberty | Long | Lowndes. |
| | | McIntosh | Miller | Mitchell | Pierce | Seminole. |
| | | Tattnall | Thomas | Toombs | Ware | Wayne. |
| | 2 | Baldwin | Banks | Barrow | Bartow | Ben Hill. |
| | | Bibb | Bleckley | Bulloch | Burke | Butts. |
| | | Calhoun | Candler | Carroll | Catoosa | Chattahoochee. |
| | | Chattooga | Cherokee | Clarke | Clay | Clayton. |
| | | Cobb | Coffee | Columbia | Coweta | Crawford. |
| | | Crisp | Dade | Dawson | DeKalb | Dodge. |
| | | Dooly | Dougherty | Douglas | Early | Elbert. |
| | | Emanuel | Fannin | Fayette | Floyd | Forsyth. |
| | | Franklin | Fulton | Gilmer | Glascock | Gordon. |
| | | Greene | Gwinnett | Habersham | Hall | Hancock. |
| | | Haralson | Harris | Hart | Heard | Henry. |
| | | Houston | Irwin | Jackson | Jasper | Jefferson. |
| | | Jenkins | Johnson | Jones | Lamar | Laurens. |
| | | Lee | Lincoln | Lumpkin | McDuffie | Macon. |
| | | Madison | Marion | Meriwether | Monroe | Montgomery. |
| | | Morgan | Murray | Muscogee | Newton | Oconee. |
| | | Oglethorpe | Paulding | Peach | Pickens | Pike. |
| | | Polk | Pulaski | Putnam | Quitman | Rabun. |
| | | Randolph | Richmond | Rockdale | Schley | Screven. |
| | | Spalding | Stephens | Stewart | Sumter | Talbot. |
| | | Taliaferro | Taylor | Telfair | Terrell | Tift. |
| | | Towns | Treutlen | Troup | Turner | Twiggs. |
| | | Union | Upson | Walker | Walton | Warren. |
| | | Washington | Webster | Wheeler | White | Whitfield. |
| | | Wilcox | Wilkes | Wilkinson | Worth. | |
| Louisiana | 1 | Acadia | Allen | Ascension | Assumption | Avoyelles. |
| | | Beauregard | Calcasieu | Cameron | East Baton Rouge | East Feliciana. |
| | | Evangeline | Iberia | Iberville | Jefferson | Jefferson Davis. |
| | | Lafayette | Lafourche | Livingston | Orleans | Plaquemines. |
| | | Pointe Coupee | Rapides | St. Bernard | St. Charles | St. Helena. |
| | | St. James | St. John the Baptist | St. Landry | St. Martin | St. Mary. |
| | | St. Tammany | Tangipahoa | Terrebonne | Vermilion | Washington. |
| | | West Baton Rouge | West Feliciana. | | | |
| | 2 | Bienville | Bossier | Caddo | Caldwell | Catahoula. |
| | | Claiborne | Concordia | De Soto | East Carroll | Franklin. |
| | | Grant | Jackson | LaSalle | Lincoln | Madison. |
| | | Morehouse | Natchitoches | Ouachita | Red River | Richland. |
| | | Sabine | Tensas | Union | Vernon | Webster. |
| | | West Carroll | Winn. | | | |
| Mississippi | 1 | Hancock | Harrison | Jackson | Pearl River | Stone. |
| | 2 | Adams | Alcorn | Amite | Attala | Benton. |
| | | Bolivar | Calhoun | Carroll | Chickasaw | Choctaw. |
| | | Claiborne | Clarke | Clay | Coahoma | Copiah. |
| | | Covington | DeSoto | Forrest | Franklin | George. |
| | | Greene | Grenada | Hinds | Holmes | Humphreys. |
| | | Issaquena | Itawamba | Jasper | Jefferson | Jefferson Davis. |
| | | Jones | Kemper | Lafayette | Lamar | Lauderdale. |
| | | Lawrence | Leake | Lee | Leflore | Lincoln. |
| | | Lowndes | Madison | Marion | Marshall | Monroe. |
| | | Montgomery | Neshoba | Newton | Noxubee | Oktibbeha. |
| | | Panola | Perry | Pike | Pontotoc | Prentiss. |
| | | Quitman | Rankin | Scott | Sharkey | Simpson. |
| | | Smith | Sunflower | Tallahatchie | Tate | Tippah. |
| | | Tishomingo | Tunica | Union | Walthall | Warren. |
| | | Washington | Wayne | Webster | Wilkinson | Winston. |
| | | Yalobusha | Yazoo. | | | |
| Texas | 1 | Anderson | Angelina | Aransas | Atascosa | Austin. |
| | | Bandera | Bastrop | Bee | Bell | Bexar. |
| | | Bosque | Brazoria | Brazos | Brooks | Burleson. |
| | | Caldwell | Calhoun | Cameron | Chambers | Colorado. |

TABLE 460.101–2—U.S. STATES WITH MORE THAN ONE CLIMATE ZONE—Continued

| State | Zone | Counties | Counties | Counties | Counties | Counties |
|---|---|---|---|---|---|---|
| | | Comal | Coryell | DeWitt | Dimmit | Duval. |
| | | Edwards | Falls | Fayette | Fort Bend | Freestone. |
| | | Frio | Galveston | Goliad | Gonzales | Grimes. |
| | | Guadalupe | Hardin | Harris | Hays | Hidalgo. |
| | | Hill | Houston | Jackson | Jasper | Jefferson. |
| | | Jim Hogg | Jim Wells | Karnes | Kenedy | Kinney. |
| | | Kleberg | La Salle | Lavaca | Lee | Leon. |
| | | Liberty | Limestone | Live Oak | Madison | Matagorda. |
| | | Maverick | McLennan | McMullen | Medina | Milam. |
| | | Montgomery | Newton | Nueces | Orange | Polk. |
| | | Real | Refugio | Robertson | San Jacinto | San Patricio. |
| | | Starr | Travis | Trinity | Tyler | Uvalde. |
| | | Val Verde | Victoria | Walker | Waller | Washington. |
| | | Webb | Wharton | Willacy | Williamson | Wilson. |
| | | Zapata | Zavala. | | | |
| | 3 | Andrews | Archer | Armstrong | Bailey | Baylor. |
| | | Blanco | Borden | Bowie | Brewster | Briscoe. |
| | | Brown | Burnet | Callahan | Camp | Carson. |
| | | Cass | Castro | Cherokee | Childress | Clay. |
| | | Cochran | Coke | Coleman | Collin | Collingsworth. |
| | | Comanche | Concho | Cooke | Cottle | Crane. |
| | | Crockett | Crosby | Culberson | Dallam | Dallas. |
| | | Dawson | Deaf Smith | Delta | Denton | Dickens. |
| | | Donley | Eastland | Ector | Ellis | El Paso. |
| | | Erath | Fannin | Fisher | Floyd | Foard. |
| | | Franklin | Gaines | Garza | Gillespie | Glasscock. |
| | | Gray | Grayson | Gregg | Hale | Hall. |
| | | Hamilton | Hansford | Hardeman | Harrison | Hartley. |
| | | Haskell | Hemphill | Henderson | Hockley | Hood. |
| | | Hopkins | Howard | Hudspeth | Hunt | Hutchinson. |
| | | Irion | Jack | Jeff Davis | Johnson | Jones. |
| | | Kaufman | Kendall | Kent | Kerr | Kimble. |
| | | King | Knox | Lamar | Lamb | Lampasas. |
| | | Lipscomb | Llano | Loving | Lubbock | Lynn. |
| | | McCulloch | Marion | Martin | Mason | Menard. |
| | | Midland | Mills | Mitchell | Montague | Moore |
| | | Morris | Motley | Nacogdoches | Navarro | Nolan. |
| | | Ochiltree | Oldham | Palo Pinto | Panola | Parker. |
| | | Parmer | Pecos | Potter | Presidio | Rains. |
| | | Randall | Reagan | Red River | Reeves | Roberts. |
| | | Rockwall | Runnels | Rusk | Sabine | San Augustine. |
| | | San Saba | Schleicher | Scurry | Shackelford | Shelby. |
| | | Sherman | Smith | Somervell | Stephens | Sterling. |
| | | Stonewall | Sutton | Swisher | Tarrant | Taylor. |
| | | Terrell | Terry | Throckmorton | Titus | Tom Green. |
| | | Upshur | Upton | Van Zandt | Ward | Wheeler. |
| | | Wichita | Wilbarger | Winkler | Wise | Wood. |
| | | Yoakum | Young. | | | |

**§ 460.102 Building thermal envelope requirements.**

(a) *Compliance options.* The building thermal envelope of a manufactured home must meet either the prescriptive requirements of paragraph (b) of this section or the performance requirements of paragraph (c) of this section.

(b) *Prescriptive requirements.* (1) The building thermal envelope must meet the minimum *R*-value, and the maximum *U*-factor and SHGC, requirements set forth in Table 460.102–1.

TABLE 460.102–1—BUILDING THERMAL ENVELOPE PRESCRIPTIVE REQUIREMENTS

| Climate zone | Ceiling insulation *R*-value | Wall insulation *R*-value | Floor insulation *R*-value | Window *U*-factor | Skylight *U*-factor | Door *U*-factor | Glazed fenestration SHGC |
|---|---|---|---|---|---|---|---|
| 1 | 30 | 13 | 13 | 0.35 | 0.75 | 0.40 | 0.25 |
| 2 | 30 | 13 | 13 | 0.35 | 0.75 | 0.40 | 0.33 |
| 3 | 30 | 21 | 19 | 0.35 | 0.55 | 0.40 | 0.33 |
| 4 | 38 | 21 | 30 | 0.32 | 0.55 | 0.40 | Not Applicable |

(2) For the purpose of compliance with the ceiling insulation *R*-value requirement of paragraph (b)(1) of this section, the truss heel height must be a minimum of 5.5 inches at the outside face of each exterior wall.

(3) Ceiling insulation must have either a uniform thickness or a uniform density.

(4) A combination of *R*-21 batt insulation and *R*-14 blanket insulation may be used for the purpose of compliance with the floor insulation *R*-value requirement of § 460.102(b)(1) for climate zone 4.

(5) An individual skylight that has an SHGC that is less than or equal to 0.30 is not subject to the glazed fenestration SHGC requirements established in Table 460.102–1.

(6) *U*-factor alternatives to *R*-value requirements. Compliance with paragraph (b)(1) of this section may be determined using the maximum *U*-factor values set forth in Table 460.102–2, which reflect the thermal transmittance of the component, excluding fenestration, and not just the insulation of that component, as an alternative to the minimum *R*-value requirements set forth in Table 460.102–1.

(7) The total area of glazed fenestration must be no greater than 12 percent of the area of the floor.

TABLE 460.102–2—*U*-FACTOR ALTERNATIVES TO *R*-VALUE REQUIREMENTS

| Climate zone | Ceiling *U*-factor | Wall *U*-factor | Floor *U*-factor |
|---|---|---|---|
| 1 | 0.0446 | 0.0943 | 0.0776 |
| 2 | 0.0446 | 0.0943 | 0.0776 |
| 3 | 0.0446 | 0.0628 | 0.0560 |
| 4 | 0.0377 | 0.0628 | 0.0322 |

(c) *Performance requirements.* (1) The building thermal envelope must have a $U_o$ that is less than or equal to the value specified in Table 460.102–3.

TABLE 460.102–3—BUILDING THERMAL ENVELOPE PERFORMANCE REQUIREMENTS

| Climate zone | Single-section $U_o$ | Multi-section $U_o$ |
|---|---|---|
| 1 | 0.087 | 0.084 |
| 2 | 0.087 | 0.084 |
| 3 | 0.070 | 0.068 |
| 4 | 0.059 | 0.056 |

(2) Area-weighted average vertical fenestration *U*-factor must not exceed 0.48 in climate zone 3 or 0.40 in climate zone 4.

(3) Area-weighted average skylight *U*-factor must not exceed 0.75 in climate zone 3 and climate zone 4.

(4) Windows, skylights and doors containing more than 50 percent glazing by area must satisfy the SHGC requirements established in Table 460.102–1 on the basis of an area-weighted average.

(d) *Determination of compliance with paragraph (b) of this section.*

(1)–(2) [Reserved].

(3) The total *R*-value of a component is the sum of the *R*-values of each layer of insulation that comprise the component.

(4)–(5) [Reserved].

(6) The *U*-factor for certain fenestration products and doors may be determined in accordance with the prescriptive default values set forth in Tables 460.102–4 and 460.102–5.

(7) [Reserved].

(8) The SHGC of certain glazed fenestration products may be determined in accordance with the prescriptive glazed fenestration default values set forth in Table 460.102–6.

(e) *Determination of compliance with § 460.102(c).* (1) $U_o$ must be determined in accordance with Overall *U*-Values and Heating/Cooling Loads—Manufactured Homes (incorporated by reference; see § 460.3) with the following exceptions:

(i)–(ii) [Reserved].

(iii) The *U*-factor for certain fenestration products and doors may be determined in accordance with the prescriptive default values set forth in Tables 460.102–4 and 460.102–5 of this section.

(2) [Reserved].

(3) The SHGC of certain glazed fenestration products may be determined in accordance with the prescriptive glazed fenestration default values set forth in Table 460.102–6.

TABLE 460.102–4—DEFAULT GLAZED FENESTRATION *U*-FACTOR VALUES

| Frame type | Window *U*-factor | Window *U*-factor | Skylight *U*-factor | |
|---|---|---|---|---|
| | | | Single pane | Double pane |
| Metal | 1.20 | 0.80 | 2.00 | 1.30 |
| Metal with Thermal Break | 1.10 | 0.65 | 1.90 | 1.10 |
| Nonmetal or Metal Clad | 0.95 | 0.55 | 1.75 | 1.05 |
| Glazed Block | 0.60 | | | |

TABLE 460.102–5—DEFAULT DOOR *U*-FACTOR VALUES

| Door type | *U*-factor |
|---|---|
| Uninsulated Metal | 1.20 |
| Insulated Metal | 0.60 |
| Wood | 0.50 |
| Insulated, nonmetal edge, maximum 45 percent glazing, any glazing double pane | 0.35 |

TABLE 460.102–6—DEFAULT GLAZED FENESTRATION SHGC VALUES

| | Single pane | | Double pane | | Glazed block |
|---|---|---|---|---|---|
| | Clear | Tinted | Clear | Tinted | |
| SHGC | 0.8 | 0.7 | 0.7 | 0.6 | 0.6 |

### § 460.103 Installation of insulation.

Insulating materials must be installed according to the insulation manufacturer's installation instructions and the requirements set forth in Table 460.103.

TABLE 460.103—INSTALLATION OF INSULATION

| Component | Installation requirements |
|---|---|
| General | Air-permeable insulation must not be used as a material to establish the air barrier. |
| Access hatches, panels, and doors | Access hatches, panels, and doors between conditioned space and unconditioned space must be insulated to a level equivalent to the insulation of the surrounding surface, must provide access to all equipment that prevents damaging or compressing the insulation, and must provide a wood-framed or equivalent baffle or retainer when loose fill insulation is installed within a ceiling assembly to retain the insulation both on the access hatch, panel, or door and within the building thermal envelope. |
| Baffles | Baffles must be constructed using a solid material, maintain an opening equal or greater than the size of the vents, and extend over the top of the attic insulation. |
| Ceiling or attic | The insulation in any dropped ceiling or dropped soffit must be aligned with the air barrier. |
| Eave vents | Air-permeable insulations in vented attics within the building thermal envelope must be installed adjacent to eave vents. |
| Floors | Floor insulation must be installed to maintain permanent contact with the underside of the rough floor decking over which the finished floor, flooring material, or carpet is laid, except where air ducts directly contact the underside of the rough floor decking. |
| Narrow cavities | Batts in narrow cavities must be cut to fit or narrow cavities must be filled by insulation that upon installation readily conforms to the available cavity space. |
| Rim joists | Rim joists must be insulated. |
| Shower or tub adjacent to exterior wall | Exterior walls adjacent to showers and tubs must be insulated. |
| Walls | Air permeable exterior building thermal envelope insulation for framed walls must completely fill the cavity, including within stud bays caused by blocking lay flats or headers. |

### § 460.104 Building thermal envelope air leakage.

Manufactured homes must be sealed against air leakage at all joints, seams, and penetrations associated with the building thermal envelope in accordance with the component manufacturer's installation instructions and the requirements set forth in Table 460.104. Sealing methods between dissimilar materials must allow for differential expansion and contraction and must establish a continuous air barrier upon installation of all opaque components of the building thermal envelope. All gaps and penetrations in the ceiling, floor, and exterior walls, including ducts, flue shafts, plumbing, piping, electrical wiring, utility penetrations, bathroom and kitchen exhaust fans, recessed lighting fixtures adjacent to unconditioned space, and light tubes adjacent to unconditioned space, must be sealed with caulk, foam, gasket or other suitable material.

TABLE 460.104—AIR BARRIER INSTALLATION CRITERIA

| Component | Air barrier criteria |
|---|---|
| Ceiling or attic | The air barrier in any dropped ceiling or dropped soffit must be aligned with the insulation and any gaps in the air barrier must be sealed with caulk, foam, gasket, or other suitable material. Access hatches, panels, and doors, drop down stairs, or knee wall doors to unconditioned attic spaces must be weatherstripped or equipped with a gasket to produce a continuous air barrier. |
| Duct system register boots | Duct system register boots that penetrate the building thermal envelope or the air barrier must be sealed to the air barrier or the interior finish materials with caulk, foam, gasket, or other suitable material. |
| Electrical box or phone box on exterior walls. | The air barrier must be installed behind electrical or communication boxes or the air barrier must be sealed around the box penetration with caulk, foam, gasket, or other suitable material. |
| Floors | The air barrier must be installed at any exposed edge of insulation. The bottom board may serve as the air barrier. |
| Mating line surfaces | Mating line surfaces must be equipped with a continuous and durable gasket. |
| Recessed lighting | Recessed light fixtures installed in the building thermal envelope must be sealed to the drywall with caulk, foam, gasket, or other suitable material. |
| Rim joists | The air barrier must enclose the rim joists. |
| Shower or tub adjacent to exterior wall | The air barrier must separate showers and tubs from exterior walls. |
| Walls | The junction of the top plate and the ceiling, and the junction of the bottom plate and the floor, along exterior walls must be sealed with caulk, foam, gasket, or other suitable material. |
| Windows, skylights, and exterior doors | The rough openings around windows, exterior doors, and skylights must be sealed with caulk or foam. |

## Subpart C—HVAC, Service Water Heating, and Equipment Sizing

### § 460.201 Duct system.

(a) Each manufactured home must be equipped with a duct system, which may include air handlers and filter boxes, that must be sealed to limit total air leakage to less than or equal to four (4) cubic feet per minute per 100 square feet of conditioned floor area when tested according to paragraph (b) of this section. Building framing cavities must not be used as ducts or plenums.

(b) [Reserved].

### § 460.202 Thermostats and controls.

(a) At least one thermostat must be provided for each separate heating and cooling system installed by the manufacturer.

(b) Programmable thermostat. Any thermostat installed by the manufacturer that controls the heating or cooling system must—

(1) Be capable of controlling the heating and cooling system on a daily schedule to maintain different temperature set points at different times of the day;

(2) Include the capability to set back or temporarily operate the system to maintain zone temperatures down to 55 °F (13 °C) or up to 85 °F (29 °C); and

(3) Be programmed with a heating temperature set point no higher than 70 °F (21 °C) and a cooling temperature set point no lower than 78 °F (26 °C).

(c) Heat pumps with supplementary electric-resistance heat must be provided with controls that, except during defrost, prevent supplemental heat operation when the heat pump compressor can meet the heating load.

### § 460.203 Service water heating.

(a) Service water heating systems installed by the manufacturer must be installed according to the service water heating manufacturer's installation instructions. Where service water heating systems are installed by the manufacturer, the manufacturer must ensure that any maintenance instructions received from the service water heating system manufacturer are provided with the manufactured home.

(b) Any automatic and manual controls, temperature sensors, pumps associated with service water heating systems must be accessible.

(c) *Heated water circulation systems must*—

(1) Be provided with a circulation pump;

(2) Ensure that the system return pipe is a dedicated return pipe or a cold water supply pipe;

(3) Not include any gravity or thermosyphon circulation systems;

(4) Ensure that controls for circulating heated water circulation pumps start the pump based on the identification of a demand for hot water within the occupancy; and

(5) Ensure that the controls automatically turn off the pump when the water in the circulation loop is at the desired temperature and when there is no demand for hot water.

(d) All hot water pipes—

(1) Outside conditioned space must be insulated to a minimum *R*-value of *R*-3; and

(2) From a service water heating system to a distribution manifold must be insulated to a minimum *R*-value of *R*-3.

### § 460.204 Mechanical ventilation fan efficacy.

(a) Whole-house mechanical ventilation system fans must meet the minimum efficacy requirements set forth in Table 460.204.

TABLE 460.204—MECHANICAL VENTILATION SYSTEM FAN EFFICACY

| Fan type description | Minimum efficacy (cfm/watt) |
|---|---|
| Range hoods (all air flow rates) | 2.8 |
| In-line fans (all air flow rates) | 2.8 |
| Bathroom and utility room fans (10 cfm ≤ air flow rate <90 cfm) | 1.4 |
| Bathroom and utility room fans (air flow rate ≥90 cfm) | 2.8 |

(b) Mechanical ventilation fans that are integral to heating, ventilating, and air conditioning equipment must be powered by an electronically commutated motor.

### § 460.205 Equipment sizing.

Sizing of heating and cooling equipment installed by the manufacturer must be determined in accordance with ACCA Manual S (incorporated by reference; see § 460.3) based on building loads calculated in accordance with ACCA Manual J (incorporated by reference; see § 460.3).

[FR Doc. 2016–13547 Filed 6–16–16; 8:45 am]

BILLING CODE 6450–01–P

MHCC MEETING
August 9, 2016

# APPENDIX C: ENERGY CONSERVATION STANDARDS PROPOSED RULEMAKING FOR MANUFACTURED HOUSING

By Joseph Hagerman, DOE, July 13, 2016

Energy Conservation Standards
Proposed Rulemaking for
Manufactured Housing

July 13, 2016

**Joseph Hagerman**

Department of Energy
Building Technologies Program
EE-2009-BT-BC-0021
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## Welcome

- Introductions (around the room)
- Role of the Facilitator
- Ground Rules
  - Speak one at a time.
  - Say your name for the record – there will be a complete transcript of this meeting.
  - Be concise – share the 'air-time'.
  - Keep the focus here – cell phones on silent; limit sidebar conversations.
  - Webinar participants turn phone on mute; "raise your hand" to be recognized to speak.
- Housekeeping Items
- Agenda Review
- Opening Remarks

## Agenda

Welcome, Introductions, and Agenda Review

Purpose of Public Meeting, Comment Submission Instructions, Opening Statements

Regulatory Authority and History

MH Background and Current Energy Standard Codes; Climate Zones

Proposed Standards

Energy Efficiency Level Analysis

Life-Cycle Cost Analysis; Shipments

National Impact Analysis

Manufacturer Impact Analysis

Environmental Assessment and Emissions

Regulatory Impact Analysis

Closing Remarks and Adjourn



## Listening Via the Webcast

- The Department is broadcasting this meeting live over the Internet.
- DOE is providing the webcast to accommodate stakeholders that are unable to attend the public meeting in person.
- The web broadcast allows stakeholders to listen in and view the slides.
- All stakeholders are encouraged to submit written comments after the public meeting.

## Purpose of the Public Meeting

- Present DOE's proposed standards for manufactured housing.
- Invite comment on the notice of proposed rulemaking (NOPR) document.
- Discuss next steps in the rulemaking.
- Invite participants to provide summary comments or statements and raise additional issues for discussion.





## Issues for Discussion

**Issue Box: DOE welcomes comments, data, and information concerning its proposed standards for Manufactured Housing. Issues that correspond to those raised in DOE's published material will be numbered in accordance with that material. Whether invited by an issue box or not, comments are welcome on any part of DOE's analysis.**

Issue box numbering corresponds to the list of issues published at the end of the NOPR document, available at: http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx?ruleid=97.

The deadline for submitting comments is August 16, 2016.

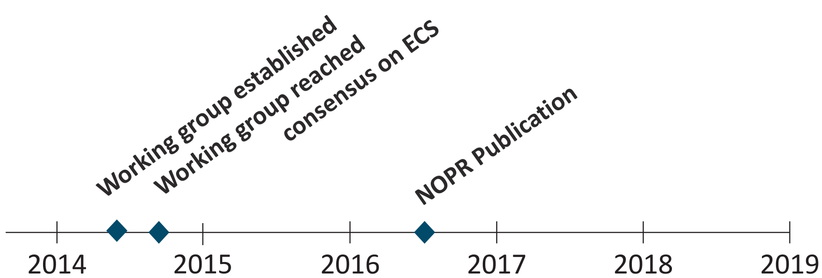
## Opening Remarks

**Meeting participants are invited to provide opening remarks or statements at this time.**





## Manufactured Housing ECS Rulemaking Schedule




| Milestone | Date |
|---|---|
| Working group established under the ASRAC committee | July 16, 2014 |
| Working group reached consensus on energy conservation standards for manufactured housing | October 31, 2014 |
| Manufactured housing NOPR published | June 17, 2016 |
| Final rule for Manufactured housing *(projected)* | TBD |
| Compliance date for Manufactured housing *(projected)* | 1-year after final rule publication |

## Public Meeting Slides Topics





## Regulatory Authority and History

- The Energy Independence and Security Act of 2007 (EISA, Public Law 110-140) directs the U.S. Department of Energy (DOE) to establish energy conservation standards for manufactured housing (MH) based on the most recent [2015] version of the International Energy Conservation Code (IECC).
- On June 13, 2014, DOE published a notice of intent to establish the manufactured housing working group (MH working group). (79 FR 33873)
- On July 16, 2014, the MH working group was established under the Appliance Standards and Rulemaking Federal Advisory Committee (ASRAC) in accordance with the Federal Advisory Committee Act and the Negotiated Rulemaking Act. (79 FR 41456; 5 U.S.C 561-570, App. 2)
- On October 31, 2014, the MH working group reached consensus on energy conservation standards for manufactured housing, and its recommendations (see public docket EERE-2009-BT-BC-0021-0107) were approved by ASRAC on December 1, 2014. ***The MH working group's recommendations form the basis of this NOPR.***
    - The MH working group consensus was reached by manufacturers, energy efficiency advocates, homeowner advocacy groups, consumer financing advocates, trade associations, and other organizations.

# Regulatory History and History

- EISA directs DOE to consult with the Secretary of the U.S. Department of Housing and Urban Development (HUD), who may seek further counsel from the Manufactured Housing Consensus Committee (MHCC). (42 U.S.C. 17071(a))
- HUD has regulated MH construction since 1976. (see 42 U.S.C 5401(b))
- In development of this NOPR, DOE's intent was to ensure compliance with the proposed requirements would not prohibit a manufacturer from complying with HUD requirements.
- The DOE-HUD consultation has consisted of several activities:
  - DOE provided a draft NOPR notice and TSD for review.
  - HUD attended all 6 DOE working group negotiation meetings in-person or by phone.
  - DOE met with HUD's MHCC twice to formally present the recommendations from the working group.
  - Many HUD MHCC members were also members of DOE's working group.
  - DOE and HUD general counsel spoke by phone several times to coordinate the consultation.
  - HUD participated in the interagency review of the NOPR coordinated by OIRA.



# Public Meeting Slides Topics

| | |
|---|---|
| 1 | Regulatory Authority and History |
| 2 | **MH Background and Current Energy Standard Codes** |
| 3 | Climate Zones |
| 4 | Proposed Standards |
| 5 | Energy Efficiency Level Analysis |
| 6 | Life-Cycle Cost (LCC) Analysis and Shipments |
| 7 | National Impact Analysis (NIA) |
| 8 | Manufacturer Impact Analysis (MIA) |
| 9 | Environmental Assessment and Emissions Monetization |
| 10 | Regulatory Impact Analysis (RIA) |
| 11 | Closing Remarks |

## Manufactured Housing Background

- A manufactured home is defined as, “a structure, transportable in one or more sections, which in the traveling mode is 8 body feet or more in width or 40 body feet or more in length or which when erected on-site is 320 or more square feet, and which is built on a permanent chassis and designed to be used as a dwelling with or without a permanent foundation when connected to the required utilities, and includes the plumbing, heating, air-conditioning, and electrical systems contained in the structure.” 24 CFR 3280.2
- The most common configurations are single-section and double-section homes.
- In 2014, MH stock consumed approximately 0.8 quads/year of primary energy, accounting for about 4 percent of total U.S. residential energy use.
- There were approximately 60,000 shipments of new manufactured homes in 2014.
- Large manufacturers provide the majority of shipments, with companies including:
  - Clayton Homes, Southern Energy Homes, Cavalier Homes, Champion Enterprises, Dutch Housing, Cavco Industries, and Skyline Corp.



## Current Energy Conservation Codes

- The ***HUD*** code includes requirements related to the energy efficiency of manufactured homes within in the United States. The code contains the following:
  - Three (3) climate zones.
  - Uo requirements for the combined thermal transmittance value of walls, ceilings, floors, fenestration, and external ducts within the building thermal envelope for manufactured homes installed in different climate zones. Requirements for air leakage control through the building thermal envelope.
  - Requirements for sealing air supply ducts and for insulating both air supply and return ducts.
- The ***IECC*** sets voluntary industry standards for the “effective use of energy” in all existing buildings. The code contains the following:
  - Definitions of terms.
  - Eight (8) climate zones used in determining compliance with the standards.
  - Information required at the building site to verify insulation level and identifies National Fenestration Rating Council (NFRC) standards for rating fenestration performance.
  - Residential energy efficiency requirements, including building thermal envelope, space heating, space cooling, water heating, air leakage testing, duct system testing and maximum duct air leakage, and lighting.

## Public Meeting Slides Topics

| | |
|---|---|
| 1 | Regulatory Authority and History |
| 2 | MH Background and Current Energy Standard Codes |
| 3 | Climate Zones |
| 4 | Proposed Standards |
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| 10 | Regulatory Impact Analysis (RIA) |
| 11 | Closing Remarks |





## Climate Zones

- DOE establishes different standards depending on climate zone.
- The MH working group considered both the 8 IECC climate zones and 3 HUD climate zones.
- The MH working group recommended 4 climate zones to maintain as much consistency with the current HUD zones as possible.
- These 4 climate zones better represent regions with similar climate than the HUD Code climate zones, while minimizing the extensive subdivision of states by the 8 IECC climate zones.




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## Issue for Comment

**Issue 6: Climate Zones**
DOE requests comment on the proposal to establish four climate zones and the categorization of states and counties included in each climate zone.





## Public Meeting Slides Topics

| | |
|---|---|
| 1 | Regulatory Authority and History |
| 2 | MH Background and Current Energy Standard Codes |
| 3 | Climate Zones |
| 4 | **Proposed Standards** |
| 5 | Energy Efficiency Level Analysis |
| 6 | Life-Cycle Cost (LCC) Analysis and Shipments |
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| 11 | Closing Remarks |

## Proposed Rule: Prescriptive Path

- DOE proposed a prescriptive path to compliance with the proposed standard. The component requirements for the prescriptive path are as follows:

| | Climate Zone | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Wall Insulation R-value (hr-ft$^2$-°F/Btu) | 13 | 13 | 21 | 21 |
| Ceiling Insulation R-value (hr-ft$^2$-°F/Btu) | 30 | 30 | 30 | 38 |
| Floor Insulation R-value (hr-ft$^2$-°F/Btu) | 13 | 13 | 19 | 30 |
| Window U-factor | 0.35 | 0.35 | 0.35 | 0.32 |
| Skylight U-factor | 0.75 | 0.75 | 0.55 | 0.55 |
| Door U-factor | 0.40 | 0.40 | 0.40 | 0.40 |
| Glazed Fenestration SHGC | 0.25 | 0.33 | 0.33 | Not Applicable |



## Proposed Rule: Prescriptive Path

- For the purpose of compliance with the ceiling insulation *R*-value requirement, the truss heel height would be required to be a minimum of 5.5 inches at the outside face of each exterior wall.
- Ceiling insulation would be required to have either a uniform thickness or a uniform density.
- A combination of *R*-21 batt insulation and *R*-14 blanket insulation could be used for the purpose of compliance with the floor insulation *R*-value requirement for climate zone 4.
- An individual skylight that has an SHGC that is less than or equal to 0.30 would not subject to the glazed fenestration SHGC requirements.
- As an alternative to the minimum prescriptive *R*-value requirements, ceilings, walls, and floors could achieve compliance by achieving the following component maximum *U*-factors:

| Climate Zone | Ceiling *U*-factor | Wall *U*-factor | Floor *U*-factor |
|---|---|---|---|
| 1 | 0.0446 | 0.0943 | 0.0776 |
| 2 | 0.0446 | 0.0943 | 0.0776 |
| 3 | 0.0446 | 0.0628 | 0.0560 |
| 4 | 0.0377 | 0.0628 | 0.0322 |

## Proposed Rule: Performance Path

- The performance path allows manufacturers design flexibility in creating manufactured homes while achieving equivalent thermal performance as a home designed using the prescriptive path.
- The performance path to compliance also includes SHGC, envelope leakage, duct leakage, and hot water pipe insulation requirements.

| | Climate Zone | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Single Section ($U_O$) | 0.087 | 0.087 | 0.070 | 0.059 |
| Multi Section ($U_O$) | 0.084 | 0.084 | 0.068 | 0.056 |

- Windows, skylights ,and doors containing more than 50 percent glazing by area would be required to satisfy the SHGC requirements established in the prescriptive option on the basis of an area-weighted average.
- Area-weighted average vertical fenestration U-factor would be prohibited from exceeding 0.48 in climate zone 3 or 0.40 in climate zone 4.
- Area-weighted average skylight U-factor would be prohibited from exceeding 0.75 in climate zone 3 and climate zone 4.



## Issue for Comment

**Issue 8: Paths for compliance with the building thermal envelope standards**
DOE requests comment on the proposal to establish prescriptive and performance options for achieving compliance with the proposed building thermal envelope requirements, the requirements of each option, and their equivalency in terms of overall thermal performance.

**Issue 10: U-factor alternatives**
DOE requests comment on the proposed U-factor alternatives and their equivalency with the prescriptive R-value requirements for ceiling, wall, and floor insulation.

**Issue 7: Home Size**
DOE requests comment on the proposal to establish separate requirements for single- and multi-section manufactured homes.

**Issue 12: Calculation of average SHGC**
DOE requests comment on the proposal to include an area-weighted average calculation of SHGC for compliance.

## Proposed Rule: Insulation Installation

- Insulating materials would be installed according to the insulation manufacturer's installation instructions.
- Insulation must also meet other requirements such as insulating the rim joists and installing floor insulation to maintain permanent contact with the underside of the rough floor decking (with some exceptions).

**Issue 13: Insulation installation requirements for floors**
DOE requests comment on whether the insulation installation requirements, including installation of insulation in floors, may be readily implemented by the manufactured housing industry.





## Proposed Rule: Building Thermal Envelope Air Leakage

- Manufactured homes would require sealing at all joints, seams, and penetrations associated with the building thermal envelope in accordance with the component manufacturer's installation instructions and DOE specifications.
- Mating line surfaces would be required to be equipped with a continuous and durable gasket.
- Sealing methods between dissimilar materials would be required to allow for differential expansion and contraction and establish a continuous air barrier upon installation of all opaque components of the building thermal envelope.
- All gaps and penetrations in the ceiling, floor, and exterior walls, including ducts, flue shafts, plumbing, piping, electrical wiring, utility penetrations, bathroom and kitchen exhaust fans, recessed lighting fixtures adjacent to unconditioned space, and light tubes adjacent to unconditioned space would require sealing with caulk, foam, gasket, or other suitable material.
- The rough openings around windows, exterior doors, and skylights would be required to be sealed with caulk or foam.



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# Proposed Rule: Building Thermal Envelope Air Leakage

***Building Thermal Envelope Air Leakage contd.***

- Duct system register boots that penetrate the building thermal envelope or the air barrier would be required to be sealed to the air barrier or the interior finish materials with caulk, foam, gasket, or other suitable material.
- Requirements would be established for the installation of air barriers in various manufactured home components, such as ceilings, walls, and floors.

**Issue 14: Design criteria for envelope sealing**
DOE requests comment on the effectiveness of the prescriptive building thermal envelope sealing requirements.



# Proposed Rule: Ducts and Thermostats & Controls

***Ducts***

- Each manufactured home would be required to be equipped with a duct system which is sealed to limit total air leakage to less than or equal to four cubic feet per minute per 100 square feet of conditioned floor area.

***Thermostats and Controls***

- Programmable thermostats would be required for each separate heating and cooling system installed by the manufacturer.
- Supplementary electric-resistance heat would be prohibited when the heat pump compressor is capable of meeting the heating load.

**Issue 16: Duct sealing**
DOE requests comment on the proposed duct sealing and duct leakage requirements.

**Issue 17: Thermostats and controls**
DOE requests comment on the proposed requirements for thermostats and controls, and any potential inconsistencies with the HUD Code.

# Proposed Rule: Service Water Heating

- Service water heating systems installed by the manufacturer would be required to be installed according to the service water heating manufacturer's installation instructions.
- DOE would require any automatic and manual controls, temperature sensors, and pumps associated with service water heating systems to be accessible
- Heated water circulation systems would be required to include a circulation pump, would be prohibited from using gravity and thermosyphon circulation systems, and would be required to use energy saving controls.
- All hot water pipes outside conditioned space or from a service water heating system to a distribution manifold would be required to be insulated to a minimum *R*-value of *R*-3.

**Issue 18: Demand recirculation systems**
DOE requests comment on the initial decision not to propose requirements related to demand recirculation systems in this rule.



# Proposed Rule: Mechanical Ventilation Fan Efficacy

- Whole-house mechanical ventilation system fans would be required to meet the following minimum efficacy requirements:

| Fan Type Description | Minimum Efficacy (cfm/Watt) |
|---|---|
| Range hoods (all air flow rates) | 2.8 |
| In-line fans (all air flow rates) | 2.8 |
| Bathroom and utility room fans (10 cfm ≤ air flow rate < 90 cfm) | 1.4 |
| Bathroom and utility room fans (air flow rate ≥ 90 cfm) | 2.8 |

- Mechanical ventilation fans integral to heating, ventilating, and air conditioning equipment would be required to be powered by an electronically commutated motor.

## Proposed Rule: Equipment Sizing

- Sizing of heating and cooling equipment installed by the manufacturer would be required to be determined in accordance with ACCA Manual S based on building loads calculated in accordance with ACCA Manual J.

**Issue 20: Equipment sizing**
DOE requests comment on the proposed requirements for equipment sizing and the applicability of ACCA Manuals S and J.

**Issue 1: Relationship with the HUD Code 24 CFR 3280.**
DOE seeks comment on potential inconsistencies or conflicts between the proposed rule and the HUD Code.




## Public Meeting Slides Topics

| | |
|---|---|
| 1 | Regulatory Authority and History |
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# Energy Efficiency Level Analysis: Overview

## Purpose

- To determine the cost and energy use of homes built with different energy efficiency measures (EEMs) and sited in different locations.
- This cost and energy use data is then used as an input to downstream economic and environmental analyses.

## Method

- Energy simulation software was used to determine energy consumption data for the set of EEMs analyzed.
- EEM options, performance characteristics, and costs were determined for all manufactured home components affected by the proposed rule.





# Energy Efficiency Level Analysis: Energy Simulation

- DOE used simulation software (EnergyPlus v8.0) to determine energy consumption based on building thermal envelope, envelope air leakage and mechanical system inputs.

- DOE used these building construction assumptions for the energy simulation:

| Dimension | Single-Section | Multi-Section |
|---|---|---|
| MH floor area | 14 feet by 66 feet; 924 square feet | 28 feet by 54 feet; 1,568 square feet |
| Floor-to-ceiling height | 7.5 feet | 7.5 feet |
| Window area | 111 square feet | 188 square feet |
| Window distribution | Equally on all four facades to yield a solar-neutral orientation. The windows are assumed to have no overhangs to represent an average manufactured home. | |
| Doors | Assumed to have two exterior doors with a total door area of 36 square feet, with a U-factor of 0.40. | |



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# Energy Efficiency Level Analysis: Energy Simulation

- The energy simulation model also included assigned values for the following:
  - Lighting efficiency
  - Internal loads
  - Envelope Leakage
  - Thermal Zoning and Thermostat Set-Points
  - HVAC System Sizing
  - HVAC Equipment Efficiency
  - Duct Leakage
  - Domestic Hot Water System

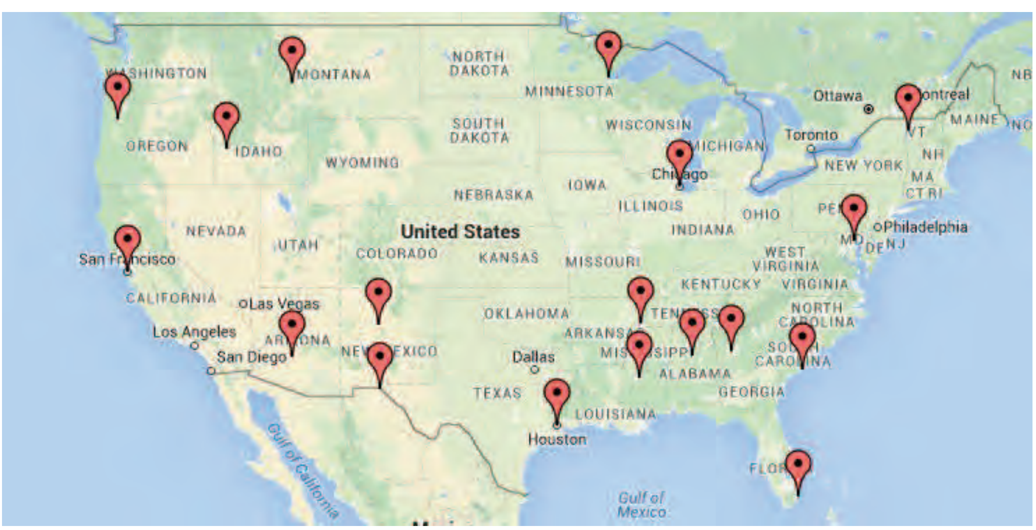
- DOE assumed that the insulation and windows were presumed to last the 30-year lifetime assumed in the analysis, so there was no replacement cost.

- DOE assumed that the energy savings from improved levels would remain for the length of the 30-year analysis period.



# Energy Efficiency Level Analysis: Climate Zones

- The energy analysis was conducted in a total of 19 cities to analyze each IECC climate zone and also provide additional focus on the southeastern United States (Mississippi, Alabama, Georgia, and South Carolina), which account for a large portion of manufactured home sales.



# Energy Efficiency Level Analysis: EEM Ranges

- EEMs are elements of a manufactured home affecting energy use.
- The energy simulation analysis gave DOE the ability to calculated overall building energy use for a given set of EEMs.
- The following table provides the range of EEMs that were included in the analysis.

| Building Component | Range of Options |
|---|---|
| Ceiling (hr-ft$^2$-°F/Btu) | R-22 to R-38 |
| Wall (hr-ft$^2$-°F/Btu) | R-11 to R-21 |
| Floor (hr-ft$^2$-°F/Btu) | R-11 to R-30 |
| Window U-Factor (Btu/hr-ft$^2$-°F) | U-1.08 to U-0.30 |
| Window SHGC | 0.7 to 0.25 |
| Duct Sealing (cfm25/100 ft$^2$ CFA)* | 12 to 4 |
| Envelope Sealing (ACH) | 8 to 5 |
| *CFA = conditioned floor area | |




# Energy Efficiency Level Analysis: EEM Cost

- Through data supplied during the MH working group, DOE assigned incremental costs to each EEM.

**Example Cost Table – Wall Insulation**

| Wall R-Value (hr-ft2-°F/Btu) | Single-Section Cost $ | Multi-Section Cost $ |
|---|---|---|
| 11 | -- | -- |
| 13 | 61.86 | 60.86 |
| 15 | 610.79 | 600.93 |
| 19 | 610.79 | 600.93 |
| 20 | 737.92 | 726.01 |
| 21 | 737.92 | 726.01 |
| 21+5* | 2,199.75 | 2,176.76 |
| * Refers to a combination of R-21 batt insulation and R-5 insulated siding. | | |

**Issue 26: Increased costs of components**
DOE requests comment on the assumptions underlying DOE's analyses associated with the increased costs of manufactured home components.

# Energy Efficiency Level Analysis: Level Selection

DOE analyzed variations to the 2015 IECC to find the most cost-effective set of EEMs.

The MH working group started its analysis with the 2015 IECC

The cost-effectiveness was calculated for a manufactured home built to the 2015 IECC relative to a manufactured home constructed with the minimum requirements of the HUD code

Several EEM options were identified as potential revisions to the 2015 IECC that could increase cost-effectiveness for manufactured housing

The most cost-effective EEMs were recommended as part of this proposal



# Energy Efficiency Level Analysis: Proposed Prescriptive Path Results

- DOE proposed 2 paths to compliance for the building thermal envelope, corresponding with the most cost-effective energy efficiency level.
- The **prescriptive path** gives exact EEMs to be implemented.

| | Climate Zone | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Wall Insulation R-value (hr-ft²-°F/Btu) | 13 | 13 | 21 | 21 |
| Ceiling Insulation R-value (hr-ft²-°F/Btu) | 30 | 30 | 30 | 38 |
| Floor Insulation R-value (hr-ft²-°F/Btu) | 13 | 13 | 19 | 30 |
| Window U-factor | 0.35 | 0.35 | 0.35 | 0.32 |
| Skylight U-factor | 0.75 | 0.75 | 0.55 | 0.55 |
| Door U-factor | 0.40 | 0.40 | 0.40 | 0.40 |
| Glazed Fenestration SHGC | 0.25 | 0.33 | 0.33 | No Rating |
| Envelope Leakage Limit (ACH) | 5 | 5 | 5 | 5 |
| Duct Leakage Limit (CFM25/100ft² CFA) | 4 | 4 | 4 | 4 |
| Domestic Hot Water Pipe Insulation (*R*-value) | 3 | 3 | 3 | 3 |

## Energy Efficiency Level Analysis: Proposed Performance Path Results

- The **performance path** provides the performance-based overall thermal transmittance ($U_o$) requirements for the entire building thermal envelope, which gives flexibility in designing the building thermal envelope.
- The Uo of a manufactured home was calculated using the EEMs proposed for the prescriptive path.

| Climate Zone | Single-Section Uo | Multi-Section Uo |
|---|---|---|
| 1 | 0.087 | 0.084 |
| 2 | 0.087 | 0.084 |
| 3 | 0.070 | 0.068 |
| 4 | 0.059 | 0.056 |



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# Life-Cycle Cost (LCC) and Payback Period (PBP) Overview

## Purpose

- Provide an economic evaluation from the end-user's perspective.
- Life-Cycle Cost (LCC) is the total purchaser cost over the life of a product.
- Payback Period (PBP) is the time required to recover the increased purchase price of more energy-efficient products through reduced operating costs.

## Method

- Determine incremental purchase price.
- Determine financial, economic, and fuel prices for analyses.
- Determine LCC by calculating total homeowner expense over the life of the manufactured home, consisting of purchase expenses (i.e., mortgage or cash purchase) and operating costs (i.e., energy costs).
- Calculate PBP by dividing incremental increase in purchase cost by the reduction in average annual operating costs.



# Life-Cycle Cost (LCC) and Payback Period (PBP): Inputs

- The main inputs to the LCC and PBP analysis include the MH home incremental purchase price, and the financial parameters for purchasing a home.

- Approximately 70 percent of manufactured homes are purchased using a loan, and 30 percent of manufactured homes are purchased outright.
  - DOE considered two different loan structures in the analysis, which include a personal property loan (often referred to as a "chattel loan") or a real estate loan.
  - According to the MH working group, 78 percent of manufactured homes that are purchased with financing use a personal property loan, and 22 percent of financed purchases use a real estate loan.

- The LCC analysis must also sum costs and benefits occurring in different years into a common valuation, known as the present value. To translate costs and benefits occurring in future years as a present value, DOE established a discount rate.
  - Mortgage prepayment was used to establish the discount rate for this analysis, because the homebuyer has borrowed money at that rate, demonstrating that his implicit discount rate must be at least that high.

# Life-Cycle Cost (LCC) and Payback Period (PBP): Inputs

- The following tables provide the MH incremental retail purchase price and financial parameter inputs to the LCC and PBP.

| MH Incremental Retail Purchase Price | | |
|---|---|---|
| | Single-Section | Multi-Section |
| | $ | $ |
| Climate Zone 1 | 2,422 | 3,748 |
| Climate Zone 2 | 2,348 | 3,668 |
| Climate Zone 3 | 2,041 | 2,655 |
| Climate Zone 4 | 2,208 | 2,877 |
| National Average | 2,226 | 3,109 |

| Finance Parameters | | |
|---|---|---|
| | Personal Property Loans | Real Estate Loans |
| Mortgage interest rates | 9% | 5% |
| Loan term | 15 years | 30 years |
| Down payment | 20% | 20% |
| Loan fees and points | 1% | 1% |
| **Other Rates and Times** | | |
| Discount rate (nominal) | 9% | **5%** |
| Analysis Period | 30 years and 10 years | |
| Property tax rate | 0.9% | |
| **Fuel Prices and Escalation Rates** | | |
| | Price | Escalation Rate |
| Electricity<br>Summer<br>Winter | <br>12.9 cents/kWh<br>12.3 cents/kWh | 2.5% |
| Natural gas | $10.67/MBtu | 3.5% |
| Liquid petroleum gas | $24.18/MBtu | 2.3% |
| Oil | $26./MBtu | 2.5% |

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# Life-Cycle Cost (LCC) and Payback Period (PBP): Results

- The following table provides the net LCC savings and PBP associated with the proposed rule compared to the HUD code for a 30-year analysis period for single-section and multi-section manufactured homes.
  - The results account for the energy cost savings and mortgage payments over the entire analysis period discounted to a present value, using the discount rates.
  - The results represent a weighted average of the three different methods for purchasing the home: outright purchase with cash, financed with a personal property loan, and financed with a real estate loan.
  - The results represent the weighted average across all five heating system types: Electric resistance, electric heat pump, natural gas furnace, LPG furnace and distillate oil furnace.

| Climate Zone | LCC Savings (2015$) | | PBP (Years) | |
|---|---|---|---|---|
| | Single-Section | Multi-Section | Single-Section | Multi-Section |
| 1 | $2,078 | $3,410 | 8.5 | 8.2 |
| 2 | $2,792 | $4,760 | 7.4 | 7.1 |
| 3 | $3,000 | $4,291 | 6.7 | 6.5 |
| 4 | $4,643 | $6,016 | 6.1 | 6.3 |
| **Nation** | **$3,211** | **$4,625** | **7.1** | **6.9** |

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# Issue for Comment

**Issue 27: Lifecycle cost analysis**
DOE requests comment on the methodology and initial findings of the lifecycle cost analysis.

**Issue 28: Affordability**
DOE requests comment on the affordability of the proposed rule with respect to the increased purchase cost, reduced operating costs (energy bills), and total lifecycle cost.



# Shipments Analysis Overview

## Purpose

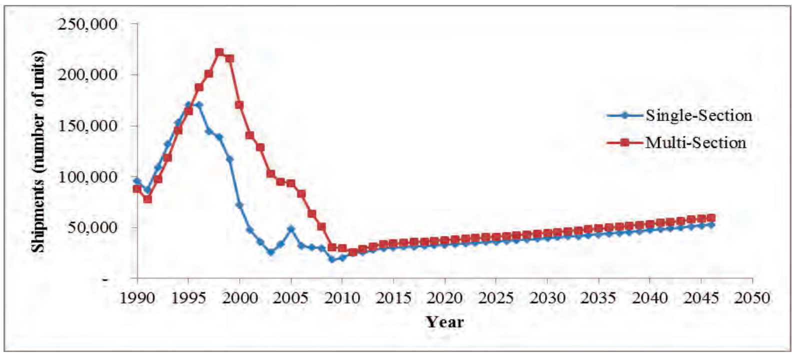
- To determine base-case shipments (with HUD standards) and standards case shipments (with proposed standards) over the analysis period (2017-2046).

## Method

- DOE developed a shipment model for manufactured housing using historical data from the Manufactured Housing Institute (MHI) and using projections for growth in new housing starts from the AEO 2015 to forecast shipments into the future.

# Shipments Analysis: Base-case Shipments Inputs

- DOE used historical data from MHI to develop the base-case shipments model.
  - MHI publishes an annual report of manufactured housing shipments categorized by state and by the number of home sections (*i.e.*, single-section or multi-section).
  - Because all energy use intensities and incremental home prices were analyzed for 19 different cities in the four proposed climate zones, DOE aggregated the shipments originally categorized by state in the MHI report into shipments for the 19 cities.
- To estimate future shipments of manufactured homes, DOE assumed the manufactured housing shipment growth rate was equal to the residential housing starts growth rate from AEO 2015.
- All base-case shipments are of baseline (HUD Code) efficiency.



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# Shipments Analysis: Standards-case Shipments Inputs

- All standards-case shipments are assumed to just meet the proposed energy conservation standard.
  - As customers shift from manufactured housing just compliant with the HUD code to manufactured housing compliant with the proposed energy conservation standard, the increase in upfront home price affects the shipment volume.
- To determine the change in shipments in the standards-case, DOE used the concept of price elasticity of demand.
  - Price elasticity of demand (price elasticity) is an economic concept that describes the change of the quantity demanded in response to a change in price. Price elasticity is typically represented as a ratio of the percentage change in quantity relative to a percentage change in price.
- DOE used the elasticity value of -0.48 in its analysis of changes to future shipments in response to the proposed energy conservation standard.
  - For a 5% increase in purchase price, shipments would decrease by 2.4%.



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# Shipments Analysis: Standards-case Shipments Inputs

$$Standards\ Case\ Shipments =$$
$$Base\ Case\ Shipments * \left(\frac{Incremental\ MH\ purchase\ price}{Average\ Sales\ Price} * (-0.48) + 1\right)$$

- DOE used this equations to calculate relative shipment reduction factors for single-section and multi-section homes in all 19 cities.
  - DOE applied these factors for each year of shipments in the analysis period to capture the impacts of the increased purchase price on manufactured home demand.
  - DOE assumed the overall and incremental cost increase of manufactured homes would not change over time (*i.e.,* no price learning), and therefore the shipment reduction factors do not change over time.



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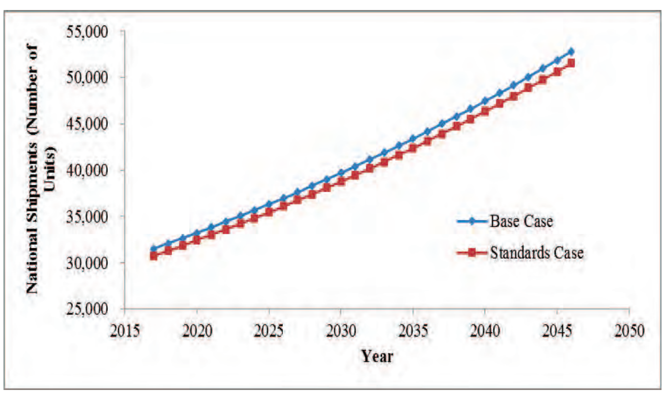
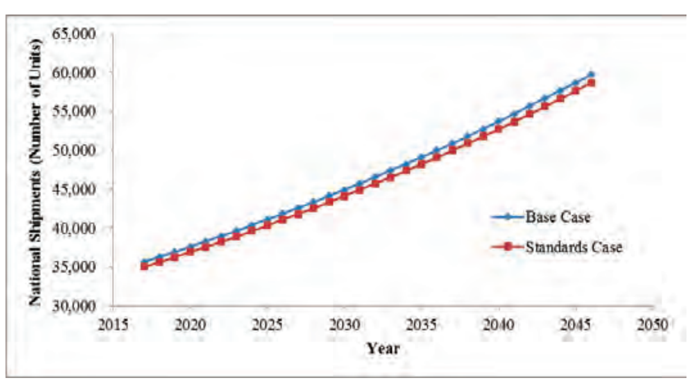
# Shipments Analysis: Results




Single-section Shipments

Multi-section Shipments



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# Issue for Comment

**Issue 30: Shipments analysis**
DOE requests comment on the methodology and initial findings of the shipments analysis.

**Issue 32: Price Elasticity**
DOE requests comment on the estimate of the price elasticity of demand of manufactured homes.



# Public Meeting Slides Topics

1. Regulatory Authority and History
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# National Impact Analysis Overview

Purpose

- Determine the projected national energy savings (NES) and consumer national net present value (NPV) of a proposed standard.

Method

- Develop annual series of national energy and economic impacts.
- Aggregate the costs and energy use per unit in any given year.
- Report estimates for economic impact as change in NPV.
- Account for the time-value of money through defined discount rates.





# National Impact Analysis: NES and NPV Calculation

- NES is calculated using the equation: $NES(y) = (AEC_{base\,case}(y) - AEC_{std}(y))$

where:

$NES(y)$ = National energy savings in year *y* (quads),

$AEC_{no\ std}(y)$ = based case annual national energy consumption at the power plant for all affected stock in year *y* (quads), and

$AEC_{std}(y)$ = standards case annual national energy consumption at the power plant for all affected stock in year *y* (quads).

- NPV is calculated using the equation: $NPV = PVS - PVC$

where:

$NPV$ = National net present value (2015$),

$PVS$ = present value of savings in operating cost (in 2015$), and

$PVC$ = present value of increase in total installed cost (in 2015$).



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# National Impact Analysis: NES Method and Inputs

- DOE modeled the annual energy consumption per square foot of floor space associated with the HUD code and the proposed standard in 19 different cities.
  - The annual unit site energy consumption was determined from the energy simulation analysis.
  - The energy use intensities were analyzed with five different types of heating systems: electric resistance heaters, air-source heat pumps, natural gas furnaces, LPG furnaces, and oil furnaces.
- DOE converted the unit site energy consumption of the HUD code and the proposed standard into primary energy consumption and full fuel cycle (FFC) energy consumption.
- DOE analyzed the NES for 30 years of manufactured home shipments, and considered the entire lifetime of each shipment.
  - In a given year, the housing stock is the cumulative number of shipments up to that year less the number of homes that have exceeded their 30-year lifetime.



# National Impact Analysis: NPV Method and Inputs

- DOE calculated the total incremental installed cost of 30-years of shipments of new manufactured homes compliant with the proposed rule, and the associated operating cost savings over the entire lifetime of those 30 years of shipments.
  - These costs and savings were discounted to a base year, 2015, using both a 3-percent and a 7-percent real discount rate.

- For each year of shipments, DOE calculated the incremental total installed cost and total operating costs of manufactured homes in each of the nineteen cities.
  - This incremental installed cost is a weighted average across three different methods of payment: personal property loans, real estate loans, and outright purchases.
  - DOE assumed that in its projections of future price trends, the real price of manufactured homes would remain constant (i.e., no price learning).
  - To forecast the nominal price increase of manufactured homes, DOE used the inflation rate associated with energy price forecasts in *AEO 2015*, which is 1.85 percent.

- DOE used energy price forecasts from the *AEO 2015* to calculate the energy cost savings associated with the proposed rule for the entire analysis period.
  - DOE used these forecasts for all 5 heating system types.

# National Impact Analysis: NES & NPV Results

| NES Results | | |
|---|---|---|
| | Single-Section quadrillion British thermal units (BTUs) (quads) | Multi-Section quadrillion BTUs (quads) |
| **Climate Zone 1** | 0.179 | 0.294 |
| **Climate Zone 2** | 0.130 | 0.245 |
| **Climate Zone 3** | 0.272 | 0.474 |
| **Climate Zone 4** | 0.303 | 0.416 |
| **Total** | 0.884 | 1.428 |

| NPV Results | | | | |
|---|---|---|---|---|
| | 7% Discount Rate | | 3% Discount Rate | |
| | Single-Section (billion 2015$) | Multi-Section (billion 2015$) | Single-Section billion 2015$ | Multi-Section billion 2015$ |
| **Climate Zone 1** | 0.19 | 0.34 | 0.66 | 1.16 |
| **Climate Zone 2** | 0.16 | 0.35 | 0.54 | 1.10 |
| **Climate Zone 3** | 0.39 | 0.74 | 1.22 | 2.26 |
| **Climate Zone 4** | 0.52 | 0.74 | 1.60 | 2.24 |
| **Total** | 1.26 | 2.18 | 4.03 | 6.75 |





# Issue for Comment

**Issue 33: National impacts analysis**
DOE requests comment on the methodology and initial findings of the national impacts analysis.



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

# Public Meeting Slides Topics

| | |
|---|---|
| 1 | Regulatory Authority and History |
| 2 | MH Background and Current Energy Standard Codes |
| 3 | Climate Zones |
| 4 | Proposed Standards |
| 5 | Energy Efficiency Level Analysis |
| 6 | Life-Cycle Cost (LCC) Analysis and Shipments |
| 7 | National Impact Analysis (NIA) |
| 8 | **Manufacturer Impact Analysis (MIA)** |
| 9 | Environmental Assessment and Emissions Monetization |
| 10 | Regulatory Impact Analysis (RIA) |
| 11 | Closing Remarks |



# MIA Overview

**Purpose**

- Assess the impacts of potential energy conservation standards on manufacturers.

**Method**

- Calculate industry-average financial metrics.
- Estimate conversion costs.
- Use Government Regulatory Impact Model (GRIM), an industry discounted cash flow model, to estimate Industry Net Present Value (INPV).

# MIA: Inputs

- Upstream Inputs
  - Incremental Retail Prices
  - Shipments Forecasts

- MIA Inputs
  - Industry Financials Metrics
  - Conversion Costs



# Industry Financial Metrics

$$\frac{Retail\ Price}{Sales\ Tax \times Retail\ Markup} = Manufacturer\ Sales\ Price$$

- Average sales tax = 1.03
- Average retail markup = 1.3

$$\frac{Manufacturer\ Sales\ Price}{Manufacturer\ Markup} = Manufacturer\ Production\ Cost$$

- Manufacturer markup = 1.25

**Issue 29: Manufacturer Impact Analysis - Markups**
DOE requests comment on the manufacturer and retailer markups

# Conversion Costs

**Product Conversion Costs**

- One-time, upfront investments in research, development, labeling updates, and other costs to make product designs comply with energy conservation standards.

**Capital Conversion Costs**

- One-time, upfront investments in property, plant and equipment to adapt or change existing manufacturing lines.

| Total Industry Conversion Costs | Product Conversion Costs | Capital Conversion Costs | Total Conversion Costs |
|---|---|---|---|
| Million 2015$ | 1.4 | 0.2 | 1.6 |





# MIA: Results

| | Single-Section | Multi-Section | Total Industry |
|---|---|---|---|
| Base Case INPV (Million 2015$) | 229 | 488 | 717 |
| Standards Case INPV (Million 2015$) | 215 to 228 | 465 to 486 | 680 to 714 |
| Change in INPV (Million 2015$) | (14) to (1) | (23) to (2) | (37) To (3) |
| Change in INPV (%) | (6.1) to (1.1) | (4.7) To (0.4) | (5.1) to (0.4) |
| Total Conversion Costs (Million 2015$) | 0.5 | 1.1 | 1.6 |



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

# Public Meeting Slides Topics

| | |
|---|---|
| 1 | Regulatory Authority and History |
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# Environmental Assessment Overview

## Purpose

- Assess the environmental impacts of the proposed rule, especially:
  - Impacts of the proposed rule on indoor air quality (IAQ).
  - Full-fuel-cycle emissions reductions resulting from amended energy conservation standards, including carbon dioxide ($CO_2$), sulfur dioxide ($SO_2$), nitrogen oxides ($NO_X$), nitrous oxide ($N_2O$), and methane ($CH_4$), mercury (Hg).

## Methodology

- Investigate impacts of increased air sealing on indoor air quality in manufactured homes.
- Compute full-fuel-cycle emissions reductions from annual energy savings from NIA using emissions factors derived from AEO 2015.



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# Environmental Assessment: Indoor Air Quality

- DOE proposes to prescribe air sealing requirements that are expected to decrease natural air infiltration on average from 8 to 5 air changes per hour when measured at a pressure difference of 50 Pa.
  - The proposed rule is not expected to change the sources of indoor air pollutants.
- DOE expects the possible impacts of the proposed rule to include:
  - Reduced infiltration into the home of outdoor air pollutants such as car exhaust.
  - Increase in indoor air pollutants due to reduction in ventilation.
- The impacts of reduced infiltration on indoor air quality depend on many factors, including:
  - Human behavior (i.e. pollutant sources present).
  - Mechanical ventilation installed in the home.
  - Climate – weather significantly impacts amount of natural infiltration.

**Issue 15: Impact of envelope sealing on indoor air quality**
DOE requests specific information on how the proposed rule may impact indoor air quality.

Note: The full environmental assessment is publically available at: 81 FR 42576 (June 30, 2016)





# Environmental Assessment: Emissions Results

| Pollutant | Home Size | |
|---|---|---|
| | Single-Section | Multi-Section |
| **Source Emissions** | | |
| **$CO_2$ (million metric tons)** | 56.5 | 91.1 |
| **Hg (metric tons)** | 0.0904 | 0.146 |
| **NOx (thousand metric tons)** | 223 | 356 |
| **$SO_2$ (thousand metric tons)** | 27.6 | 44.4 |
| **$CH_4$ (thousand metric tons)** | 3.78 | 6.09 |
| **$N_2O$ (thousand metric tons)** | 0.632 | 1.02 |
| **Upstream Emissions** | | |
| **$CO_2$ (million metric tons)** | 4.01 | 6.45 |
| **Hg (metric tons)** | 0.000944 | 0.00153 |
| **NOx (thousand metric tons)** | 51.8 | 83.2 |
| **$SO_2$ (thousand metric tons)** | 0.615 | 0.991 |
| **$CH_4$ (thousand metric tons)** | 239 | 385 |
| **$N_2O$ (thousand metric tons)** | 0.0294 | 0.0474 |
| **Full-Fuel-Cycle Emissions** | | |
| **$CO_2$ (million metric tons)** | 60.5 | 97.6 |
| **Hg (metric tons)** | 0.0913 | 0.148 |
| **NOx (thousand metric tons)** | 275 | 439 |
| **$SO_2$ (thousand metric tons)** | 28.2 | 45.4 |
| **$CH_4$ (thousand metric tons)** | 243 | 391 |
| **$N_2O$ (thousand metric tons)** | 0.661 | 1.07 |



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# Emissions Monetization Overview

- DOE uses the most current Social Cost of Carbon (SCC) values developed by interagency process.
  - SCC is intended to be a monetary measure of the incremental damage resulting from greenhouse gas (GHG) emissions, including, but not limited to, agricultural productivity loss, human health effects, property damage from rising sea levels, and ecosystem changes.
- The most recent U.S. government interagency estimates of the SCC for emissions in 2015, per metric ton avoided (in 2015 dollars):
  - **$13.5** (average value from a distribution with a 5% discount rate)
  - **$42.9** (average value from a distribution with a 3% discount rate)
  - **$65.4** (average value from a distribution with a 2.5% discount rate)
  - **$122.9** ($95^{th}$-percentile value from a distribution with a 3% discount rate)
- The SCC in constant dollars increases over time.
- DOE also monetizes the $NO_X$ emissions reductions resulting from amended standards.



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

# Emissions Monetization: $CO_2$ Results

Global Net Present Value of Reduced Emissions of $CO_2$ for Each SCC Value for Manufactured Homes Shipped 2017-2046

| Home Size | SCC Case | | | |
|---|---|---|---|---|
| | 5% Discount Rate, Average | 3% Discount Rate, Average | 2.5% Discount Rate, Average | 3% Discount Rate, $95^{th}$ Percentile |
| | Million 2015$ | | | |
| **Site Monetized Emissions** | | | | |
| **Single Section** | 344.1 | 1,691.9 | 2,732.6 | 5,214.5 |
| **Multi Section** | 555.1 | 2,729.1 | 4,407.7 | 8,411.2 |
| **Upstream Monetized Emissions** | | | | |
| **Single Section** | 24.0 | 119.0 | 192.5 | 367.0 |
| **Multi Section** | 38.6 | 191.4 | 309.5 | 590.3 |
| **Full-Fuel-Cycle Monetized Emissions** | | | | |
| **Single Section** | 368.2 | 1,810.9 | 2,925.0 | 5,581.5 |
| **Multi Section** | 593.7 | 2,920.5 | 4,717.3 | 9,001.5 |



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

## Emissions Monetization: $NO_X$ Results

Net Present Value of Reduced Emissions of $NO_X$ for Each Discount Rate for Manufactured Homes Shipped 2017–2046

| Home Size | Discount Rate | |
|---|---|---|
| | 3% | 7% |
| | Million 2015$ | |
| **Site Emissions** | | |
| Single Section | 252.8 | 97.4 |
| Multi Section | 404.4 | 155.8 |
| **Upstream Emissions** | | |
| Single Section | 58.6 | 22.5 |
| Multi Section | 94.3 | 36.1 |
| **Full-Fuel-Cycle Emissions** | | |
| Single Section | 311.5 | 119.8 |
| Multi Section | 498.6 | 191.9 |

**Issue 34: Emissions analysis**
DOE requests comment on the methodology and initial findings of the emissions analysis.



## Public Meeting Slides Topics

1. Regulatory Authority and History
2. MH Background and Current Energy Standard Codes
3. Climate Zones
4. Proposed Standards
5. Energy Efficiency Level Analysis
6. Life-Cycle Cost (LCC) Analysis and Shipments
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# Regulatory Impact Analysis Overview

## Purpose

- To analyze the impacts of the regulatory alternatives on purchase price of single-section and multi-section manufactured homes, impacts on total annualized economic costs and benefits to the nation and impacts on manufacturers.

## Method

- DOE modified the NIA, Emissions and MIA Analyses to represent the following non-regulatory alternatives:
  - 2009 IECC code
  - 2012 IECC code





# Regulatory Impact Analysis: Key differences

- In all but three of the analyzed cities, the 2012 IECC has a more stringent requirement of 3 ACH for the envelope leakage limit relative to the 2009 IECC (7 ACH for all cities and climate zones) and the proposed rule (5 ACH for all cities and climate zones).

- The 2012 IECC leads to the largest incremental purchase price increase compared to the 2009 IECC and the proposed rule in all but one of the 19 cities.

## Regulatory Impact Analysis: Results

| | Discount Rate | 2009 IECC | 2012 IECC | Proposed Rule |
|---|---|---|---|---|
| Benefits (Million 2015$/year) | | | | |
| Operating (Energy Cost Savings) | 7 | 286 | 636 | 516 |
| | 3 | 468 | 1,040 | 843 |
| $CO_2$, Average SCC Case | 5 | 34 | 77 | 63 |
| $CO_2$, Average SCC Case | 3 | 133 | 298 | 241 |
| $CO_2$, Average SCC Case | 2.5 | 201 | 451 | 365 |
| $CO_2$, $95^{th}$ Percentile SCC Case | 3 | 410 | 919 | 744 |
| $NO_X$ Reduction at $2,723/metric ton | 7 | 13 | 33 | 25 |
| | 3 | 22 | 54 | 41 |
| Total (Operating Cost Savings, $CO_2$ Reduction and $NO_X$ Reduction) | 7 plus $CO_2$ range | 334 to 709 | 746 to 1,588 | 604 to 1,285 |
| | 7 | 432 | 967 | 783 |
| | 3 | 623 | 1,392 | 1,126 |
| | 3 plus $CO_2$ range | 524 to 900 | 1,171 to 2,013 | 947 to 1,628 |
| Costs (Million 2015$/year) | | | | |
| Incremental Purchase Price Increase | 7 | 170 | 281 | 220 |
| | 3 | 214 | 355 | 277 |
| Net Benefits/Costs (Million 2015$/year) | | | | |
| Total (Operating Cost Savings, $CO_2$ Reduction and $NO_X$ Reduction, Minus Incremental Cost Increase to Homes) | 7 plus $CO_2$ range | 164 to 539 | 465 to 1,307 | 384 to 1,065 |
| | 7 | 262 | 686 | 563 |
| | 3 | 409 | 1,037 | 849 |
| | 3 plus $CO_2$ range | 310 to 686 | 816 to 1,658 | 670 to 1,351 |





## Regulatory Impact Analysis: Results

| | 2009 IECC | 2012 IECC | Propose Rule |
|---|---|---|---|
| **Base Case INPV Million 2015$** | 716.7 | 716.7 | 716.7 |
| **Standards Case INPV Million 2015$** | 680.0 to 713.6 | 655.7 to 711.4 | 667.8 to 711.6 |
| **Change in INPV Million 2015$** | (36.8) to (3.1) | (61.0) to (5.3) | (48.9) to (5.2) |
| **Change in INPV %** | (5.1) to (0.4) | (8.5) to (0.7) | (6.8) to (0.7) |
| **Total Conversion Costs Million 2015$** | 1.6 | 1.6 | 1.6 |

# Public Meeting Slides Topics

| | |
|---|---|
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# Request for Closing Remarks

At this time DOE welcomes any closing remarks from interested parties



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

# How to Submit Written Comments

**In all correspondence, please refer to the manufactured housing rulemaking by:**

| Title | MH Energy Conservation Standard |
|---|---|
| Docket Number: | EERE-2009-BT-BC-0021 |
| Regulation Identification Number (RIN): | 1904-AC11 |
| Email: | ManufacturedHousing2009BC0021@ee.doe.gov |
| Comments Due: | August 16, 2016 |

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MHCC MEETING
August 9, 2016

# APPENDIX D:
# ISSUES ON WHICH DOE SEEKS COMMENT

Issues on Which DOE Seeks Comment

Although DOE welcomes comments on any aspect of this proposal, DOE is particularly interested in receiving comments and views of interested parties concerning the following issues:

**1. Relationship With the HUD Code**

Potential inconsistencies or conflicts between the proposed rule and the HUD Code, as discussed in detail in section II.B.1 of this document.

**2. Scope and Effective Date**

The scope and effective date of the proposed rule, as discussed in section III.B.1.a) of the document. DOE requests comment on whether a one-year compliance period would be sufficient for manufacturers to transition their designs, materials, and factory operations and processes in order to comply with the finalized DOE energy conservation standards and for DOE to develop and implement regulations to enforce its standards. DOE also requests comments on what additional lead time should be allowed if it elects to use HUD's existing enforcement system, which would require HUD to adopt the energy standards resulting from this rulemaking. The agency also requests comment on whether there are any particular timing considerations that the agency should consider due to manufacturers choosing to comply with either the prescriptive or thermal envelope compliance paths.

**3. Definitions**

Proposed additions, exclusions, modifications, and potential inconsistencies among the definitions proposed under this rule, the HUD Code, and the 2015 IECC, as discussed in section III.B.1.b) of this document.

**4. Air Barrier**

Potential clarification on the meaning of the term ``air barrier,'' as discussed in section III.B.1.b) of this document.

**5. Tubular Daylighting Devices**

Whether to include tubular daylighting devices in the definition of the term ``fenestration,'' as discussed in section III.B.1.b) of this document.

**6. Climate Zones**

The proposal to establish four climate zones and the specific categorization of states and counties included in each climate zone, as discussed in section III.B.2.a) of this SUPPLEMENTARY INFORMATION and chapter 4 of the TSD. DOE also requests comment on the proposed use of four climate zones relative to adopting the three HUD climate zones and whether there are any potential impacts on manufacturing costs, compliance costs, or other impacts, in particular in Arizona, Texas, Louisiana, Mississippi, Alabama, and Georgia, where the agency has proposed two different energy efficiency standards within the same state.

**7. Home Size**

The proposal to establish separate requirements for single- and multi-section manufactured homes, as discussed in section III.B.2.a) of this document.

**8. Paths for Compliance With the Building Thermal Envelope Standards**

The proposal to establish prescriptive and performance options for achieving compliance with the proposed building thermal envelope requirements, the requirements of each option, and their equivalency in terms of overall thermal performance, as discussed in section III.B.2.b) of this SUPPLEMENTARY INFORMATION and chapter 6 of the TSD.

**9. Insulated Siding**

The proposal to include a requirement similar to section R402.1.3 of the 2015 IECC while excluding the insulated siding specification, as discussed in section III.B.2.b) of this document.

**10. U-Factor Alternatives**

**11. The proposed U-factor alternatives and their equivalency with the prescriptive R-value requirements for ceiling, wall, and floor insulation, as discussed in section III.B.2.b) of the NOPR.**

**12. Calculation of Average SHGC**

The proposal to include an area-weighted average calculation of SHGC for compliance with Sec. 460.102(c), as discussed in section III.B.2.b) of this document.

**13. Insulation Installation Requirements for Floors**

Whether the insulation installation requirements in Sec. 460.103, including installation of insulation in floors, may be readily implemented by the manufactured housing industry, as discussed in section III.B.2.c) of this document.

**14. Design Criteria for Envelope Sealing**

The effectiveness of the prescriptive building thermal envelope sealing requirements, as discussed in section III.B.2.d) of this SUPPLEMENTARY INFORMATION.

**15. Impact of Envelope Sealing on Indoor Air Quality**

The potential impacts associated with the reduction in levels of natural air infiltration (through sealing leaks in the building thermal envelope), if any, relative to the minimum requirements of the HUD Code on reduced indoor air quality, the importance of natural air infiltration for whole-house ventilation strategies in manufactured housing, the relationship between the proposed standards and the mechanical ventilation requirements under the HUD Code, the basis by which the ICC determines a whole-house ventilation strategy is safe, and the minimum total air flow (in ACH units) through a manufactured home that is required to adequately protect public health and safety, as discussed in section V.E of this document.

**16. Duct Sealing**

The proposed duct sealing and duct leakage requirements, as discussed in section III.B.3.a) of this document.

**17. Thermostats and Controls**

The proposed requirements for thermostats and controls, and any potential inconsistencies with the HUD Code, as discussed in III.B.3.b) of this document.

**18. Demand Recirculation Systems**

The initial decision not to propose requirements related to demand recirculation systems in this rule, as discussed in section III.B.3.c) of this document.

**19. Drain Water Heat Recovery Units**

The initial decision not to propose requirements related to drain water heat recovery units, as discussed in section III.B.3.c) of this document.

**20. Equipment Sizing**

The proposed requirements for equipment sizing and the applicability of ACCA Manuals S and J, as discussed in section III.B.3.e) of this document.

**21. Lighting Equipment Standards**

The initial determination not to propose lighting equipment standards specific to manufactured housing, as discussed in section III.C.6 of this document.

**22. Simulated Performance Alternative**

The exclusion of a simulated performance alternative as a pathway to compliance, as discussed in section III.C.7 of this document.

**23. Waivers and Exception Relief**

A process for authorizing manufacturers to obtain waivers or exception relief from the energy conservation requirements, as discussed in section II.B.3 of this document.

**24. Compliance and Enforcement Program Options**

The potential options DOE may consider in a future rulemaking regarding compliance and enforcement, as discussed in section III.E of this document.

**25. Compliance and Enforcement Program Costs and Time Requirements**

The estimated costs (only direct compliance and enforcement costs, not engineering costs for redesign) and time (design compliance review, inspection frequency and duration, administrative procedures) associated with the potential compliance and enforcement options, as discussed in section III.E of this document.

**26. Increased Costs of Components**

The assumptions underlying DOE's analyses associated with the increased costs of manufactured home components, as discussed in section IV.A of this document.

**27. Lifecycle Cost Analysis**

The methodology and initial findings of the lifecycle cost analysis, as discussed in IV.A of this SUPPLEMENTARY INFORMATION and chapter 8 of the TSD.

**28. Affordability**

The affordability of the proposed rule, with respect to the increased purchase cost, reduced operating costs (energy bills), and total lifecycle cost, as discussed in IV.A of this SUPPLEMENTARY INFORMATION and chapter 8 of the TSD.

**29. Manufacturer Impacts Analysis--Markups**

Whether manufacturer and retailer mark-ups for the base-case and standards case other than the primary estimate should be considered. (e.g., a combined mark-up of 2.30 has historically been used in the past to assess combined manufacturer and retailer mark-ups to determine potential first cost impacts on consumers), as discussed in IV.B of this SUPPLEMENTARY INFORMATION and chapter 12 of the TSD.

**30. Shipments Analysis**

The methodology and initial findings of the shipments analysis, as discussed in section IV.B of this SUPPLEMENTARY INFORMATION and chapter 10 of the TSD.

**31. Shipment Growth Rate**

The estimate of the future growth rate of manufactured home shipments, as discussed in section IV.C of this SUPPLEMENTARY INFORMATION and chapter 10 and appendix 11A of the TSD.

**32. Price Elasticity**

The estimate of the price elasticity of demand of manufactured homes, as discussed in section IV.C of this SUPPLEMENTARY INFORMATION and chapter 10 and appendix 11A of the TSD.

**33. National Impacts Analysis**

The methodology and initial findings of the national impacts analysis, as discussed in section IV.C of this SUPPLEMENTARY INFORMATION and chapter 11 of the TSD.

**34. Emissions Analysis**

The methodology and results of the emissions analysis and the proper monetization of emissions, as discussed in section IV.D of this SUPPLEMENTARY INFORMATION and chapter 13 of the TSD.

MHCC MEETING

August 9, 2016

# APPENDIX E:
# LIST OF KEY ISSUES ON THE PROPOSED RULE

Richard Mendlen

# MHCC TELECONFERENCE ON DOE PROPOSED RULE

**TO FACILITATE THE MHCC REVIEW OF THE DOE PROPOSED RULE ON ENERGY EFFICIENCY STANDARDS FOR MANUFACTURED HOUSING, THE FOLLOWING AREAS, ISSUES, AND QUESTIONS HAVE BEEN PREPARED FOR REVIEW AND CONSIDERATION.**

**HAS DOE ADEQUATELY CONSIDERED THE IMPACT OF THE PROPOSED RULE ON THE FUTURE AFFORDABILITY AND ACCESS TO CREDIT FOR LOW INCOME PURCHASERS? *(45)**

**DOE PROJECTED AN AVERAGE RETAIL COST INCREASE OF 5% OR $2,226 FOR SINGLE SECTION HOMES AND $3,109 FOR A MULTI-SECTION HOMES. *(43)**

**SHOULD DOE FURTHER REVISE ITS RETAIL COST IMPACT ANALYSIS BASED ON THE PAST INDUSTRY PROJECTED RETAIL COST MARK-UP FACTOR OF 2.30, RATHER THAN 1.67 FACTOR USED BY DOE IN ITS COST ANALYSIS? *(62)**

**HAS DOE UNDER ESTIMATED THE REDUCTION IN PRODUCTION LEVELS AND FUTURE AVAILABILITY OF MANUFACTURED HOMES DUE TO IMPLEMETATION OF ITS PROPOSED STANDARDS?**

**DOE PROJECTIONS, BASED ON 2014 SHIPMENT DATA, WOULD SUGGEST A LOSS IN PRODUCTION AND AVAILABILITY OF OVER 40,000 HOMES OVER A 30 YEAR PERIOD USING A -0.48 ELASTICITY IN DEMAND FACTOR (AS PRICE GOES UP-DEMAND GOES DOWN). *(46-50)**

**PAST HUD ESTIMATES OF ELASTICITY ON DEMAND OF USED A HIGHER FACTOR OF -2.40 WHICH WOULD SUGGEST A LOSS OF PRODUCTION OF OVER 200,000 HOMES OVER THE SAME 30 YEAR PERIOD. *(46-50)**

**SHOULD DOE DEVELOP ENFORCEMENT REGULATIONS BEFORE ISSUING A FINAL RULE FOR ITS ENERGY STANDARDS? CURRENTLY, COMPLIANCE IS NOT COVERED IN THE PROPOSED RULE OR INCLUDED IN DOE'S COST ESTIMATES AND ANALYSIS. (P99-100, 152 of DOE Proposed Rule)**

**HUD HAS ENCOURAGED DOE TO ADOPT ITS ENFORCEMENT PROCEDURES FOR MANUFACTURED HOMES.**

**HAS DOE ADEQUATELY ADDRESSED THE IMPACT OF THE RULE ON SMALL MANUFACTURERS.**

> **SMALL MANUFACTURERS MAY NOT BE ABLE TO COMPETE IN THE MARKETPLACE DUE TO ECONOMIES OF SCALE AFFORDED TO LARGE MANUFACTURERS THAT ARE ABLE TO PURCHASE MATERIALS IN VOLUME AT DISCOUNTED RATES NOT AVAILABLE TO SMALLER MANUACTURERS?**

> **DOE COULD NOT CERTIFY THAT THE PROPOSED RULE WOULD NOT HAVE A SIGNIFICANT IMPACT ON SMALL MANUFACTURERS. (SEE REGULATORY FLEXIBILITY ANALYSIS IN PREAMBLE OF PROPOSED RULE) (P133 of DOE Proposed Rule)**

**SHOULD DOE USE 3 CLIMATE ZONES DIVIDED ALONG STATE LINES RATHER THAN THE 4 CLIMATE ZONES INDICATED IN ITS PROPOSED RULE FOR BIFURCATED CLIMATE ZONES 1 AND 2, DUE ONLY TO DIFERENT SOLAR GLAZING REQUIREMENTS? *(16, 17, 19)**

> **IF SO, WHICH SOLAR HEAT GAIN COEFICIENT SHOULD BE USED TO COMBINE CLIMATE ZONES 1 AND 2? THE MORE RESTRICTIVE 0.25 SOLAR COEFICIENT OR THE LESS RESTRICTIVE 0.33 FACTOR. *(19)**

**SHOULD DOE CONSIDER MORE PRACTICAL ALTERNATIVES TO REQUIRING THE INSTALLATION OF FLOOR INSULATION IN THE BELLY AREA TO BE IN CONTACT WITH THE FLOOR DECKING? *(23)**

**SHOULD DOE CONSIDER OTHER ALTERNATIVES FOR REQUIRING THE MINIMUM TRUSS HEEL HEIGHT TO BE 5-1/2 INCHES WHEN USING THE PRESCRIPTIVE OPTION FOR DETERMINING R VALUE AND U FACTOR DETERMINATIONS? *(20)**

**SHOULD DOE REMOVE ITS PROPOSED LIMITATION OF 12% MAXIMUM GLAZING OF THE FLOOR AREA FOR THE PRESCRIPTIVE METHODS FOR R VALUE AND U FACTOR DETERMINATIONS? (P166 of the DOE Proposed Rule)**

**HAS DOE ADEQUATELY ADDRESSED THE POTENTIAL HEALTH AFFECTS ON INDOOR AIR QUALITY THAT MAY RESULT FROM SEVERAL PROPOSED MEASURES TO INCREASE THE TIGHTNESS AND THEREBY REDUCE NATURAL AIR INFILTRATION THROUGH THE THERMAL ENVELOPE, WITH NO PROPOSED INCREASE IN MECHANICAL VENTILATION REQUIREMENTS? (P66,67, and DOE's Draft Environmental Assessment)**

**ARE ALL OF THE MEASURES TO ENHANCE THE TIGHTNESS OF THE THERMAL ENVELOPE NEEDED TO ACHIEVE THE PROJECTED REDUCTION OF NATURAL AIR INFILTRATION FROM 8 AIR CHANGES PER HOUR TO 5 AIR CHANGES PER HOUR OR SHOULD OTHER BENCHMARKS BE CONSIDERED? *(25)**

**THESE ENHANCED MEASURES TO TIGHTEN THE THERMAL ENVELOPE INCLUDE THE ADDITION OF A CONTINOUS AIR BARRIER; SEALING OF ALL GAPS AND PENETRATIONS IN CEILING WALLS, AND FLOORS; SEALING OF ROUGH OPENINGS AROUND WINDOWS, DOORS, AND SKYLIGHTS; SEALING OF AIR LEAKAGE FROM DUCTS TO LIMIT AIR LEAKAGE TO 4 CFM/100 SF; AND SEALING OF REGISTERS AND BOOT EXTENSIONS. (24, 25)**

**DOE PROPOSED ENERGY STANDARDS NEEDS TO CONSIDER THE FOLLOWING CONFLICTS OR DIFFERENCES WITH THE HUD STANDARDS.**

**UNDER THE DOE PROPOSAL THERE ARE FOUR CLIMATE ZONES THAT WOULD BE DELINEATED BY HOME SIZE THROUGHOUT AND BY COUNTY BOUNDARIES IN CLIMATE ZONES 1 AND 2. THE HUD STANDARDS HAVE THREE CLIMATE ZONES WITH SOME STATES LOCATED IN DIFFERENT CLIMATE ZONES THAN IN THE DOE PROPOSED RULE. *(16, 17, 19))**

**UNDER THE DOE PROPOSAL, SPECIFIC REQUIREMENTS WOULD BE ESTABLISHED FOR THE INSTALLATION OF INSULATION INCLUDING PROVISIONS FOR UNIFORM DENSITY OR THICKNESS OF CEILING INSULATION AND FLOOR INSULATION TO BE IN CONTACT WITH THE FLOOR DECKING. THERE ARE NO CORRESPONDING REQUIREMENTS IN THE HUD STANDARDS. *(20, 23)**

**UNDER THE DOE PROPOSAL, ENHANCED PROVISIONS WOULD BE ESTABLISHED FOR SEALING ALL SEAMS, JOINTS, AND PENETRATIONS OF THE BUILIDNG THERMAL ENVELOPE AGAINST AIR LEAKAGE, THE HUD STANDARDS CONTAIN EXEMPTIONS TO SEALING CERTAIN PENETRATIONS OF THE THERMAL ENVELOPE. *(24)**

**UNDER THE DOE PROPOSAL, DEFAULT VALUES WOULD BE ESTABLISHED FOR FENESTRATION AND DOOR U FACTORS, SOLAR HEAT GAIN COEFICIENTS AND SKYLIGHTS. THE HUD STANDARDS ALLOW THE USE OF THE ASHRAE HANDBOOK OF FUNDEMENTALS OR DETERMINATION OF GLAZING VALUES USING AAMA OR NFRC TEST METHODS. *(19) and 24 CFR § 3280.508(e)**

**UNDER THE DOE PROPOSAL, THERE ARE NO REQUIREMENTS FOR PROVIDING AND COMPLETING A HEATING AND COOLING CERTFICATE AS CURRENTLY REQUIRED BY THE HUD STANDARDS. (24 CFR § 3280.510 AND § 3280.511)**

**UNDER THE DOE PROPOSAL, ALL HEATING AND COOLING EQUIPMENT MUST BE SIZED IN ACCORDANCE WITH ACCA MANUALS S AND J. THE HUD STANDARDS DO NOT CURRENTLY REFERENCE THESE METHODS FOR DETERMING HEATING AND COOLING EQUIPMENT SIZING. *(29)**

**UNDER THE DOE PROPOSAL, THERMOSTATS CONTROLLING HEATING AND COOLING SYSTEMS MUST BE CAPABLE OF MAINTAINING DIFFERENT SETBACK TEMPERATURES AT DIFFERENT TIMES OF THE DAY. THE HUD STANDARDS DO NOT HAVE ANY CORRESPONDING REQUIREMENTS. *(26)**

**UNDER THE DOE PROPOSED RULE, FRAMING MEMBERS ARE NOT PERMITTED TO BE USED AS RETURN AIR DUCTS AS CURRENTLY ALLOWED IN THE HUD STANDARDS. (P170 of the DOE Proposed Rule)**

**UNDER THE DOE PROPOSAL, ALL HOT WATER PIPING OUTSIDE OF THE CONDITIONED SPACE AND FROM THE SERVICE WATER HEATING SYSTEM TO A DISTRIBUTION MANIFOLD WOULD BE REQUIRED TO BE INSULATED TO A MINIMUM VALUE OF R-3. THE HUD STANDARDS DO NOT HAVE REQUIREMENTS FOR INSULATING HOT WATER PIPING. *(27)**

**WHAT COST IMPACT AND OTHER CONSIDERATIONS ARE ASSOCIATED WITH THE PROPOSAL TO REQUIRE PROGRAMABLE THERMOSTATS WITH SETBACK TEMPERATURE CONTROLS IN THE PROPOSED RULE? *(26)**

**SHOULD DOE REQUIRE HEATING AND COOLING EQUIPMENT SIZING TO BE EXCLUSIVELY DETERMINED IN ACCORDANCE WITH ACCA MANUALS S AND J AS INDICATED IN DOE'S PROPOSED RULE? *(29)**

**ARE CURRENT WHOLE HOUSE MECHANICAL FANS USED IN THE CURRENT PRODUCTION OF HUD CODE HOMES IN COMPLIANCE WITH THE MINIMUM EFFICACY REQUIREMENTS IN THE DOE PROPOSED RULE? *(28)**

***( ) See DOE Summary – Energy Conservation Standards for Manufactured Housing, July 13, 2016**

MHCC MEETING
August 9, 2016

# APPENDIX F:
# DOE ENVIRONMENTAL ASSESSMENT

DOE, June 2016

# DRAFT ENVIRONMENTAL ASSESSMENT

# FOR

# Notice of Proposed Rulemaking, 10 CFR Part 460, "Energy Conservation Standards for Manufactured Housing"

# WITH

# REQUEST FOR INFORMATION ON IMPACTS TO INDOOR AIR QUALITY

**(RIN 1904-AC11)**

**(DOE/EA-2021)**

**Prepared by the**

**U.S. Department of Energy**

**Office of Energy Efficiency and Renewable Energy**

**June 2016**

## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| ANSI | American National Standards Institute |
| ASHRAE | American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. |
| CAIR | Clean Air Interstate Rule |
| CEQ | Council on Environmental Quality |
| CFR | Code of Federal Regulations |
| $CH_4$ | methane |
| $CO_2$ | carbon dioxide |
| CO | carbon monoxide |
| CSAPR | Cross-State Air Pollution Rule |
| D.C. | District of Columbia |
| DOE | Department of Energy |
| EA | environmental assessment |
| EGU | electric generating unit |
| EPA | Environmental Protection Agency |
| EUI | energy use intensity |
| FR | Federal Register |
| GHG | greenhouse gas |
| IPCC | Intergovernmental Panel on Climate Change |
| kBtu | one thousand British thermal units |
| Hg | mercury |
| NAS | National Academy of Sciences |
| NEPA | National Environmental Policy Act of 1969 |
| NESHAP | national emissions standards for hazardous air pollutants |
| $N_2O$ | nitrous oxide |
| $NO_2$ | nitrogen dioxide |
| $NO_X$ | nitrogen oxide |
| NRC | National Research Council |
| $O_3$ | ozone |
| PM | particulate matter |
| $SO_2$ | sulfur dioxide |
| $SO_x$ | sulfur oxide gases |
| UNEP | United Nations Environment Programme |
| U.S.C. | United States Code |
| VOC | volatile organic compounds |

## CONTENTS

## TABLES

# 1 INTRODUCTION

## 1.1 National Environmental Policy Act

The U.S. Department of Energy (DOE) prepared this draft Environmental Assessment (EA) to evaluate the potential direct, indirect, and cumulative environmental impacts of establishing energy conservation standards for manufactured housing (the Proposed Action). In this Draft EA, DOE also evaluates the impacts that could occur if DOE were not to establish energy conservation standards for manufactured housing (the No Action Alternative) and an action alternative wherein DOE would adopt some, but not all, of the proposed energy conservation standards (the No Sealing Alternative). DOE prepared this Draft EA pursuant to the National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. 4321 et seq.), the implementing regulations of the Council on Environmental Quality (CEQ) (40 CFR Parts 1500-1508), and DOE's regulations for implementing NEPA (10 CFR Part 1021).

In conjunction with issuance of this Draft EA for public review and comment, DOE is issuing a request for information that will help it analyze potential impacts on indoor air quality. See section 3.3.1.2 and chapter 4.

## 1.2 Background

Section 413 of the Energy Independence and Security Act of 2007 (EISA) directs DOE to establish energy conservation standards for manufactured housing. Section 413 further directs DOE to base its energy conservation standards on the most recent version of the International Energy Conservation Code (IECC) and any supplements to that document, except where DOE finds that the IECC is not cost effective or where a more stringent standard would be more cost effective, based on the impact of the IECC on the purchase price of manufactured housing and on total lifecycle construction and operating costs. See 42 U.S.C. 17071. In accordance with this statutory directive, DOE is proposing to establish energy conservation standards for manufactured housing.

During the development of the Proposed Rule, DOE consulted with the U.S. Department of Housing and Urban Development (HUD) and sought input from the manufactured housing community and the public. On February 22, 2010, DOE published an advance notice of proposed rulemaking (ANOPR) to initiate the process of developing energy conservation standards for manufactured housing and to solicit information and data from industry and stakeholders. See 75 FR 7556. After considering the input received, DOE ultimately determined that development of proposed manufactured housing energy conservation standards would benefit from a negotiated rulemaking process. DOE initiated a negotiated rulemaking process by establishing the manufactured housing working group (MH working group), which consisted of representatives of interested stakeholders

The MH working group reached consensus on energy conservation standards in manufactured housing and provided its recommendations to DOE to develop the Proposed Rule. After considering the information provided by the MH working group, DOE developed the Proposed Rule that would establish energy conservation standards for manufactured housing.

DOE based the Proposed Rule on the negotiated consensus recommendations of the MH working group. The MH working group made recommendations to DOE based on the 2015 version of the

IECC (the 2015 IECC), the most recent version of the model industry energy conservation code that applies to residential site-built buildings. The MH working group made recommendations to DOE to adopt some of the 2015 IECC provisions directly into its Proposed Rule and to establish other standards, which are modifications of the 2015 IECC. The MH working group developed its recommendations based on the 2015 edition of the IECC, the impact of the 2015 IECC on the purchase price of manufactured housing, total lifecycle construction and operating costs, factory design and construction techniques unique to manufactured housing, and the current construction and safety standards set forth by HUD.

After developing the Proposed Rule, DOE published the Proposed Rule for public comment, along with a Public Meeting Notice. Please see the Proposed Rule for further information on the rulemaking process. [http://energy.gov/eere/buildings/appliance-and-equipment-standards-program](http://energy.gov/eere/buildings/appliance-and-equipment-standards-program).

### 1.3 Purpose and Need

EISA directs DOE to establish energy conservation standards for manufactured homes. The establishment of energy conservation standards for manufactured homes can help to reduce national energy consumption, reduce outdoor pollutants, reduce the emissions of greenhouse gases that may lead to climate change, and reduce energy costs for manufactured housing homeowners.

Based on 2005 statistics, manufactured homes constitute about 6% of U.S. households and about 5% of U.S. residential energy consumption (DOE 2005). These same data show that on average manufactured homes consume more energy per unit floor area on an annual basis, 850 JM/m2 (75,0000 Btu/ft2), than detached homes, which consume 450 MJ/m2 (39,800 Btu/ft2). Given the smaller size of manufactured homes, the average energy consumption per household is about 74 GJ/y (70 MBtu/y) compared with 114 GJ/y (108 MBtu/y) for detached homes. Low energy manufactured homes have been constructed, with annual energy consumption as low as 52 MJ/y (49 MBtu/y) (Lubiner, Hadley et al. 2004). Therefore, while manufactured homes constitute a small fraction of the national housing stock, they also provide an opportunity for significant energy savings through improved design, construction and operation.

Establishing energy conservation standards for manufactured homes would also help reduce energy expenses for manufactured home owners. Manufactured home owners, on average, have a median annual income of $35,000, which is roughly $17,000 below the national average. Among households with very-low incomes (that is, less than 50 percent of area median), 23 percent of home-ownership growth between 1993 and 1999 came through manufactured housing. Nationwide, manufactured homes are a major source of unsubsidized, low-cost housing for many owners and renters with few housing alternatives (Apgar et al., 2002). Of the 540,000 affordably priced new units added to the housing stock from 1997 to 1999, two-thirds were manufactured units (Collins, Crowe and Carliner, 2000).

The Proposed Action would establish energy conservation standards for manufactured housing. These standards would meet the requirements mandated by EISA for DOE to establish standards, as well as meet the national goals of saving energy, reducing outdoor pollutants and greenhouse gases, and reducing energy costs for manufactured home owners.

### 1.4 Public Participation and Agency Consultation

DOE encourages public participation in the NEPA process. This Draft EA is being released for public review and comment on June 30, 2016. The public is invited to provide written comments by the close of the comment period on August 15, 2016. DOE is providing written notification of this Draft EA to the EERE Building Technology Office Group Stakeholder lists, though DOE welcomes input from any interested party. In preparing a final EA, DOE will consider all written comments received by the stated comment period deadline. The Draft EA is also available on the DOE website:

www.energy.gov/node/1840021

In additional to soliciting comments on the Draft EA, DOE is seeking information on the specific items set forth in Chapter 4.

**Send comments to:**

Roak Parker
US Department of Energy
15013 Denver West Parkway
Golden, CO 80401

Or

RulemakingEAs@ee.doe.gov

# 2 ALTERNATIVES INCLUDING THE PROPOSED ACTION

This section describes the Proposed Action and alternatives.

## 2.1 Proposed Action

DOE's Proposed Action is to establish, for the first time, energy conservation standards for all new manufactured homes by adopting the energy efficiency recommendations of the MH working group, which are based on the 2015 IECC. The Proposed Action would include the specific recommendations found in Subpart B and C of the Proposed Rule. Currently the HUD building code (found at 245 CFR 280) sets forth certain building requirements that may be supplanted by the Proposed Action. Thus, the baseline for this analysis is the HUD code found at 24 CFR 280.

Subpart B of the Proposed Rule would require manufacturers to produce manufactured homes that, at a minimum, meet energy efficiency requirements related to climate zones and the building thermal envelope[1].

Section 460.101 would establish four climate zones within the U.S.

Section 460.102 would establish requirements related to the building thermal envelope. Under this section manufacturers would have two options for compliance; the prescriptive option or the performance option. The prescriptive approach would establish specific component R-value, U-factor, and solar heat gain coefficient (SHGC) requirements, providing a straightforward option for construction planning. The performance approach would allow a manufacturer to use a variety of materials with various thermal properties so long as the building thermal envelope achieved a required level of overall thermal performance. The proposed performance-based requirements would be functionally equivalent to the prescriptive-based requirements in that both options would result in manufactured homes with approximately the same amount of energy use. Table 1 identifies the proposed thermal envelope prescriptive requirements.

**Table 1: Proposed Building Thermal Envelope Prescriptive Requirements**

| Climate Zone | Ceiling R-value | Wall R-value | Floor R-value | Window U-factor | Skylight U-factor | Door U-factor | Glazed Fenestration SHGC |
|---|---|---|---|---|---|---|---|
| 1 | 30 | 13 | 13 | 0.35 | 0.75 | 0.40 | 0.25 |
| 2 | 30 | 13 | 13 | 0.35 | 0.75 | 0.40 | 0.33 |
| 3 | 30 | 21 | 19 | 0.35 | 0.55 | 0.40 | 0.33 |
| 4 | 38 | 21 | 30 | 0.32 | 0.55 | 0.40 | No Rating |

Section 460.103 would establish requirements regarding the installation of insulation. Manufacturers would be required to install insulation in accordance with insulation manufacturer's installation instructions. In addition, Section 460.103 would include specific

[1] Subpart B includes Sections 460.101-460.104 of the Proposed Rule.

requirements for insulation installation in the following locations: near access hatches, panels, doors between conditioned space and unconditioned space, adjacent top baffles, ceilings, attics, floors, wall cavities, narrow cavities, rim joists, and exterior walls adjacent to showers and tubs.

Section 460.104 would establish both general and specific requirements for sealing a manufactured home to prevent air leakage.  The general requirements in section 460.104 require that manufacturers properly seal all joints, seams, and penetrations in the building thermal envelope to establish a continuous air barrier, and use appropriate sealing materials to allow for differential expansion and contraction of dissimilar materials.  Section 460.104 would establish specific sealing requirements for: ceilings or attics, duct system register boots, recessed lighting, windows, skylights, exterior doors walls, floors, electrical boxes or phone boxes on exterior walls, mating line surfaces[2], rim joists, and showers or tubs adjacent to exterior walls.

In addition, the Proposed Action, in Subpart C of the Proposed Rule, would establish requirements related to duct leakage, heating, ventilation and air conditioning (HVAC), service hot water systems, mechanical ventilation fan efficacy, and heating and cooling equipment size[3].

Section 460.201 would require manufacturers to equip each manufactured home with a duct system designed to limit total air leakage to less than or equal to four cubic feet per minute per 100 square feet of conditioned floor area.

Section 460.202 would mandate specific requirements for number and types of thermostats.

Section 460.203 would require manufacturers to install service water heating systems according to the service water heating system manufacturer's installation instructions.  In addition, this section would require that automatic controls, temperature sensors, and pumps related to service water heating must be accessible and that manual controls be readily accessible; that homeowners have adequate control over service water heating equipment; and, that all pipes outside conditioned space, and all hot water pipes from a water heater to a distribution manifold be insulated to at least R-3.

Section 460.204 includes requirements for mechanical ventilation system fan efficacy.

Section 460.205 sets forth specifications on the appropriate sizing of heating and cooling equipment within a manufactured home.

Table 2 present a crosswalk between the Proposed Action and the existing baseline.

---

[2] A mating line surface is the area of connection between two sections of a multi-section manufactured home.  This requirement is designed to ensure that multi-section manufactured homes have a continuous air barrier.

[3] Subpart C includes Sections 460.201-205 of the Proposed Rule.

## Table 2: Crosswalk of Proposed Action and Existing Baseline

| Proposed Action (Reference to DOE Proposed Rule 10 CFR Part 460) | No Action Alternative (Existing Baseline) (Reference to Existing HUD Requirements Applicable to Manufactured Housing--24 CFR Part 3280) |
|---|---|
| § 460.101 would establish four climate zones, which would be delineated by home size and both state and county boundaries. | § 3280.506 establishes three climate zones delineated by state boundaries, and one standard for homes of all sizes within a climate zone. |
| § 460.102(a) would establish building thermal envelope prescriptive and performance compliance options. | § 3280.506 establishes a performance approach. |
| § 460.102(b) would set forth the prescriptive option for compliance with the building thermal envelope requirements. | § 3280.506 establishes a performance approach only. |
| § 460.103(b)(2) would establish a minimum truss heel height. | No corresponding requirement |
| § 460.103(b)(3) would require ceiling insulation to have uniform thickness and density. | No corresponding requirement. |
| § 460.103(b)(4) would establish an acceptable batt and blanket insulation combination for compliance with the floor insulation requirement in climate zone 4. | No corresponding requirement. |
| § 460.103(b)(5) would identify certain skylights not subject to SHGC requirements. | No corresponding requirements. |
| § 460.102(b)(6) would establish U-factor alternatives for the R-value requirements under § 460.102(b)(1). | No corresponding requirements. |
| § 460.102(b)(7) would establish a maximum ratio of 12 percent for glazed fenestration area to floor area under the prescriptive option. | No corresponding requirements. |
| § 460.102(c)(1) would establish maximum building thermal envelope $U_o$ requirements by home size and climate zone. | § 3280.506(a) establishes maximum building thermal envelope $U_o$ requirements by climate zone. |
| § 460.102(c)(2) would establish maximum area-weighted vertical fenestration U-factor requirements in climate zones 3 and 4 | No corresponding requirements. |
| § 460.102(c)(3) would establish maximum area-weighted average skylight U-factor requirements in climate zones 3 and 4. | No corresponding requirements. |
| § 460.102(c)(4) would authorize windows, skylights and doors containing more than 50 percent glazing by area to satisfy the SHGC requirements of § 460.102(a) on the basis of an area-weighted average. | No corresponding requirements. |
| § 460.102(d)(3) would establish a method of determining total R-value where multiple layers comprise a component. | § 3280.508(a) and (b) reference the Overall U-values and Heating/Cooling Loads—Manufactured Homes method and the 1997 ASHRAE Handbook of Fundamentals. |
| § 460.102(d)(6) would establish prescriptive default U-factor values. | § 3280.508(a) and (b) reference the Overall U-values and Heating/Cooling Loads—Manufactured Homes method and the 1997 ASHRAE Handbook of Fundamentals. |
| § 460.102(d)(8) would establish prescriptive default U-factor values | No corresponding requirements. |
| § 460.102(e)(1) would establish a method of determining $U_o$. | § 3280.508(a) and (b) reference the Overall U-values and Heating/Cooling Loads—Manufactured Homes |

| | |
|---|---|
| | method and the 1997 ASHRAE Handbook of Fundamentals. |
| § 460.102(e)(3) would establish default fenestration and door U-factor and fenestration SHGC values. | § 3280.508(a) and (b) reference the Overall U-values and Heating/Cooling Loads—Manufactured Homes method and the 1997 ASHRAE Handbook of Fundamentals. These references contain default values. |
| § 460.103(a) would require insulating materials to be installed according to the manufacturer installation instructions and the prescriptive requirements of Table 460.103. | No corresponding requirements. |
| § 460.103(b) would establish requirements for the installation of batt, blanket, loose fill, and sprayed insulation materials. | No corresponding requirements. |
| § 460.104 would require manufactured homes to be sealed against air leakage at all joints, seams, and penetrations associated with the building thermal envelope in accordance with the manufacturer's installation instructions and the requirements set forth in Table 460.104. | § 3280.505 establishes air sealing requirements of building thermal envelope penetrations and joints. |
| § 460.201(a) would require each manufactured home to be equipped with a duct system that must be sealed to limit total air leakage to less than or equal to 4 cfm per 100 square feet of floor area when tested according to § 460.201(b) and specifies that building framing cavities are not to be used as ducts or plenums. | § 3280.715(a)(4) establishes requirements for airtightness of supply duct systems. |
| § 460.202(a) would require at least one thermostat to be provided for each separate heating and cooling system installed by the manufacturer. | § 3280.707(e) requires that each space heating, cooling, or combination heating and cooling system be provided with at least one adjustable automatic control for regulation of living space temperature. |
| § 460.202(b) would require that installed thermostats controlling the primary heating or cooling system be capable of maintaining different set temperatures at different times of day. | No corresponding requirements. |
| § 460.202(c) would require heat pumps with supplementary electric resistance heat to be provided with controls that, except during defrost, prevent supplemental heat operation when the pump compressor can meet the heating load. | § 3280.714(a)(1)(ii) requires heat pumps to be certified to comply with ARI Standard 210/240-89, Heat pumps with supplemental electrical resistance heat to be sized to provide by compression at least 60 percent of the calculated annual heating requirements of the manufactured home, and that a control be provided and set to prevent operation of supplemental electrical resistance heat at outdoor temperatures above 40ºF. |
| § 460.203(a) would establish requirements for the installation of service water heating systems. | No corresponding requirements. |
| § 460.203(b) would require any automatic and manual controls, temperature sensors, pumps associated with service water heating systems to be accessible. | No corresponding requirement. |
| § 460.203(c) would establish requirements for heated water circulation systems. | No corresponding requirements. |

| | |
|---|---|
| § 460.203(d) would establish requirement for the insulation of hot water pipes. | No corresponding requirements. |
| § 460.204 would establish requirements for mechanical ventilation system fan efficacy. | No corresponding requirements. |
| § 460.205 would establish requirements for heating and cooling equipment sizing. | No corresponding requirements. |

### 2.2 No Action Alternative

Under the No Action Alternative, DOE would not adopt a rule establishing energy conservation standards for manufactured housing. The standards for manufactured housing would remain at current, or baseline, levels established in the HUD Code. See Table 2 above. The environmental effects identified in the EA may still occur if more manufacturers voluntarily seek to build manufactured homes that are more energy efficient than required under current standards, but those impacts would not be the result of a DOE action. However, for purposes of providing a comparative analysis of the current baseline and the anticipated environmental consequences of the action alternatives, the EA presumes there would be no changes to environmental impacts on indoor air quality, energy usage, or emissions if DOE adopted the No Action Alternative.

### 2.3 No Sealing Alternative

Under the No Sealing Alternative, all aspects of the Proposed Action are preserved, except for the prescriptive requirements for sealing of the building, found in Section 460.104. Under the No Sealing Alternative DOE would not adopt any requirements relating to sealing a manufactured home to prevent air leakage.

# 3 AFFECTED ENVIRONMENT AND IMPACTS

This section describes the existing environmental setting for environmental resources with potential to be affected by the Proposed Action and the No Sealing Alternative, as well as provides the potential environmental impacts to resource areas that may result from implementing the Proposed Action, the No Sealing Alternative, and the No Action Alternative. Resource areas evaluated and not carried forward for detailed analysis are also identified. The Proposed Action and the No Sealing Alternative would apply to all 50 states and U.S. territories.

## 3.1 Environmental Consequence of the No Action Alternative

Under the No Action Alternative, DOE would not establish energy conservation standards for manufactured homes. Therefore, there would be no direct, indirect, or cumulative impacts to the environment and resources discussed in this Draft EA from activities related to the Proposed Action. The expected reductions in fossil fuel generated energy pollutant emissions realized by the action alternatives would not be realized under the No Action Alternative.

## 3.2 Environmental Resources Evaluated and Dismissed from Detailed Analysis

Consistent with NEPA implementing regulations and guidance, DOE focused the analysis in this Draft EA on topics with the greatest potential for environmental impacts (40 CFR 1502.2(b)). Table 3 presents DOE's evaluations of the environmental resource areas on which the Proposed Action and No Sealing Alternative would not be expected to have any measurable effects. These resource areas were not carried forward for detailed analysis.

**Table 3: Resource Areas Not Carried Forward for Detailed Analysis**

| Resource Area | Considerations |
|---|---|
| Sensitive Ecosystems | • Action alternatives are not site specific |
| Geology and Soils | • Action alternatives are not site specific |
| Wetlands and Floodplains | • Action alternatives are not site specific |
| Prime Agricultural Lands | • Action alternatives are not site specific |
| Historic, Cultural or Archeological Resources | • Action alternatives are not site specific |
| Species, including Threatened and Endangered Species | • Action alternatives are not site specific<br>• Action alternatives reduce pollutant emissions |
| Solid Waste Management | • Action alternatives do not impact waste generation |
| Hazardous Materials and Hazardous Waste[4] | • No hazardous materials used or produced as result of action alternatives |
| Intentionally Destructive Acts | • Action alternatives are not site specific |

[4] Manufactured Homes may contain certain materials which would be considered pollutants or contaminants, as discussed in section 3.3.1.1. However, no additional hazardous materials would be generated as a result of this Proposed Action or the Action Alternative, and thus the generation of hazardous materials or wastes is not carried forward for additional analysis.

### 3.3 Environmental Resources Carried Forward for Analysis

This section of the draft EA describes the affected environment and analyzes the environmental impacts of the Proposed Action and No Sealing Alternative on the following resource areas.

- Indoor Air
- Outdoor Air
- Socioeconomic and Environmental Justice
- Climate Change

#### 3.3.1 Indoor Air

Indoor air quality, and specifically building habitability, is a resource area with possible impacts from the Proposed Action and No Sealing Alternative. In developing its recommendations, the MH working group identified concerns regarding the potential impacts of some of the recommendations on the indoor air quality in manufactured homes. However, the MH working group determined it could not consider potential impacts to indoor air quality when making their recommendations because the means for addressing the issue (change in mechanical ventilation standards) was outside of their scope. (See, October 1, 2014 and October 31, 2014 transcripts of MH working group).

##### 3.3.1.1 Affected Environment

According to the 2007 American Housing Survey (AHS), 8.7 million manufactured homes account for 6.3% of the 128.3 million housing units in the United States and house 17.2 million people (U.S. Census Bureau 2007, 2008). The main sources of indoor air pollutants in manufactured homes, and in site-built homes as well, are furnishings within a building (e.g., carpet, furniture), building materials (e.g., insulation material, pressed wood materials, paints, adhesives), the ground (e.g., radon), the building occupants' indoor activities (e.g., tobacco smoking, painting), fossil fuel appliances (e.g. gas stoves, gas water heaters), and wood stoves and fireplaces. The primary indoor air pollutants that can adversely affect human health in typical manufactured homes are particulate matter (PM), carbon monoxide (CO), carbon dioxide ($CO_2$), nitrogen dioxide ($NO_2$), radon, formaldehyde, volatile organic compounds (VOCs), and biological contaminants. Fossil-fuel-burning appliances (including gas stoves/ovens) and, if allowed, tobacco smoke, are the main sources of combustion products. Potential combustion emissions include CO, $CO_2$, $NO_X$, and $SO_2$. While pollutant levels from individual sources may not pose a significant health risk by themselves, most manufactured homes have more than one source that contributes to indoor air pollution (EPA, 2015g). There can be a serious risk from the cumulative effects of these sources (EPA, 2015g). In addition to internal sources of pollutants, pollutants entrained in outdoor air, particularly vehicle exhaust, can enter into the manufactured home through leaks in the building envelope or outdoor air inlets.

Poor indoor air quality is connected with a range of undesirable health effects, such as respiratory diseases, neurodevelopmental problems for children, increased cancer risks, and asthma symptoms (CDC, Safety and Health in Manufactured Structures, 2011). Groups that are more likely to be adversely affected by air pollution, such as infants, the elderly, and the infirm are indoors a greater proportion of the time than the general public (Sexton, 1993). Even low concentrations of air pollutants can be injurious to long-term health because exposure to indoor pollutants is more frequent and more prolonged than is ambient air exposure (Smith, 1993). “The confined spaces of manufactured structures, and in some cases lower ventilation and air exchange rates, can make indoor air quality a concern in manufactured homes,” (CDC, Safety and Health in Manufactured Structures, 2011, at page 5).

Table 4 summarizes the principal indoor air pollutants that can potentially be of concern within manufactured homes.

**Table 4: Indoor-Air Pollutants in Manufactured Homes**

| Pollutant | Potential Health Impacts | Sources |
|---|---|---|
| Particulate Matter | Bronchitis and respiratory infections. Eye, nose, and throat irritations.[ǀ] | Combustion, dust.[ǀ] |
| Carbon Monoxide | CO is an odorless and colorless gas that is an asphyxiate and disrupts oxygen transport. At high concentration levels, CO causes loss of consciousness and death.[°] | Unvented kerosene and gas space heaters; leaking chimneys and furnaces; back drafting from furnaces, gas water heaters, wood stoves, and fireplaces; gas stoves; and automobile exhaust. |
| Carbon Dioxide | An excessive concentration of $CO_2$ triggers increased breathing to maintain the proper exchange of oxygen and $CO_2$. Exposure to concentrations of $CO_2$ in air of 5% for 30 minutes can cause symptoms of intoxication, and exposure to concentrations of 7% to 10% for few minutes can cause loss of consciousness.[*] | Human respiration, tobacco smoking, gas stoves, and gas ovens. |
| Nitrogen Dioxide | Short term exposure to $NO_2$ is linked with negative respiratory effects including inflammation of airways and increased symptoms of those with asthma.[**] | Kerosene heaters, gas stoves, ovens, and tobacco smoke. |
| Radon | Radon in breathed air can deposit and stay in the lungs, contributing to lung cancer. Radon is the leading cause of lung cancer in non-smokers.[†] | Radon is a radioactive gas that occurs in nature and comes from the decay of uranium that is found in soil.[††] |
| Formaldehyde | The EPA has classified formaldehyde as a probable human carcinogen. In low concentration levels, formaldehyde irritates the eyes and mucous membranes of the nose and throat. Formaldehyde can cause watery eyes; burning sensations in the eyes, nose, and throat; nausea; coughing; chest tightness; wheezing; skin rashes; and allergic reactions.[□] | Various pressed-wood products can emit formaldehyde, including particle board, plywood, pressed wood, paneling, some carpeting and backing, some furniture and dyed materials, urea-formaldehyde insulating foam, and pressed textiles.[□□] |
| Volatile organic compounds (VOCs) | VOCs can cause a wide variety of health problems. Some examples of potential health effects include increased cancer risks, depression of the central nervous system, irritation to the | VOCs are emitted from a variety of products including paints and lacquers, paint strippers, cleaning supplies, pesticides, building materials and furnishings, office equipment such as copiers and printers, correction fluids |

| Pollutant | Potential Health Impacts | Sources |
|---|---|---|
| | eyes and respiratory tract, and liver and kidney damage.[‡] | and carbonless copy paper, graphics and craft materials including glues and adhesives, permanent markers, and photographic solutions.[‡] |
| Biological Contaminants | Many biological pollutants are small enough to be inhaled and can cause allergic reactions as well as infectious illnesses. Molds and mildews in particular release disease-causing toxins. Symptoms of health problems include sneezing, watery eyes, coughing, shortness of breath, dizziness, lethargy, fever, and digestive problems.[‡‡] | Common biological pollutants include mold; dust mites; pet dander; droppings and body parts from cockroaches, rodents and other pests; viruses; and bacteria. These contaminants are typically found in damp or wet areas such as humidifiers, condensate pans, or unvented bathrooms as well as in areas where dust accumulates.[‡‡] |

| U.S. Environmental Protection Agency. Particulate Matter | Air & Radiation | US EPA. at <https://www3.epa.gov/pm/>
° U.S. Environmental Protection Agency. Carbon Monoxide | Air & Radiation | US EPA. at <https://www3.epa.gov/airquality/carbonmonoxide/>
* CDC - Immediately Dangerous to Life or Health Concentrations (IDLH): Carbon dioxide. at <http://www.cdc.gov/niosh/idlh/124389.html>
** U.S. Environmental Protection Agency. Health | Nitrogen Dioxide | US EPA. at <http://www.epa.gov/air/nitrogenoxides/health.html>
† U.S. Environmental Protection Agency. Radon Health Risks. at <http://www.epa.gov/radon/healthrisks.html>
†† U.S. Environmental Protection Agency. EPA's Radon Program Home Page. at <http://www.epa.gov/radon/?_ga=1.96254044.1118407248.1426515419>
▫ U.S. Environmental Protection Agency. Formaldehyde. at <http://www2.epa.gov/formaldehyde>
▫▫ U.S. Consumer Product Safety Commission. *An Update on Formaldehyde*. (Washington, DC, 2015).
‡ U.S. Environmental Protection Agency. An Introduction to Indoor Air Quality: Volatile Organic Compounds (VOCs). at <http://www.epa.gov/iaq/voc.html>
‡‡ U.S. Environmental Protection Agency. An Introduction to Indoor Air Quality: Biological Pollutants. at <http://www.epa.gov/iaq/biologic.html>

While no comprehensive data are available on the quality of air in manufactured homes, several studies have addressed indoor air quality in manufactured homes to a limited extent. Studies have addressed specific contaminants, overall indoor air quality and pollutant concentrations, and building tightness[5]. It is generally accepted that air leakage[6] alone is not enough to ensure

[5] For example, multiple studies have examined formaldehyde concentrations, generally from building materials, in manufactured and site-built homes (Liu et al., 1991; CDC et al., 2008; Offerman 2009)

[6] Air leakage, or natural infiltration, refers to passive ventilation of air into and out of the building. "Passive ventilation takes place naturally through windows, doors, and other air leakage sites," (GAO, 2012).

adequate indoor air quality and that appropriate mechanical ventilation[7] is necessary to remove pollutants and ensure adequate indoor air quality in all homes, including manufactured homes[8] (ASHRAE 2014, DOE 2015). It is also accepted that manufactured homes with relatively less air circulation may develop higher levels of indoor contaminants (CDC, 2011). Many studies and reports have addressed the importance of appropriate mechanical ventilation in all homes, including manufactured homes, confirming the importance of "build tight, ventilate right"[9].

#### 3.3.1.2 Impacts of Proposed Action

In analyzing the impacts of the Proposed Action, DOE examined how the Proposed Action would impact indoor air quality as compared to the baseline indoor air quality conditions in manufactured homes. The analysis below considers both the role of air leakage and mechanical ventilation. It is generally accepted that indoor air quality and building energy performance are substantially linked because indoor air quality often improves with increased mechanical ventilation (ASHRAE, 2014). Generally speaking, the tighter the thermal envelope of a home, the less air leakage that occurs, so mechanical ventilation is the technique used to make air exchange occur. However, while indoor air quality and building energy performance are linked, it is difficult to analyze the anticipated impacts of the Proposed Action due to lack of specific data regarding how the Proposed Action would impact indoor air quality. In addition, since no Federal agency or program regulates contaminants as they apply to air quality in residential buildings, the lack of agreed upon standards for levels of exposure in residential buildings, both in concentration levels of pollutants and time of exposure of occupants, makes it difficult to draw conclusions about the extent of the impacts.

While the Proposed Action would seal manufactured homes more tightly than the No Action Alternative, it is not anticipated that the Proposed Action would change the sources of pollutants within a manufactured home, including sources or types of building materials. The Proposed Action establishes thermal envelope requirements under section 460.102, but does not mandate how manufacturers would achieve those requirements. Thus, while the type of building materials used to construct manufactured homes may not change under the Proposed Action, the quantity of some materials may change as manufacturers increase materials in order to achieve the thermal envelope requirements of 460.102. For example, more insulation material may be used to meet the building thermal envelope requirements under the Proposed Action than would be used under the No Action Alternative. Therefore, a manufactured home compliant with the Proposed Action may contain an increased amount of construction materials. If those materials outgas[10] or otherwise contribute pollutants to the indoor air, an increase in materials could lead to

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[7] Mechanical ventilation refers to active ventilation of air into and out of the building. "Mechanical ventilation uses fans and ducts to bring fresh air into the home or draw contaminated air to the outdoors," (GAO, 2012).

[8] Mechanical ventilation rates for manufactured homes are regulated by HUD at 24 CFR 3280.

[9] See, for example, Burch, 1993; Hales, 2007; Offerman, 2009; GAO 2012; ASHRAE, 2014; DOE, 2015.

[10] Some construction materials may outgas contaminants. Such materials could include, for example, certain paints, wood products, and certain spray foam insulation. See, for example, https://www.epa.gov/saferchoice/spray-polyurethane-foam-spf-insulation-and-how-use-it-more-safely.

an increase in indoor air pollutants. Any increase will depend on the materials chosen for construction, as well as their method of installation.

In addition, because the Proposed Action would seal manufactured homes more tightly than the No Action Alternative, outdoor pollutants, such as car exhaust, may be less likely to enter the manufactured home.

The Proposed Action would mandate prescriptive sealing requirements under Section 460.104, the effect of which would be to create a tighter building envelope and reduce air leakage relative to the existing baseline condition. MH working group members estimated that the measures in the Proposed Action would achieve a maximum building thermal envelope air leakage rate of five air changes per hour (ACH) when measured using a blower door test at a pressure differential of 50 pascals (ACH50). Based on discussions with the MH working group, DOE has assumed in this analysis that a typical manufactured home compliant with existing requirements has an air leakage rate of eight ACH50[11]. Therefore, the Proposed Action would seal manufactured homes more tightly by decreasing the amount of air exchange via air leakage relative to the No Action Alternative.

The Proposed Action is expected to reduce air leakage. However, any resulting impacts to indoor air quality are difficult to quantify, as air leakage is heavily dependent on weather, location, climate, elevation, time of day, etc. The National Institute of Standards and Technology (NIST) conducted modeling research to evaluate ventilation requirements for future revisions to HUD's Manufactured Housing Construction and Safety Standards (Persily, 2000). The modeling found that the air leakage rates vary by as much as five times, based on variations in weather conditions.

Air leakage alone, without any mechanical ventilation, could not provide adequate ventilation in tightly sealed homes (Persily, 1998). Thus, the amount of mechanical ventilation in a home will influence indoor air quality. Mechanical ventilation involves a system of fans and/or ducts to intake and distribute fresh air and expel stale air and pollutants, and is a required system on all manufactured homes. Some mechanical ventilation systems may be integrated into the heating and cooling system, while others may consist of a central ceiling exhaust fan. Mechanical ventilation is more stable than air leakage rates because mechanical ventilation is not significantly influenced by weather; however, some systems are dependent upon the homeowner to turn on the ventilation system[12]. If the homeowner does not turn on the system, or runs the system only intermittently, mechanical ventilation may not adequately ventilate a home.

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[11] Existing requirements for sealing can be found in the HUD regulations at 24 CFR 3280.505(a).

[12] A study of 105 manufactured homes built and sited in the Pacific Northwest in 2000 and 2001, found that 30% of occupants do not turn on their whole house fans (often a major component in mechanical ventilation systems), which may have health implications (Davis, et al., 2001).

The 2015 IECC requires, for site-built homes, the use of the International Residential Code (IRC) or International Mechanical Code (IMC) or other approved means of ventilation[13]. While the Proposed Action mandates air sealing requirements based on the 2015 IECC which may reduce air leakage, the Proposed Action does not address mechanical ventilation[14]; existing mechanical ventilation requirements would remain in place[15]. Because the Proposed Action mandates sealing a manufactured home tighter than existing conditions, without any change to existing mechanical ventilation requirements, the Proposed Action may decrease the total amount of ventilation in a manufactured home. A potential decrease in total ventilation may be of concern, as ventilation may remove some air pollutants from the indoor environment of a manufactured home. To the extent that there are sources of pollutants within a given manufactured home, the proposed air leakage requirements may also lead to increased time-averaged pollutant concentrations and exposure levels for occupants.

Differences exist among existing manufactured housing mechanical ventilation requirements, which will remain in place under the Proposed Action, and those referenced in the 2015 IECC upon which the Proposed Action is based. Those differences may be important in determining the extent the Proposed Action would impact indoor air quality[16].

These factors and potentially others currently limit DOE's ability to analyze the potential impacts of the Proposed Action on indoor air quality, including potential epidemiological (population-level) impacts to occupant health, in this Draft EA. DOE has previously sought the missing information or information from which it could extrapolate relevant data. On June 25, 2013 DOE issued a request for information (RFI) regarding "data, studies, and other such materials that address the relationship between potential reductions in levels of natural air infiltration and both indoor air quality and occupant health for a manufactured home.[17]" 78 FR 37995. DOE has conducted a literature review and determined specific data regarding the missing information is not available.

In conjunction with issuance of this Draft EA for public review and comment, DOE is issuing a second RFI that seeks information to help it analyze potential impacts on indoor air quality. See

[13] The 2015 IECC was developed by the International Code Council (ICC), an independent organization whose mission is to provide the highest quality codes, standards, products and services for all concerned with the safety and performance of the built environment. The ICC develops codes through a government consensus process and by convening a committee composed of building science professionals, state officials, licensed engineers and architects, health safety representatives, and members of the general public with a diverse range of expertise and varying degrees of professional credentials.

[14] Section 460.04 addresses system (fan) efficacy but does not address actual mechanical ventilation requirements.

[15] Existing requirements for mechanical ventilation can be found in the HUD Code at 24 CFR 3280.103(b).

[16] For example, differences include accounting for occupancy rates, home size, number of bedrooms, and accounting for intermittent use versus continuous use of a system. See, Davis, et al., 2001; DOE, 2011a; CDC, 2011 Lawrence Berkeley National Laboratory, 2015.

[17] DOE received five responses to the RFI, though none sited specific data or studies.

chapter 4. DOE will consider responses to this RFI along with comments on this Draft EA in determining how to proceed with its analysis of potential environmental impacts. As part of its analysis, DOE will consider the applicability of a provision in the CEQ regulations regarding incomplete or unavailable information (40 CFR 1502.22). Though this provision refers to preparation of an environmental impact statement, the approach also is relevant to the preparation of EAs. Under the CEQ regulations, an agency shall clearly state if there is incomplete or unavailable information, and the agency shall include such information if it is essential to a reasoned choice among alternatives and if the overall costs of obtaining it are not exorbitant. If it is not possible to obtain the information because the overall costs of obtaining it are exorbitant or the means to obtain the information are not known, the agency must, for example, describe the relevance of the information, summarize existing relevant credible scientific evidence and evaluate reasonably foreseeable significant adverse impacts based upon theoretical approaches or research methods generally accepted in the scientific community. 40 CFR 1502.22(b).

#### 3.3.1.3 Impacts of No Sealing Alternative

The No Sealing Alternative would not mandate the sealing requirements of Section 460.104 of the Proposed Rule. Because this alternative does not require building the manufactured home tighter than the No Action Alternative, DOE has determined that impacts to indoor air quality caused by sealing the building may be minimally different from the baseline condition.

While the No Sealing Alternative would not include the prescriptive sealing requirements of the Proposed Action, the No Sealing Alternative would include all other requirements of the Proposed Action. Therefore, a manufactured home compliant with the No Sealing Alternative may contain an increased amount of construction materials, such as insulation, as discussed in connection with the Proposed Action. Consequently, the amount of potential pollutants within a manufactured home may increase, potentially impacting indoor air quality. (See discussion of section 460.102 of the Proposed Action in 3.3.1.2 above). Any such change in indoor air quality would depend on the materials chosen for construction, as well as their method of installation.

### 3.3.2 Outdoor Air

Outdoor air quality is a resource area with possible impacts from the Proposed Action and the No Sealing Alternative. Specifically, impacts would include changes in pollutant emissions due to changes in fossil fuel generated energy use associated with operation of the manufactured home.

#### 3.3.2.1 Affected Environment

An air pollutant is any substance in the air that can cause discomfort or harm to humans or the environment. Pollutants may be natural or man-made (*i.e.,* anthropogenic), and may take the form of solid particles (*i.e.,* particulates or particulate matter), liquid droplets, or gases.[18]

The generation of electricity from fossil fuels results in emission of air pollutants and is the largest source of U.S. greenhouse gas (GHG) emissions. According to DOE's Buildings Energy Data Book, U.S. buildings account for 39 percent of primary energy consumption and 72 percent

[18] More information on air pollution characteristics and regulations is available on EPA's website at www.epa.gov.

of all electricity consumed domestically. Moreover, in 2010, residential buildings account for 22.07 quads of primary energy consumption, or 22.5% of total primary energy consumption in the U.S. The DOE Buildings Energy Data Book indicates that in 2010, total site $CO_2$ emissions associated with residential buildings are expected to total 1231 million metric tons. Buildings accounted for more energy use than the entire U.S. transportation sector in 2006 and produced more greenhouse gases than any other country in the world except China. The two most common sources of energy for buildings are electricity and direct consumption of natural gas and petroleum for heating and cooking. Electricity accounts for approximately 78 percent of total building energy consumption and contributes to GHG emissions. According to EPA, GHG emissions from electricity have increased by about 18 percent since 1990, as the demand for electricity has grown and fossil fuel has remained the dominant source for generation. In addition, U.S. buildings account for nearly 40 percent of the nation's man-made $CO_2$ emissions, 18 percent of the NOx emissions, and 55 percent of the $SO_2$ emissions. These emissions in turn contribute to smog, acid rain, haze, and global climate change. Improving the efficiency of the nation's buildings can play a role in reducing air pollution (Park, 2013).

Because the action alternatives would impact energy usage, they would also impact levels of emissions of air pollutants that are emitted as a result of energy production. This Draft EA considered the following outdoor air pollutants: $CO_2$, $NO_X$, Hg, $SO_2$, $CH_4$, and $N_2O$. This section describes these pollutants as well as relevant regulations that control the emission of these pollutants.

***Carbon Dioxide.*** $CO_2$ is of interest because of its classification as a greenhouse gas (GHG). GHGs trap the sun’s radiation inside the Earth’s atmosphere and either occur naturally in the atmosphere or result from human activities. Naturally occurring GHGs include water vapor, $CO_2$, $CH_4$, $N_2O$, and ozone ($O_3$). Human activities, however, add to the levels of most of these naturally occurring gases. For example, $CO_2$ is emitted to the atmosphere when solid waste, fossil fuels (oil, natural gas, and coal), wood, and wood products are burned. In 2013, 93.7 percent of anthropogenic $CO_2$ emissions resulted from burning fossil fuels (EPA 2015d).

Concentrations of $CO_2$ in the atmosphere are naturally regulated by numerous processes, collectively known as the “carbon cycle.” The movement of carbon between the atmosphere and the land and oceans is dominated by natural processes, such as plant photosynthesis. While these natural processes can absorb some of the anthropogenic $CO_2$ emissions produced each year, billions of metric tons are added to the atmosphere annually. In the United States, in 2013, $CO_2$ emissions from electricity generation accounted for nearly 40 percent of total U.S. GHG emissions (EPA 2015d).

***Nitrogen Oxides.*** Nitrogen oxides is the generic term for a group of highly reactive gases, all of which contain nitrogen and oxygen. In the context of air pollution, nitrogen oxide generally refers to the gases NO and $NO_2$, abbreviated as $NO_X$. Many of the nitrogen oxides are colorless and odorless. However, one common pollutant, $NO_2$, along with particles in the air, can often be seen as a reddish-brown layer over many urban areas. In the atmosphere, $NO_X$ gases react to form smog and acid rain, impairing visibility in areas such as national parks, as well as contribute significantly to the formation of tropospheric, or ground-level, ozone, which can trigger serious respiratory problems. $NO_X$ also contributes to the formation of fine particles that can harm human health (EPA 2015b).

$NO_X$ gases generally form in combustion systems via the reaction of nitrogen and oxygen at high temperatures. The primary manmade sources of $NO_X$ are motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fossil fuels. $NO_X$ can also be formed naturally. Electric utilities account for about 22 percent of $NO_X$ emissions in the United States.

***Mercury.*** Coal-fired power plants emit Hg found in coal during the burning process. Coal-fired power plants are the largest remaining source of human-generated Hg emissions in the United States (EPA 2015c). U.S. coal-fired power plants emit Hg in three different forms: oxidized Hg (likely to deposit within the United States); elemental Hg, which can travel thousands of miles before depositing to land and water; and Hg that is in particulate form. Atmospheric Hg is deposited on land, lakes, rivers, and estuaries through rain, snow, and dry deposition. Once there, it can transform into methylmercury and accumulate in fish tissue through bioaccumulation.

Americans are exposed to methylmercury primarily by eating contaminated fish. Women of childbearing age are regarded as the population of greatest concern because the developing fetus is the most sensitive to the toxic effects of methylmercury. Children exposed to methylmercury before birth may be at increased risk of poor performance on neurobehavioral tasks, such as those measuring attention, fine motor function, language skills, visual-spatial abilities, and verbal memory (Trasande et al. 2006).

***Sulfur Dioxide.*** $SO_2$ belongs to the family of sulfur oxide gases ($SO_X$). These gases dissolve easily in water. Sulfur is prevalent in all raw materials, including crude oil, coal, and ore that contains common metals like aluminum, copper, zinc, lead, and iron. $SO_X$ gases are formed when fuel containing sulfur, such as coal and oil, is burned, and when gasoline is extracted from oil or metals are extracted from ore. $SO_2$ dissolves in water vapor to form acid, and interacts with other gases and particles in the air to form sulfates and other products that can be harmful to people and their environment (EPA 2015a).

***Methane.*** $CH_4$ emissions are primarily from human-related sources, not natural sources. U.S. $CH_4$ emissions come from three categories of sources, each accounting for about one-third of total emissions: (1) energy sources, (2) emissions from domestic livestock, and (3) decomposition of solid waste in landfills. The $CH_4$ emitted from energy sources occurs primarily during the production and processing of natural gas, coal, and oil; not in the actual use (combustion) of these fuels. $CH_4$ is the primary ingredient in natural gas, and production, processing, storage, and transmission of natural gas account for 60 percent of the energy source emissions (or 25 percent of all $CH_4$ emissions) (DOE 2011).

***Nitrous Oxide.*** $N_2O$ emission rates are more uncertain than those for $CO_2$ and $CH_4$, with nitrogen fertilization of agricultural soils being the primary human-related source. Fuel combustion is also a source of nitrous oxide; however, in the commercial and residential sector total emissions are a negligible amount of all U.S. emissions (DOE 2011).

***Outdoor Air Quality Regulation***

The Clean Air Act Amendments of 1990 list 188 toxic air pollutants that EPA is required to control (EPA 1990). EPA has set national air quality standards for six common pollutants (also referred to as "criteria" pollutants), two of which are $SO_2$ and $NO_X$. Also, the Clean Air Act Amendments of 1990 gave EPA the authority to control acidification and to require operators of electric power plants to reduce emissions of $SO_2$ and $NO_X$. Title IV of the 1990 amendments established a cap-and-trade program for $SO_2$, in all 50 states and the District of Columbia (D.C.), intended to help control acid rain. This cap-and-trade program serves as a model for more recent programs with similar features.

In 2005, EPA issued the Clean Air Interstate Rule (CAIR) under sections 110 and 111 of the Clean Air Act (40 CFR Parts 51, 96, and 97),[19] (70 FR 25162–25405 (May 12, 2005)). CAIR limited emissions from 28 eastern States and D.C. by capping emissions and creating an allowance-based trading program. Although CAIR was remanded to EPA by the U.S. Court of Appeals for the District of Columbia Circuit (D.C. Circuit), (see *North Carolina v. EPA*, 550 F.3d 1176 (D.C. Cir. 2008)), it remained in effect temporarily, consistent with the D.C. Circuit's earlier opinion in *North Carolina v. EPA*, 531 F.3d 896 (D.C. Cir. 2008).

On July 6, 2011, EPA promulgated a replacement for CAIR, entitled "Federal Implementation Plans: Interstate Transport of Fine Particulate Matter and Ozone and Correction of SIP Approvals," but commonly referred to as the Cross-State Air Pollution Rule (CSAPR), or the Transport Rule (76 FR 48208 (Aug. 8, 2011)).[20] On August 21, 2012, the D.C. Circuit issued a decision to vacate CSAPR. See *EME Homer City Generation, LP v. EPA*, 696 F.3d 7, 38 (D.C. Cir. 2012). The court ordered EPA to continue administering CAIR. More recently, however, EPA requested that the court lift the CSAPR stay and toll the CSAPR compliance deadlines by three years. On October 23, 2014, the D.C. Circuit granted EPA's request. CSAPR took effect January 1, 2015 for $SO_2$ and annual $NO_X$, and May 1, 2015 for ozone season $NO_X$.

On February 16, 2012, EPA issued national emissions standards for hazardous air pollutants (NESHAPs) for Hg and certain other pollutants emitted from coal and oil-fired electric generating units (EGUs), which are also known as the Mercury and Air Toxics Standards (MATS) for power plants (77 FR 9304). More recently, the Supreme Court remanded EPA's 2012 MATS rule regarding national emission standards for hazardous air pollutants from certain electric utility steam generating units. See *Michigan v. EPA* (Case No. 14-46, 2015).

On October 23, 2015, EPA published the final Clean Power Plan (CPP) for existing electricity generating units in the Federal Register (80 FR 64966). In the CPP the Environmental Protection Agency (EPA) proposes a federal plan to implement the greenhouse gas (GHG) emission guidelines (EGs) for existing fossil fuel-fired electric generating units (EGUs) under the Clean Air Act (CAA). The October 23, 2015, EPA notice also included the EPA's proposed model plans for states and its draft federal implementation plan (FIP) (80 FR 64662). The former is intended to guide states as they craft their own plans or to act as a ready-made option, and the latter describes how EPA would enforce $CO_2$ emission reductions on power plants in states that opt not to comply. The CPP went into effect on December 22, 2015. In response, multiple states and industry groups challenged the CPP. The U.S. Supreme Court has stayed the rule

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[19] See http://www.epa.gov/cleanairinterstaterule/.
[20] See also http://www.epa.gov/crossstaterule/.

implementing the Clean Power Plan until the current litigation against it concludes. *Chamber of Commerce, et al. v. EPA, et al.*, Order in Pending Case, 577 U.S. ___ (2016).

#### 3.3.2.2 Outdoor Air Impacts: General Analysis

To assess estimated impacts to outdoor emissions, it is first necessary to determine changes to energy consumption. This section provides the potential energy savings that may result from implementing the action alternatives. Because the No Action Alternative represents the base-case scenario, all energy savings presented are relative to the No Action Alternative. DOE analyzed the national energy savings for each action alternative assuming 30 years of manufactured housing shipments and a 30-year lifetime for manufactured homes.

DOE modeled the annual energy use per square foot of floor space (energy use intensity) associated with the No Action Alternative, the Proposed Action, and the No Sealing Alternative. DOE completed simulations using the EnergyPlus modeling software for manufactured homes in 19 representative cities with differing climate characteristics. In addition, DOE analyzed two sizes of manufactured homes: single-section and multi-section. Using these energy use intensities and the typical floor space of single-section and multi-section manufactured homes respectively, DOE calculated the annual unit site energy consumption[21].

DOE converted the unit site energy consumption of the No Action Alternative, the Proposed Action, and the No Sealing Alternative into primary energy consumption[22] and Full-fuel-cycle (FFC) energy consumption[23]. DOE calculated primary energy savings (power plant consumption) from site electricity savings by applying a factor to account for losses associated with the generation, transmission, and distribution of electricity. DOE calculated FFC energy savings from primary energy savings by applying a factor to account for the energy losses associated with the energy consumed in extracting, processing, and transporting or distributing primary fuels. DOE derived these factors based on the version of the National Energy Modeling System (NEMS) that corresponds to the 2014 Annual Energy Outlook (*AEO 2014*).

The factors change over time in response to projections of future oil, natural gas and coal supply, energy use for oil and gas field and refinery operations, and fuel consumption and emissions related to electric power production.

Table 5 shows the primary energy factors and FFC factors for the different fuel types used in the analysis from 2020 to 2040 in 5-year increments. Because the analysis period goes beyond 2040, DOE assumed the primary energy and FFC factors for all years beyond 2040 were equal to the 2040 factors.

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[21] Unit site energy consumption refers to energy consumed on site of the building, but does not incorporate transmission, delivery, and production losses.

[22] Primary energy refers to the raw fuel that is burned to create heat and electricity.

[23] Full-fuel-cycle measures source energy, that is total energy required including transmission, delivery, and production losses.

**Table 5: Primary Energy and FFC Factors, 2020-2040**

| **Factor Type** | **Fuel Type** | **Dimensionless Factor** | | | | |
|---|---|---|---|---|---|---|
| | | 2020 | 2025 | 2030 | 2035 | 2040 |
| Primary | Electricity | 3.042 | 2.813 | 2.623 | 2.533 | 2.558 |
| FFC | Electricity | 1.044 | 1.045 | 1.046 | 1.047 | 1.047 |
| | Natural Gas | 1.109 | 1.111 | 1.113 | 1.114 | 1.114 |
| | LPG/Oil | 1.176 | 1.176 | 1.174 | 1.172 | 1.170 |

DOE analyzed the national energy savings for 30 years of single-section and multi-section manufactured home shipments, and considered the entire lifetime of each shipment. DOE developed a shipment model to project shipments of manufactured homes from 2017 until 2046. The shipment model uses historical shipments published by the Manufactured Housing Institute (MHI), and uses the *AEO 2015* reference case growth rate in new residential housing starts to project shipments to 2045. DOE assumes the lifetime of a manufactured home to be 30 years. In a given year, the housing stock is the cumulative number of shipments from 2016 through that year less the number of homes that have exceeded their 30-year lifetime. For example, in 2046, the total housing stock is the sum of all shipments from 2016 to 2045 less the shipments from 2016. In each year, the total housing stock is multiplied by the unit energy consumption to calculate annual energy consumption for all housing stock. With annual energy consumption values over the entire analysis period for the No Action Alternative, the Proposed Action, and the No Sealing Alternative, DOE calculated the energy savings associated with the Proposed Action and the No Sealing Alternative.

Table 6 presents the national energy savings resulting from implementation of the Proposed Action and the No Sealing Alternative relative to the No Action Alternative.

**Table 6: Cumulative National Energy Savings, Including FFC of Manufactured Homes Purchased 2017-2047 with a 30-Year Lifetime**

| | **Single-Section Homes quads**[24] | **Multi-Section Homes quads** | **Total quads** |
|---|---|---|---|
| Proposed Action | 0.884 | 1.428 | 2.312 |
| No Sealing Alternative | 0.650 | 1.011 | 1.661 |

The outdoor air analysis for each action alternative estimates the impact of the action on pollutant emissions, which are largely driven by reductions in electricity demand and fuel usage. The emissions analysis consists of two components. The first component estimates the effect of potential energy conservation standards on site emissions, which include both power sector emissions and site combustion emissions of $CO_2$, $NO_X$, $SO_2$ and Hg. These emissions are those

[24] A quad is 1 quadrillion btus.

directly related to the consumption of electricity or combustion fuel. The second component estimates the impacts of a potential standard on emissions of two additional greenhouse gases, $CH_4$ and $N_2O$, as well as the reductions to emissions of all pollutants due to “upstream” activities in the fuel production chain. These upstream activities comprise extraction, processing, and transporting fuels to the site of combustion. The associated emissions are referred to as upstream emissions. Together, the site and upstream emissions account for the FFC, in accordance with DOE’s FFC Statement of Policy. (76 FR 51282; Aug. 18, 2011).

***Methodology***

The analysis of power sector emissions uses marginal emissions intensity factors calculated by DOE. As of 2014, DOE is using a new methodology based on results published for the *AEO 2014* reference case and a set of side cases that implement a variety of efficiency-related policies. The new methodology is described in the report “Utility Sector Impacts of Reduced Electricity Demand” authored by Coughlin (2014). The *AEO* does not publish estimates of the $CH_4$ and $N_2O$ emissions associated with combustion of fossil fuels. For these pollutants, the power sector emissions are estimated using emissions intensity factors published by the U.S. Environmental Protection Agency (EPA). Site combustion emissions are also estimated using emissions intensity factors published by the EPA. The FFC upstream emissions are estimated based on the methodology developed by Coughlin. The upstream emissions include both emissions from fuel combustion during extraction, processing and transportation of fuel, and “fugitive” emissions (direct leakage to the atmosphere) of $CH_4$ and $CO_2$.

***Air Quality Regulations and Impact on Assumptions***

Sulfur dioxide emissions from affected electric generating units (EGUs) are subject to nationwide and regional emissions cap and trading programs, as discussed in section 3.3.2.1. Title IV of the Clean Air Act sets an annual emissions cap on $SO_2$ for affected EGUs in the 50 states and the District of Columbia (D.C.). $SO_2$ emissions from 28 eastern states and D.C. were also limited under EPA’s CAIR and CSAPR regulation. In this analysis, the *AEO 2014* emissions factors used for the present analysis were computed prior to January 1, 2015, and therefore assume that CAIR remains a binding regulation through 2040.

The attainment of emissions caps is typically flexible among affected EGUs and is enforced through the use of emissions allowances and tradable permits. Under existing EPA regulations, any excess $SO_2$ emissions allowances resulting from the lower electricity demand caused by the imposition of an energy conservation standard could be used to permit offsetting increases in $SO_2$ emissions by any regulated EGU. In past rulemakings, DOE recognized that there was uncertainty about the effects of energy conservation standards on $SO_2$ emissions covered by the existing cap-and-trade system, but it concluded that no reductions in power sector emissions would occur for $SO_2$ as a result of the proposed standards.

Beginning in 2016, however, $SO_2$ emissions will fall as a result of the Mercury and Air Toxics Standards (MATS) for power plants. 77 FR 9304 (Feb. 16, 2012). In the final MATS rule, EPA established a standard for hydrogen chloride as a surrogate for acid gas hazardous air pollutants (HAP), and also established a standard for $SO_2$ (a non-HAP acid gas) as an alternative equivalent surrogate standard for acid gas HAP. The same controls are used to reduce HAP and non-HAP acid gas; thus, $SO_2$ emissions will be reduced as a result of the control technologies installed on coal-fired power plants to comply with the MATS requirements for acid gas. *AEO 2014* assumes that, in order to continue operating, coal plants must have either flue gas desulfurization or dry sorbent injection systems installed by 2016. Both technologies, which are used to reduce acid gas emissions, also reduce $SO_2$ emissions. Under the MATS, emissions will be far below the cap established by CAIR, so it is unlikely that excess $SO_2$ emissions allowances resulting from the lower electricity demand would be needed or used to permit offsetting increases in $SO_2$ emissions by any regulated EGU. Therefore, energy conservation standards would reduce $SO_2$ emissions in 2016 and beyond.

CAIR established a cap on $NO_X$ emissions in 28 eastern states and the District of Columbia. Energy conservation standards are expected to have little effect on $NO_X$ emissions in those States covered by CSAPR because excess $NO_X$ emissions allowances resulting from the lower electricity demand could be used to permit offsetting increases in $NO_X$ emissions. However, standards would be expected to reduce $NO_X$ emissions in the states not affected by CAIR. As a result, DOE estimated $NO_X$ emissions reductions from potential standards for those states.

The MATS limit Hg emissions from power plants, but they do not include emissions caps and, as such, DOE's energy conservation standards would likely reduce Hg emissions. DOE estimated Hg emissions reductions using emissions factors based on *AEO 2014*, which incorporates the MATS.

DOE notes that the Supreme Court recently remanded EPA's 2012 rule regarding national emission standards for hazardous air pollutants from certain electric utility steam generating units. See *Michigan v. EPA* (Case No. 14-46, 2015). DOE has tentatively determined that the remand of the MATS rule does not change the assumptions regarding the impact of energy efficiency standards on $SO_2$ emissions. Further, while the remand of the MATS rule may have an impact on the overall amount of mercury emitted by power plants, it does not change the impact of the energy efficiency standards on mercury emissions.

***Site Emissions Factors***

The analysis of power sector emissions uses marginal emissions intensity factors derived from analysis of the *AEO 2014* reference case and a number of side cases incorporating enhanced equipment efficiencies. To model the impact of a standard, DOE calculates factors that relate a unit reduction to annual site electricity demand for a given end use to corresponding reductions to installed capacity by fuel type, fuel use for generation, and power sector emissions. Total emissions reductions are estimated by multiplying the emissions factors, computed for specific end uses and years, by the corresponding calculated energy savings associated with a particular efficiency scenario. Details on the approach have been described by Coughlin (2014). The electricity end uses relevant to manufactured housing are residential space heating, residential space cooling, and residential water heating. Tables 7, 8, and 9 list the power sector emissions factors for these three end uses for selected years. Years beyond 2040 were assumed to have the same emissions factors as the year 2040. The *AEO* does not publish estimates of the $CH_4$ and $N_2O$ emissions associated with combustion of fossil fuels. For these pollutants, the power sector emissions are estimated using emissions intensity factors published by the EPA (2014). This publication provides emissions intensity factors for different grades of coal, petroleum fuels and natural gas. DOE uses these fuel-specific emissions factors to develop time-dependent emissions factors as a function of the changing fuel mix in the power sector.

**Table 7: Power Sector Emissions Factors for Residential Space Heating**

| | **Unit** | **2020** | **2025** | **2030** | **2035** | **2040** |
|---|---|---|---|---|---|---|
| $CO_2$ | kg/MWh | 831 | 743 | 674 | 618 | 563 |
| $SO_2$ | g/MWh | 0.00230 | 0.00179 | 0.00151 | 0.00127 | 0.00113 |
| $NO_X$ | g/MWh | 731 | 696 | 650 | 615 | 564 |
| Hg | g/MWh | 617 | 482 | 405 | 340 | 304 |
| $N_2O$ | g/MWh | 83.5 | 66.9 | 57.1 | 48.9 | 43.9 |
| $CH_4$ | g/MWh | 12.0 | 9.6 | 8.1 | 6.9 | 6.2 |

**Table 8: Power Sector Emissions Factors for Residential Space Cooling**

| | **Unit** | **2020** | **2025** | **2030** | **2035** | **2040** |
|---|---|---|---|---|---|---|
| $CO_2$ | kg/MWh | 786 | 709 | 643 | 594 | 546 |
| $SO_2$ | g/MWh | 0.00199 | 0.00155 | 0.00131 | 0.00109 | 0.00098 |
| $NO_X$ | g/MWh | 722 | 688 | 641 | 610 | 566 |
| Hg | g/MWh | 535 | 418 | 351 | 294 | 263 |
| $N_2O$ | g/MWh | 72.6 | 58.3 | 49.8 | 42.7 | 38.4 |
| $CH_4$ | g/MWh | 10.4 | 8.3 | 7.1 | 6.0 | 5.4 |

**Table 9: Power Sector Emissions Factors for Residential Water Heating**

| | **Unit** | **2020** | **2025** | **2030** | **2035** | **2040** |
|---|---|---|---|---|---|---|
| $CO_2$ | kg/MWh | 813 | 730 | 662 | 609 | 556 |
| $SO_2$ | g/MWh | 0.00220 | 0.00172 | 0.00144 | 0.00121 | 0.00108 |
| $NO_X$ | g/MWh | 723 | 690 | 644 | 611 | 561 |
| Hg | g/MWh | 591 | 462 | 388 | 326 | 291 |
| $N_2O$ | g/MWh | 80.2 | 64.3 | 54.9 | 47.0 | 42.2 |
| $CH_4$ | g/MWh | 11.6 | 9.2 | 7.8 | 6.6 | 6.0 |

Site combustion of fossil fuels in buildings (for example in water-heating, space-heating, or cooking applications) also produces emissions of $CO_2$ and other pollutants. DOE used emissions factors published by the EPA, which are constant in time. These factors are presented in Table 10.

**Table 10: Site Combustion Emissions Factors**

| Species | Natural Gas<br>*g/mcf** | Fuel Oil/Liquefied Petroleum Gas<br>*g/bbl*** |
|---|---|---|
| $CO_2$ | 54116 | 446241 |
| $SO_2$ | 69.9048 | 11531 |
| $NO_X$ | 0.27083 | 219.66 |
| $N_2O$ | 1.022 | 13.260 |
| $CH_4$ | 0.1022 | 8.6481 |
| *g/mcf = grams per one-thousand cubic feet<br>**g/bbl = grams per barrel of oil | | |

***Upstream Emission Factors***

The upstream emissions accounting uses the same approach as the upstream energy accounting described by Coughlin (2013, 2014). When demand for a particular fuel is reduced, there is a corresponding reduction in the emissions from combustion of that fuel at either the building site or the power plant. The associated reduction in energy use for upstream activities leads to further reductions in emissions. These upstream emissions are defined to include the combustion emissions from the fuel used upstream, the fugitive emissions associated with the fuel used upstream, and the fugitive emissions associated with the fuel used on site.

Fugitive emissions of $CO_2$ occur during oil and gas production, but are small relative to combustion emissions. They comprise about 2.5 percent of total $CO_2$ emissions for natural gas and 1.7 percent for petroleum fuels. Fugitive emissions of methane occur during oil, gas, and coal production. Combustion emissions of $CH_4$ are very small, while fugitive emissions (particularly for gas production) may be relatively large. Hence, fugitive emissions make up more than 99 percent of total methane emissions for natural gas, about 95 percent for coal, and 93 percent for petroleum fuels.

Upstream emissions factors account for both fugitive emissions and combustion emissions in extraction, processing, and transport of primary fuels. DOE estimated fugitive emissions factors for methane from coal mining and natural gas production based on a review of recent studies compiled by Burnham. This review includes estimates of the difference between fugitive emissions factors for conventional production of natural vs. unconventional (shale or tight gas). These estimates rely in turn on data gathered by EPA under new greenhouse gas reporting requirements for the petroleum and natural gas industries (EPA 2009, 2012). As more data are made available, DOE will continue to update these estimated emissions factors.

For ease of application in its analysis, DOE developed all of the emissions factors using site (point of use) energy savings in the denominator. Table 11 presents the electricity upstream emissions factors for selected years. These were used to estimate the emissions associated with the decreased electricity use. The caps that apply to power sector $NO_X$ emissions do not apply to upstream combustion sources. Tables 12 and 13 present upstream emissions factors for natural gas and fuel oil/LPG, respectively.

**Table 11: Electricity Upstream Emissions Factors**

| | Unit | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|
| $CO_2$ | kg/MWh | 30.3 | 30.7 | 30.8 | 30.4 | 30.0 |
| $SO_2$ | g/MWh | 0.0000134 | 0.0000126 | 0.0000117 | 0.0000111 | 0.0000108 |
| $NO_X$ | g/MWh | 388 | 395 | 399 | 396 | 391 |
| Hg | g/MWh | 5.62 | 5.45 | 5.20 | 5.06 | 5.00 |
| $N_2O$ | g/MWh | 2127 | 2163 | 2200 | 2196 | 2160 |
| $CH_4$ | g/MWh | 0.275 | 0.270 | 0.261 | 0.253 | 0.246 |

**Table 12: Natural Gas Upstream Emissions Factors**

| | Unit | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|
| $CO_2$ | kg/mcf | 7.89 | 7.96 | 7.90 | 7.85 | 7.88 |
| $SO_2$ | g/mcf | 115 | 116 | 115 | 114 | 114 |
| $NO_X$ | g/mcf | 0.0344 | 0.0348 | 0.0344 | 0.0341 | 0.0343 |
| $N_2O$ | g/mcf | 686 | 689 | 686 | 686 | 687 |
| $CH_4$ | g/mcf | 0.0126 | 0.0128 | 0.0127 | 0.0126 | 0.0126 |

**Table 13: Fuel Oil/Liquefied Petroleum Gas Upstream Emissions Factors**

| | Unit | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|
| $CO_2$ | kg/bbl | 70.0 | 69.1 | 67.8 | 67.7 | 67.5 |
| $SO_2$ | g/bbl | 0.0000069<br>3 | 0.0000064<br>7 | 0.0000062<br>2 | 0.0000062<br>1 | 0.0000060<br>9 |
| $NO_X$ | g/bbl | 814 | 810 | 791 | 787 | 781 |
| Hg | g/bbl | 15.4 | 15.3 | 15.0 | 14.9 | 14.8 |
| $N_2O$ | g/bbl | 882 | 872 | 857 | 855 | 854 |
| $CH_4$ | g/bbl | 0.630 | 0.625 | 0.611 | 0.608 | 0.603 |

***Emission Reduction Results***

Table 14 lists the estimated cumulative emissions reductions relative to the No Action Alternative, for single-section and multi-section manufactured homes, under the Proposed Action and the No Sealing Alternative, for homes sold from 2017 through 2046.

**Table 14: Emissions Reductions Under the Proposed Action and No Sealing Alternative**

| Pollutant | Proposed Action | | | No Sealing Alternative | | |
|---|---|---|---|---|---|---|
| | Single-Section | Multi-Section | Total | Single-Section | Multi-Section | Total |
| **Site Emissions Reduction** | | | | | | |
| $CO_2$ (million metric tons) | 56.5 | 91.1 | 148 | 41.2 | 64.0 | 105 |
| Hg (metric tons) | 0.0904 | 0.146 | 0.236 | 0.0681 | 0.107 | 0.175 |
| $NO_X$ (thousand metric tons) | 223 | 356 | 579 | 142 | 207 | 349 |
| $SO_2$ (thousand metric tons) | 27.6 | 44.4 | 72.0 | 20.3 | 31.5 | 51.8 |
| $CH_4$ (thousand metric tons) | 3.78 | 6.09 | 9.87 | 2.81 | 4.37 | 7.18 |
| $N_2O$ (thousand metric tons) | 0.632 | 1.02 | 1.65 | 0.455 | 0.701 | 1.156 |
| **Upstream Emissions Reduction** | | | | | | |
| $CO_2$ (million metric tons) | 4.01 | 6.45 | 10.5 | 2.8 | 4.25 | 7.05 |
| Hg (metric tons) | 0.000944 | 0.00153 | 0.00247 | 0.000707 | 0.00111 | 0.00182 |
| $NO_X$ (thousand metric tons) | 51.8 | 83.2 | 135 | 36.2 | 55 | 91.2 |
| $SO_2$ (thousand metric tons) | 0.615 | 0.991 | 1.61 | 0.435 | 0.665 | 1.1 |
| $CH_4$ (thousand metric tons) | 239 | 385 | 624 | 171 | 264 | 435 |
| $N_2O$ (thousand metric tons) | 0.0294 | 0.0474 | 0.0768 | 0.0209 | 0.032 | 0.0529 |
| **Full-Fuel-Cycle Emissions Reduction*** | | | | | | |
| $CO_2$ (million metric tons) | 60.5 | 97.6 | 158 | 44.0 | 68.3 | 112 |
| Hg (metric tons) | 0.0913 | 0.148 | 0.239 | 0.0688 | 0.108 | 0.177 |
| $NO_X$ (thousand metric tons) | 275 | 439 | 714 | 178 | 262 | 440 |
| $SO_2$ (thousand metric tons) | 28.2 | 45.4 | 73.6 | 20.7 | 32.2 | 52.9 |
| $CH_4$ (thousand metric tons) | 243 | 391 | 634 | 174 | 268 | 442 |
| $N_2O$ (thousand metric tons) | 0.661 | 1.07 | 1.73 | 0.476 | 0.733 | 1.21 |

* Full-fuel-cycle emissions reductions are calculated by summing site and upstream emissions reductions. The FFC totals in this table have been rounded to 3 significant digits.

#### 3.3.2.3 Impacts of Proposed Action

As identified in Table 6, under the Proposed Action total energy savings would be 2.184 quads. As identified in Table 14, above, under the Proposed Action cumulative FFC emissions reductions would be 146 million metric tons of $CO_2$, 0.247 metric tons of Hg 661,000 metric tons of $NO_X$, 89,400 metric tons of $SO_2$, 627,000 metric tons of $CH_4$, and 1,650 metric tons of $N_2O$, for 30 years of construction (2016 through 2045) and 30 years of energy reduction for all manufactured homes shipped during that period.

#### 3.3.2.4 Impacts of No Sealing Alternative

As identified in Table 6, under the No Sealing Alternative total energy savings would be 1.56 quads, which would be 71 percent of the energy savings achieved under the Proposed Action. Under the No Sealing Alternative cumulative FFC emissions reductions would be 107 million metric tons of $CO_2$, 0.19 metric tons of Hg, 446,000 metric tons of $NO_X$, 67,000 metric tons of

$SO_2$, 452,000 metric tons of $CH_4$, and 1,230 metric tons of $N_2O$, for 30 years of construction (2016 through 2045) and 30 years of energy reduction for all manufactured homes shipped during that period. These emission reductions are less than those obtained from the Proposed Action; specifically, the reductions are between 67 percent (for $NO_X$) and 76 percent (for Hg) of the emission reductions for the Proposed Action.

### 3.3.3 Global Climate Change

Climate change has evolved into a matter of global concern because it is expected to have widespread, adverse effects on natural resources and systems. A growing body of evidence points to anthropogenic sources of greenhouse gases, such as $CO_2$, as major contributors to climate change. Climate change is a resource area with possible impacts from the Proposed Action and No Sealing Alternative.

#### 3.3.3.1 Affected Environment

Climate is defined as the average weather, over a period ranging from months to many years. Climate change refers to a change in the state of the climate, which is identifiable through changes in the mean and/or the variability of its properties (e.g., temperature or precipitation) over an extended period, typically decades or longer. The World Meteorological Organization (WMO) and United Nations Environment Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC) to provide an objective source of information about climate change. According to the IPCC Fourth Assessment Report (IPCC Report), published in 2007, climate change is consistent with observed changes to the world's natural systems; the IPCC expects these changes to continue (IPCC WGI 2007A).[25]

The IPCC Report states that the world has warmed by about 0.74°C in the last 100 years. Additionally, the IPCC Report finds that most of the temperature increase since the mid-20th century is very likely caused by the increase in anthropogenic concentrations of $CO_2$ and other long-lived greenhouse gases such as $CH_4$ and $N_2O$ in the atmosphere, rather than from natural causes.

Increasing the concentration of $CO_2$ and greenhouse gases in the atmosphere partially blocks the Earth's re-radiation of captured solar energy in the infrared band, inhibits the radiant cooling of the Earth, and thereby alters the energy balance of the planet, which gradually increases its average temperature. The IPCC Report estimates that currently, $CO_2$ makes up about 77 percent of the total $CO_2$-equivalent global warming potential in GHGs emitted from human activities, with the vast majority (74 percent) of the $CO_2$ attributable to fossil fuel use.[26] Globally, 49

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[25] Note that a fifth IPCC Assessment Report is now available at http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-ts.pdf. DOE will update this section of this EA in subsequent versions of this EA.

[26] GHGs differ in their warming influence (radiative forcing) on a global climate system due to their different radiative properties and lifetimes in the atmosphere. These warming influences may be expressed through a common metric based on the radiative forcing of $CO_2$, i.e., $CO_2$-

billion metric tons of $CO_2$ equivalent of anthropogenic (man-made) greenhouse gases are emitted every year.[27] For the future, the IPCC Report describes a wide range of GHG emissions scenarios, but under each scenario, $CO_2$ would continue to comprise more than 70 percent of the total global warming potential (IPCC 2000).

Researchers have focused on considering atmospheric $CO_2$ concentrations that likely will result in some level of global climate stabilization, and the emissions rates associated with achieving the "stabilizing" concentrations by particular dates. They associate these stabilized $CO_2$ concentrations with temperature increases that plateau in a defined range. For example, at the low end, the IPCC Report scenarios target $CO_2$ stabilized concentrations range between 350 ppm and 400 ppm (essentially today's value)—because of climate inertia, concentrations in this low-end range would still result in temperatures projected to increase 2.0°C to 2.4°C above pre-industrial levels[28] (about 1.3 °C to 1.7 °C above today's levels). To achieve concentrations between 350 ppm to 400 ppm, the IPCC scenarios present that there would have to be a rapid downward trend in total annual global emissions of greenhouse gases to levels that are 50 to 85 percent below today's annual emissions rates by no later than 2050. Because it is assumed that there would continue to be growth in global population and substantial increases in economic production, the scenarios identify required reductions in greenhouse gas emissions intensity (emissions per unit of output) of more than 90 percent. However, even at these rates, the scenarios describe some warming and some climate change is projected because of already accumulated $CO_2$ and GHGs in the atmosphere (IPCC WGI 2007b).

#### 3.3.3.2 Impacts of Action Alternatives

It is difficult to correlate specific emissions rates with atmospheric concentrations of $CO_2$ and specific atmospheric concentrations with future temperatures because the IPCC Report describes a clear lag in the climate system between any given concentration of $CO_2$ (even if maintained for long periods) and the subsequent average worldwide and regional temperature, precipitation, and extreme weather regimes. For example, a major determinant of climate response is "equilibrium climate sensitivity", a measure of the climate system response to sustained radiative forcing. It is defined as the global average surface warming following a doubling of carbon dioxide concentrations. The IPCC Report describes its estimated, numeric value as about 3°C, but the likely range of that value is 2°C to 4.5°C. Further, as illustrated above, the IPCC Report scenarios for stabilization rates are presented in terms of a range of concentrations, which then correlates to a range of temperature changes. Thus, climate sensitivity is a key uncertainty for $CO_2$ mitigation scenarios that aim to meet specific temperature levels.

The Council on Environmental Quality's 2014 Revised Draft Guidance for Greenhouse Gas Emissions and Climate Change Impacts recommends using the "projected GHG emissions…as

equivalent. $CO_2$ equivalent emission is the amount of $CO_2$ emission that would cause the same- time integrated radiative forcing, over a given time horizon, as an emitted amount of other long- lived GHG or mixture of GHGs.

[27] Other non-fossil fuel contributors include $CO_2$ emissions from deforestation and decay from agriculture biomass, agricultural and industrial emissions of $CH_4$, and emissions of nitrous oxide and fluorocarbons.

[28] IPCC Working Group 3, Table TS 2.

the proxy for assessing a proposed actions potential climate change impacts.” The IPCC lists $NO_X$, $CH_4$, and $N_2O$ as having global warming potential factors of -11, 28, and 265 times the impact of CO2 over a 100 year horizon (Myhre, 2013). The IPCC does not list $SO_2$ or Hg as having $CO_2$ equivalent global warming potential factors. The full fuel cycle emissions reductions of $NO_X$, $CH_4$, and $N_2O$ were converted to CO2 equivalents using these global warming potential factors. The $CO_2$ equivalent emissions were summed to determine the total CO2 equivalent emissions avoided under the proposed action and the no air sealing alternative. The total $CO_2$ equivalent greenhouse gas emissions avoided under the proposed action is 168 million metric tons. The total $CO_2$ equivalent greenhouse gas emissions avoided under the no sealing alternative is 120 million metric tons.

#### 3.3.4 Socioeconomic and Environmental Justice

This consideration of Environmental Justice is made pursuant to Executive Order 12898, “Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations” (59 FR 7629, EO signed Feb. 11, 1994). The Executive Order requires Federal agencies to address disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on low-income or minority populations.

Manufactured home owners, on average, have a median annual income of $35,000, which is roughly $17,000 below the national average. Among households with very-low incomes (that is, less than 50 percent of area median), 23 percent of home-ownership growth between 1993 and 1999 came through manufactured housing. For southern households the figure was 30 percent, and for rural households 35 percent. In the rural South manufactured home purchases accounted for 63 percent of the increase in very-low-income home ownership. Nationwide, manufactured homes are a major source of unsubsidized, low-cost housing for many owners and renters who have few housing alternatives (Apgar et al., 2002). Of the 540,000 affordably priced new units added to the housing stock from 1997 to 1999, two-thirds were manufactured units (Collins, Crowe and Carliner, 2000).

DOE has determined that any action alternative would affect manufactured home residents in an equal manner. However, DOE acknowledges that manufactured home purchasers and residents are disproportionately from lower income populations. As discussed above, DOE has not been able to determine the extent of impacts to indoor air quality that would result from the Proposed Action, and thus has not determined that any impacts would occur. DOE can determine that if any adverse impacts to indoor air quality from the Proposed Action would occur, those impacts may have disproportionately affect low income populations. There would be no adverse health effects on minorities and, or, low-income populations under the No Sealing and the No Action Alternatives since there will be minimal or no impacts to indoor air quality.

DOE expects there to be positive and negative economic benefits under the action alternatives for low-income populations. The negative economic impacts result from the increase in the purchase price of manufactured homes from builders incorporating the action alternatives energy conservation measures. However, the increase in purchase price would be offset by the benefits manufactured homeowners would experience in operating cost savings under the action alternatives. Establishing robust energy conservation requirements for manufactured homes would result in the dual benefit of substantially reducing manufactured home energy use and easing the financial burden on owners of manufactured homes in meeting their monthly utility expenses.

### 3.4 Cumulative Impacts

Cumulative impacts are those potential environmental impacts that result "from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such action. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time" (40 CFR 1508.7).

The Proposed Action would establish energy conservation standards for manufactured homes. The Proposed Action is not a site specific action or project which would impact any specific geographic area or region. Cumulative impacts are discussed for those resource areas where cumulative impacts could occur, specifically for indoor air and outdoor air.

#### 3.4.1 Cumulative Indoor Air Impacts

Indoor air quality may be impacted by existing regulations regarding construction, health and safety of manufactured homes. Those regulations are set forth by HUD at 24 CFR 3280.

Indoor air quality may also be impacted by future regulations. EPA is proposing new requirements under the Formaldehyde Standards for Composite Wood Products Act of 2010, or Title VI of the Toxic Substances Control Act (TSCA). These proposed requirements are designed to implement the statutory formaldehyde emission standards for hardwood plywood, medium-density fiberboard, and particleboard. No final rules have been issued. The formaldehyde levels in composite wood products that are used in the construction of manufactured homes currently regulated by HUD are higher than those established by the 2010 Act. Section 4 of the 2010 Act directs HUD to update its regulations to ensure that their regulations reflect the standards established by section 601 of TSCA. DOE expects that the changes, if placed into law, would have a beneficial impact on indoor air quality of manufactured homes. Given that formaldehyde is but one of many potential pollutants, DOE expects that the total cumulative impact from updates to formaldehyde regulations would be minimal. However, because the impacts of the Proposed Action on indoor air remain uncertain, the cumulative impacts also remain uncertain.

#### 3.4.2 Cumulative Outdoor Air impacts

While the EPA is continuously working on updating and creating regulations to improve outdoor air quality, the cumulative impact of the action alternatives with any potential regulations would be small relative to the impact of those potential regulations.

The known impact of the action alternatives on outdoor air would be beneficial in that those impacts would be to reduce air pollutant emissions. While the combination of the action alternatives with reasonably foreseeable regulations on outdoor air may be minor, the action alternatives could have a small positive cumulative effect on the amount of outdoor pollutant emissions.

# 4 REQUEST FOR INFORMATION

DOE seeks comment on the potential impacts of the Proposed Action on indoor air quality and occupant health for manufactured homes. Commenters should address the question: "How would the prescriptive sealing requirements as defined in Section 460.104 of the Proposed Action impact indoor air quality and occupant health for manufactured homes?" DOE is interested in data, calculations, expert opinions, and studies, including epidemiological studies that would support the positions set forth in response to this RFI. DOE will consider the information received in analyzing potential air quality impacts, as discussed in section 3.3.1.2. Areas of interest include, but are not limited to:

1. The relationship among indoor air quality, natural air infiltration and mechanical ventilation in manufactured homes, residential buildings or other building types.
2. Whether the Proposed Action would be protective of human health given the existing requirements for mechanical ventilation at 24 CFR 3280.103(b).
3. Data on safe or unsafe levels of indoor pollutants within manufactured homes, residential buildings or other building types.
4. Data on existing levels of indoor pollutants within manufactured homes, residential buildings or other building types.

**DISCLAIMER AND IMPORTANT NOTES:** This is a Request for Information (RFI) only. It is issued solely for information purposes; this RFI does not constitute a formal solicitation for proposals or abstracts. Your response to this notice will be treated as information only. In accordance with FAR 15.201(e), responses to this notice are not offers and cannot be accepted by the Government to form a binding contract. DOE will not provide reimbursement for costs incurred in responding to this RFI. Respondents are advised that DOE is under no obligation to acknowledge receipt of the information received or provide feedback to respondents with respect to any information submitted under this RFI. Responses to this RFI do not bind DOE to any further actions related to this topic.

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# 6 LIST OF AGENCIES, ORGANIZATIONS AND INDIVIDUALS CONSULTED IN THE DRAFTING OF THIS EA

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MHCC MEETING

August 9, 2016

# APPENDIX G: SKYLINE COMMENTS

Jeffrey Legault

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574-294-6521

August 4, 2016

**Comments to DOE Proposed Rule on Energy Conservation Standards for Manufactured Homes (06-17-2016)**

1) Table 460.101-1 & 2. The State of California is not included in the tables. It appears the entire State of California is located in Climate Zone III.

2) 460.102 Building thermal envelope requirements. Climate Zones I and II of the 2015 IECC closely matches Climate Zone I of the proposed rule. Climate Zone I and II of the 2015 IECC allows a window U-factor of 0.40, which is significantly higher than the window U-factor of 0.35 in the proposed rule for the same area. I recommend raising the window U-factor in the proposed rule to 0.40 for climate zone 1.

3) 460.102 Building thermal envelope requirements. The only difference between Climate Zone I and II of the proposed rule is the SHGC. I recommend combining these climate zones into a single zone, and use a SHGC of 0.33.

4) Table 460.102-1. Note 3 states “Ceiling Insulation must have either a uniform thickness or uniform density.” Uniform thickness will not generally be possible. Therefore a uniform density will be required in the prescriptive method. This seems to not allow compression of insulation in the truss heel area. If will be very difficult to build a roof with the insulation levels required by the proposed rule without some compression.

5) Table 460.102-1. Note 7 requires a maximum glazing area of 12% of the floor area, when using the prescriptive method. There is no such glazing area restriction in the 2015 IECC. I recommend eliminating this requirement.

6) Table 460.103 – Installation of Insulation. Under floors, the proposed rule requires floor insulation to be installed in contact with the underside of the floor decking. This requirement has been debunked by building scientists, and has been removed from the 2015 IECC. It serves no purpose since the rim joist is required to be insulated. It is extremely difficult to do in a factory environment. I recommend this section be removed.

7) 460.201 Duct system – The proposed rules states “Each manufactured home must be equipped with a duct system.” This seems to imply that ductless systems, such as mini-split heat pumps are not allowed. I recommend revising the section to state “when a duct system is installed.”

8) 460.201 Duct system – Section (b) states “Building framing cavities must not be used as ducts or plenums”. Does this section apply to return air plenums? I recommend revising this section to state “….supply ducts or plenums…..”

9) The use of 2x4 exterior walls will be extremely difficult to make work under the proposed rule for thermal Zone III and IV. This will encompass approximately 75% of the country. This will impose a significant financial burden on the industry.

10) The proposed rule does not address how these standards will be enforced. Does DOE have an enforcement plan? How are plan review and inspections to be performed? If would be a burden on the industry to have to deal with an additional Federal Agency. There needs to be regulatory clarity before this rule can be final.

# APPENDIX H: COSTS OF NEW ENERGY STANDARD (ESTIMATED)

Provided by Steven Anderson

| | Current Regulations | | Proposed Regulations | |
|---|---|---|---|---|
| | Single | Double | Single | Double |
| Average Price | $44,500 | $88,300 | $44,500 | $88,300 |
| Estimated Siting Cost, etc. | $8,000 | $10,000 | $8,000 | $10,000 |
| New Energy Standards Costs (est) | $0 | $0 | $4,602 | $5,825 |
| 2x4 to 2x6 Exterior Walls | $0 | $0 | $624 | $864 |
| **Total Home Cost (est)** | **$52,500** | **$98,300** | **$57,726** | **$104,989** |
| 20% Down Payment | $10,500 | $19,660 | $11,545 | $20,998 |
| **Estimated Mortgage Amount** | **$42,000** | **$78,640** | **$46,181** | **$83,991** |
| Estimated Monthly Payment @ 10% Interest for 15 Years | -$451 | -$845 | -$496 | -$903 |
| Annual Mortgage Payment | $5,416 | $10,141 | $5,955 | $10,831 |
| **Minimum Annual Income for Mortgage - based on 25% debt-to-income ratio** | **$21,664.04** | **$40,563.33** | **$23,820.54** | **$43,323.54** |
| 2013 Median Income for Manufactured Home Buyers | $28,400 | $28,400 | $28,400 | $28,400 |
| **Difference:** | **-$6,736** | **$12,163** | **-$4,579** | **$14,924** |

MHCC MEETING
August 9, 2016

# APPENDIX I:
# METHODOLOGY FOR DEVELOPING THE RES*check*™ SOFTWARE THROUGH VERSION 3.7

Submitted by John Weldy

PNNL-14864-1-2

# Methodology for Developing the RES*check*™ Software through Version 3.7

R. Bartlett
L. M. Connell
R. G. Lucas
R. W. Schultz
Z. T. Taylor
J. D. Wiberg

October 2005

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

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# Methodology for Developing the REScheck™ Software through Version 3.7

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# Summary

The Energy Policy Act of 1992 (EPAct, Public Law 102-486) establishes the 1992 Model Energy Code (MEC), published by the Council of American Building Officials (CABO), as the target for several energy-related requirements for residential buildings (CABO 1992). The U.S. Department of Housing and Urban Development (HUD) and the U.S. Department of Agriculture (via Rural Economic and Community Development [RECD] [formerly Farmers Home Administration]) are required to establish standards for government-assisted housing that "meet or exceed the requirements of the Council of American Building Officials Model Energy Code, 1992." CABO has issued 1992, 1993, and 1995 editions of the MEC (CABO 1992, 1993, and 1995).

Effective December 4, 1995, CABO assigned all rights and responsibilities for the MEC to the International Code Council (ICC). The first edition of the ICC's International Energy Conservation Code (ICC 1998) issued in 1998 therefore replaced the 1995 edition of the MEC. The 1998 IECC incorporates the provisions of the 1995 MEC and includes the technical content of the MEC as modified by approved changes from the 1995, 1996, and 1997 code development cycles. The ICC subsequently issued the 2000 edition of the IECC (ICC 1999). Many states and local jurisdictions have adopted one edition of the MEC or IECC as the basis for their energy code.

In a Federal Register notice issued January 10, 2001 (FR Vol. 99, No. 7, page 1964), the U.S. Department of Energy (DOE) concluded that the 1998 and 2000 editions of the IECC improve energy efficiency over the 1995 MEC. DOE has previously issued notices that the 1993 and 1995 MEC also improved energy efficiency compared to the preceding editions.

To help builders comply with the MEC and IECC requirements, and to help HUD, RECD, and state and local code officials enforce these code requirements, DOE tasked Pacific Northwest National Laboratory (PNNL)[a] with developing the MEC*check*™ compliance materials. In November 2002, MEC*check* was renamed RES*check*™ to better identify it as a residential code compliance tool. The "MEC" in MEC*check* was outdated because it was taken from the Model Energy Code, which has been succeeded by the IECC. The "RES" in RES*check* is also a better fit with the companion commercial product, COM*check*™.

The easy-to-use RES*check* compliance materials include a compliance and enforcement manual for all the MEC and IECC requirements and three compliance approaches for meeting the code's thermal envelope requirements—prescriptive packages, software, and a trade-off worksheet (included in the compliance manual). The compliance materials can be used for single-family and low-rise multifamily dwellings. The materials allow building energy efficiency measures (such as insulation levels) to be "traded off" against each other, allowing a wide variety of building designs to comply with the code.

This report explains the methodology used to develop Version 3.7 of the RES*check* software developed for the 1992, 1993, and 1995 editions of the MEC, and the 1998, 2000, and 2003 editions of

(a) Pacific Northwest National Laboratory is operated for the U.S. Department of Energy by Battelle under contract DE-AC06-76RLO 1830.

the IECC.  Although some requirements contained in these codes have changed, the methodology used to develop the RES*check* software for these five editions is similar.

RES*check* assists builders in meeting the most complicated part of the code—the building envelope $U_o$-, U-, and R-value requirements in Section 502 of the code.  This document details the calculations and assumptions underlying the treatment of the code requirements in RES*check*, with a major emphasis on the building envelope requirements.

# Contents

# Figures



# Tables

# 1.0 Introduction

The Energy Policy Act of 1992 (EPAct, Public Law 102-486) establishes the 1992 Model Energy Code (MEC), published by the Council of American Building Officials (CABO), as the target for several energy-related requirements for residential buildings (CABO 1992). The U.S. Department of Housing and Urban Development (HUD) and the U.S. Department of Agriculture (via Rural Economic and Community Development [RECD] [formerly Farmers Home Administration]) are required to establish standards for government-assisted housing that "meet or exceed the requirements of the Council of American Building Officials Model Energy Code, 1992." CABO has issued 1992, 1993, and 1995 editions of the MEC (CABO 1992, 1993, and 1995).

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PNNL developed RES*check* compliance materials for three different editions of the MEC (CABO 1992, 1993, and 1995) and the three editions of the IECC (ICC 1998, 1999, and 2003). This report explains the methodology used to develop Version 3.6 of the RES*check* software developed for these editions of the MEC and IECC. Although some requirements contained in the MEC and IECC have changed over time, the methodology used to develop the RES*check* software for these three editions is similar.

Section 2.0 of this report summarizes the differences in the various editions of the MEC and IECC. Section 3.0 provides a summary of the methodology used to develop the RES*check* software. Section 4.0 gives the technical basis for the simplified presentation of some of the code's miscellaneous requirements in the RES*check* materials.  The methodology for the RES*check* software is discussed in Section 5.0. Section 6.0 discusses the methodology for trading increased heating or cooling efficiency for lowered envelope efficiency in the RES*check* software.  All references cited in this report are identified in Section 7.0.  Appendix A documents the assumptions and equations used in the calculation of the envelope component $U_o$-factors for the RES*check* software.  Documentation for specific state energy codes supported in the RES*check* software has been added to this report as additional appendices.  These appendices are intended to provide technical documentation for features and changes made for state-specific codes that differ from the standard features that support compliance with the national model codes.  Documentation for the AreaCalc software is also included as an appendix.

# 2.0 Differences in Various Editions of the MEC and IECC

The 1993 MEC (CABO 1993) contains much more stringent requirements for walls in multifamily buildings than the 1992 MEC (CABO 1992). For mild climates, the 1993 MEC contains more stringent requirements for walls in single-family houses and ceilings in all residential buildings. The 1993 MEC also has different duct insulation requirements (see Section 4.1) and other minor differences from the 1992 MEC. However, these differences did not affect the methodology used to develop the RES*check* software.

The 1995 MEC (CABO 1995) is similar to the 1993 MEC, but the 1995 MEC references the *1993 ASHRAE Handbook: Fundamentals* (ASHRAE 1993), whereas the 1993 MEC references the *1989 ASHRAE Handbook: Fundamentals* (ASHRAE 1989a). The 1993 handbook specifies that wood-frame walls have a higher percentage of framing area than that specified in the 1989 handbook. The wall framing area percentages from the ASHRAE handbooks were used in the calculation of overall wall U-factors ($U_o$-factors) in the RES*check* materials. Because wood framing has a lower R-value than cavity insulation, using the increased framing area percentage results in a higher wall $U_o$-factor requirement when determining compliance with the 1995 MEC relative to the 1993 (or 1992) MEC. The differences in wall $U_o$-factors are shown in Appendix A. Otherwise, the methodology used to develop the RES*check* materials for the 1993 and 1995 MEC is identical.

The 1998 IECC (ICC 1998) contains a variety of revisions to the 1995 MEC. The most notable revision is that glazed fenestration products (windows and doors) in new housing in locations with less than 3500 heating degree-days (HDDs) (approximately the southern quarter of the United States) must have an average solar heat gain coefficient (SHGC) of 0.4 or less. Other code changes include a requirement for heat traps on water heaters and provisions for skylight shaft insulation. Also, new prescriptive compliance paths have been added, including paths for small additions and window replacements. None of these code changes affect any of the calculations or methodology underlying RES*check*; the only changes to RES*check* are the addition of these new requirements in the "Inspection Checklist" printout produced by the software. The 2000 IECC (ICC 1999) contains relatively minor changes in requirements compared to the 1998 IECC. Exposed foundation insulation is required to have a weather-resistant protective coating. Additional requirements have been added for replacement windows. The duct sealing requirements have been revised. None of these changes affect the methodology used to develop RES*check*. The 2003 IECC (ICC 2003) includes steel-frame joist/rafter assembly ceilings, steel-frame truss assembly ceilings, and steel-frame floors over unheated spaces.

# 3.0 Methodology Summary

Users can use one of the three RES*check* products (prescriptive packages, software, or trade-off worksheet) to demonstrate compliance with the MEC thermal envelope $U_o$[(a)] (thermal transmittance) requirements. We developed all three approaches to use trade-offs of energy efficiency measures against each other, allowing a wide variety of building designs to comply with the code.[(b)] Trade-offs allow parts of a residential building to not meet individual MEC envelope component requirements if other components exceed the requirements, as long as the annual energy consumption does not increase (the code allows these trade-offs). The RES*check* materials thus promote design flexibility while still meeting code requirements.

The code's component performance approach (Chapter 5) specifies maximum $U_o$-factor requirements for walls, ceilings, floors, crawl space walls, and basement walls, and minimum R-value requirements for slab perimeter insulation. Section 502.1.1 of the MEC and Section 502.2.2 of the IECC state that the $U_o$-factor or U-factor of a given assembly may be increased or the R-factor of a given assembly may be decreased if the total heat gain or loss for the entire building does not exceed the total resulting from conformance to these requirements. Chapter 4 of the code goes even further by allowing any design that does not increase annual energy consumption relative to the component performance approach of Chapter 5 to comply (the code addresses space heating and cooling and water heating).

The RES*check* products are heavily based on U-factor x Area (UA, the heat loss/gain rate) calculations for each building assembly to determine the whole-building UA for the building design. The whole-building UA from a building conforming to the code requirements (the code building) is compared against the UA from the user's building design (the proposed building). If the total heat loss (represented as a UA) through the envelope of the user's building design does not exceed the total heat loss from the building conforming to the code, then the user's design passes. The following equation is used to compute both the UA for the user's proposed building and the UA for the code building:

$$\text{Whole-Building UA} = U_1 \times \text{Size}_1 + U_2 \times \text{Size}_2 + \ldots + U_n \times \text{Size}_n \qquad (3.1)$$

where $U_n$ = the U-factor or F-factor of component n (component U-factors and F-factors may be different for the proposed and code buildings).

$\text{Size}_n$ = the area ($ft^2$) or the perimeter (ft) of component n (component sizes are the same for both the proposed and code buildings).

(a) Throughout this document, the term "$U_o$" is the overall *conductive* thermal transmission coefficient of an envelope component or the envelope of the entire residential structure. This coefficient excludes, for example, the effects of mechanical ventilation and natural air infiltration.

(b) In this document, "the code" refers to the 1992, 1993, and 1995 editions of the MEC (CABO 1992, 1993, and 1995) and the 1998, 2000, and 2003 editions of the IECC (ICC 1998, 2000, and 2003).

The prescriptive packages and software offer trade-offs for high-efficiency heating and cooling equipment.  This type of trade-off is allowed in Chapter 4 of the code.  This credit is applied as a percentage reduction of the user's proposed building UA.  Additional trade-offs are planned for future versions of the RES*check* materials.

# 4.0 Simplifying Miscellaneous Code Requirements

Some of the requirements in the code are presented as a function of climate and it is not readily apparent what specific requirement applies for any given location. To make the code simpler to use, these requirements are more clearly presented in the RES*check* materials. This section gives the technical basis for the simplified presentation of some of the code's miscellaneous requirements. These miscellaneous requirements are presented in the RES*check* software's *Inspection Checklist*. This section does not address the thermal transmittance requirements for the thermal envelope, which are covered in Sections 5.0 through 7.0.

## 4.1 Simplified Duct R-Value Requirements

The code requires that ducts be insulated, with some exceptions.

### 4.1.1 1992 MEC Duct Requirements

A calculation is required to determine the duct insulation R-value requirement in the 1992 MEC. This calculation is not intuitive and often results in a minimum R-value requirement that does not match the R-values of commercially available products. The R-value requirement can also vary within different locations in a house.

The required duct insulation R-value in the 1992 MEC is equal to the design temperature differential between the air in the duct and the duct surface temperature divided by 15.

$$\text{Insulation R - Value} = \frac{\Delta t}{15} \qquad (4.1)$$

where $\Delta t$ = the design temperature differential between the air in the duct and the duct surface in degrees Fahrenheit (°F).

Because of the complexity in determining the 1992 MEC duct insulation requirements, we established a simple table of minimum duct insulation R-values for RES*check*. These R-values depend on duct location and climate zone.

To establish simplified duct insulation requirements, we made assumptions about the temperatures of conditioned air in ducts and the air outside the ducts. We assumed supply ducts contain 130°F air in the heating season and 60°F air in the cooling season, and return ducts contain 70°F air in the heating season and 75°F air in the cooling season. We obtained design temperatures at 2.5% and 97.5% conditions for approximately 700 U.S. locations (ASHRAE 1993). As specified in Table 503.9.1 of the 1992 MEC, the heating season attic temperature was set to 10°F above the outdoor design temperature. This same temperature was used for ducts located in crawl spaces. Unheated basement temperatures were assumed to be halfway between 70°F and the outdoor design temperature in the heating season. For the cooling season, attic temperatures were set at 140°F, as specified in Table 503.9.1 for attics with moderate roof slopes. For crawl spaces and basements, cooling season temperature differences between duct air and outside duct surfaces are small. The minimum duct insulation requirements are therefore determined by heating season temperature differences.

We calculated minimum duct R-value requirements based on the temperatures described above. We grouped all ducts together, except for ducts in unheated basements. We rounded these R-values to match commonly available duct insulation products. We set unheated basement R-value requirements to R-6 in Zone 1, although R-4 is required, to simplify the duct R-value table. This setting will have little effect because few buildings with basements are built in Zone 1, which includes southern Florida and Hawaii (NAHB 1991). We set return duct R-value requirements equal to supply duct requirements for simplicity and to reduce confusion at the building site. Note that the total surface area of return ducts is typically much smaller than the total surface area of supply ducts.

### 4.1.2 1993 and 1995 MEC and IECC Duct Requirements

The duct insulation requirements in the 1993 and 1995 MEC and the 1998 and 2000 IECC differ from those in the 1992 MEC. The insulation R-value requirements in these later four editions are identical to those in *ASHRAE/IES Standard 90.1-1989* (ASHRAE 1989b). These codes contain a table with separate R-value requirements for ducts inside the building envelope boundary or in unconditioned spaces, and ducts outside the building. For ducts inside the building envelope boundary or in unconditioned spaces, R-5 is required when the temperature difference between the heated or cooled air in the duct and the temperature at design conditions of the space where the duct is located is 40°F or more. Because temperatures of heated air in ducts will exceed 100°F (except perhaps for heat pumps) and temperatures in unconditioned spaces (e.g., unheated basements, crawl spaces, and attics) will normally drop below 60°F during the winter, we assumed a temperature difference of 40°F to occur in all climate zones. Therefore, R-5 insulation is required. The 40°F difference will also occur for ducts in attics during the summer in most climates.

For ducts outside the building, the duct R-value requirements depend on both cooling degree-days (CDD), base 65°F, and heating degree-days (HDD), base 65°F. We determined average CDDs (weighted by housing starts) for each of the 19 U.S. climate zones from climate data for 881 cities. Note that in Table 2 of the RES*check* Basic Requirements Guide, the requirements in Zones 5 through 14 are actually lower than the requirements in Zones 1 through 4 because the CDD values in Zones 1 through 4 result in higher R-value requirements for cooling mode than for heating mode.

### 4.1.3 2003 IECC Duct Requirements

In the 2003 IECC, the duct requirements were changed to differentiate between supply and return ducts. The requirements are listed in Table 4.1.

**Table 4.1.** 2003 IECC Duct Requirements

| | Insulation R-Value | | | |
|---|---|---|---|---|
| | Ducts in unconditioned attics or outside building | | Ducts in unconditioned basements, crawl spaces, garages, and other unconditioned spaces | |
| **Annual Heating Degree Days** | **Supply** | **Return** | **Supply** | **Return** |
| < 1500 | 8 | 4 | 4 | 0 |
| 1,500 to 3,500 | 8 | 4 | 6 | 2 |
| 3,501 to 7,500 | 8 | 4 | 8 | 2 |
| > 7500 | 11 | 6 | 11 | 2 |

## 4.2 Simplified Vapor Retarder Exemption

Section 502.1.4 of the 1992, 1993, and 1995 MEC, Section 502.1.2 of the 1998 IECC, and Section 502.1.1 of the 2000 and 2003 IECC require that vapor retarders be installed on the warm-in-winter side of the thermal insulation in walls, ceilings, and floors. The following locations in hot and humid climates are exempted from this requirement:

- locations where 67°F or higher wet-bulb temperatures occur for 3000 or more hours during the warmest six consecutive months of the year, or

- locations where 73°F or higher wet-bulb temperatures occur for 1500 or more hours during the warmest six consecutive months of the year.

Most builders and code officials will not have access to temperature data of this type and will therefore be unable to determine whether a building qualifies for the exemption.

To simplify this exemption, we evaluated Test Reference Year (TRY) and Weather Year for Energy Calculation (WYEC) data for over 200 locations. Based on these data, locations exempted from the vapor retarder requirement on the warm-in-winter side of the wall were presented by state and climate zone. (The climate zones, presented in the maps that accompany the Prescriptive Packages, fall along county boundaries [DOE 1995b].)

The TRY and WYEC data provided annual totals of all hours above the cutoff wet-bulb temperatures and all the hours were assumed to occur in the warmest six consecutive months of the year. All cities in Florida, Hawaii, Louisiana, and Mississippi had more than the required number of hot and humid hours, therefore qualifying for the exemption. Six states had some locations that qualified for the exemption and some locations that did not qualify. Table 4.2 shows the number of hours at or above the cutoff wet-bulb temperatures for cities in these six states with the HDD for each city. All other states had no locations that qualified for the exemption. Based on the results shown in Table 4.2, we selected climate zones in the six southern states that qualify for the exemption.

**Table 4.2.** Locations Not Requiring Vapor Retarders on Warm-in-Winter Side

| Location | Number of Hours Wet-Bulb Temperature At or Above 67°F | Number of Hours Wet-Bulb Temperature At or Above 73°F | HDD, Base 65°F |
|---|---|---|---|
| Alabama | | | |
| Mobile | 3975 | 2182 | 1702 |
| Montgomery | 3281 | 1859 | 2224 |
| Arkansas | | | |
| Fort Smith | 2993 | 1548 | 3478 |
| Little Rock | 3070 | 1874 | 3155 |
| Florida | | | |
| All locations | -- | -- | -- |
| Georgia | | | |
| Augusta | 3088 | 1398 | 2565 |
| Macon | 3173 | 1420 | 2334 |
| Savannah | 3585 | 1959 | 1847 |
| Hawaii | | | |
| All locations | -- | -- | -- |
| Louisiana | | | |
| All locations | -- | -- | -- |
| Mississippi | | | |
| All locations | -- | -- | -- |
| North Carolina | | | |
| Cape Hatteras | 3270 | 1826 | 2698 |
| Cherry Point | 3235 | 1494 | 2556 |
| South Carolina | | | |
| Charleston | 3581 | 1918 | 1866 |
| Columbia | 3139 | 1547 | 2242/2649 |
| Texas | | | |
| Austin | 3908 | 2445 | 1688 |
| Brownsville | 5884 | 4109 | 635 |
| Dallas | 5505 | 4005 | 1016 |
| Del Rio | 3449 | 2140 | 2407 |
| Forth Worth | 4040 | 1783 | 1506 |
| Houston | 3147 | 1545 | 2407 |
| Kingsville | 4358 | 3009 | 1599 |
| Laredo | 5432 | 4030 | 911 |
| Lufkin | 4815 | 3205 | 1025 |
| Port Arthur | 4140 | 2527 | 1951 |
| San Antonio | 4299 | 2955 | 1499 |
| Sherman | 4109 | 2371 | 1644 |
| Waco | 3089<br>3621 | 1516<br>2139 | 289<br>2179 |
| Tennessee | | | |
| Memphis | 3244 | 1653 | 3082 |

# 5.0 Software Approach

The RES*check* software performs a simple UA calculation for each building assembly in the user's proposed building to determine the overall UA of the building (DOE 1995c). The UA that would result from a building conforming to the envelope component requirements in Chapter 5 of the MEC and IECC is compared against the UA for the proposed building (CABO 1992, 1993, 1995; ICC 1998, 1999). If the total envelope UA of the proposed building does not exceed the total envelope UA for the same building conforming to the code, then the software declares that the building complies. Additionally, the software allows credit for space heating and cooling equipment efficiencies above the code minimums.

In addition to meeting the UA compliance some locations must also meet a solar heat gain coefficient (SHGC) compliance for the fenestration components of a building. This requirement will be in effect when the heating degree days (base 65) is less than 3500 and the selected code is 1998 IECC, 2000 IECC, 2003 IECC, or one of the state-based codes that are based on either of these codes.

Sections 5.1 through 5.3 describe the methodology used by the RES*check* software in determining the UA for the proposed building, the code building, and individual building components. Section 6.4 fully describes the solar heat gain compliance requirement. The last section briefly discusses the weather data used in the software.

## 5.1 Proposed Building UA Calculation

Equation (3.1) in Section 3.0 is used to compute whole-building UAs. Although this equation uses envelope component $U_o$-factors, the RES*check* software does not allow the user to enter these $U_o$-factors directly (except for glazing and door assemblies and "other" assembly types). Table 5.1 lists all of the construction types offered by the software and shows which inputs are required ("x") by the software to establish the component $U_o$-factors and sizes used in Equation (3.1). The calculations for determining component $U_o$-factors from the insulation R-values are described in Appendix A.

## 5.2 Code Building UA Calculation

The overall UA for the proposed building is compared against the UA from a building just meeting the code requirements, referred to here as the "code building" (the dimensions entered by the user apply to both the proposed building and the code building). The code building $U_o$-factors for each envelope component are determined by the code requirements (Chapter 5 of the MEC and IECC).

Table 5.2 correlates each building component allowed by the RES*check* software and its corresponding requirement as given in figures near the end of the MEC. All MEC requirements for the components listed below are given in terms of component $U_o$-factors, with three exceptions: 1) the slab requirements are given as an insulation R-value, 2) the basement and crawl space wall requirements are given as the U-factor of the wall components and surface air films, and 3) the MEC gives a credit to high-mass walls (e.g., log, concrete) such that they have less-stringent $U_o$-factor requirements than low-mass walls (e.g., wood-frame walls).

**Table 5.1**. Construction Types Offered by RES*check* Software and Required Inputs

| Component Description | Cavity Insulation R-Value | Continuous Insulation R-Value | Assembly U-Factor | Size |
|---|---|---|---|---|
| Ceiling Assemblies | | | | |
| Flat Ceiling or Scissor Truss | x | x | | Gross Area ($ft^2$) |
| Cathedral Ceiling (no attic) | x | x | | Gross Area ($ft^2$) |
| Raised or Energy Truss | x | x | | Gross Area ($ft^2$) |
| Structural Insulated Panels (SIPs) | | x | | Gross Area ($ft^2$) |
| Other | x | | x | Gross Area ($ft^2$) |
| Above-Grade Walls | | | | |
| Wood Frame, 16 in. O.C. | x | x | | Gross Area ($ft^2$) |
| Wood Frame, 24 in. O.C. | x | x | | Gross Area ($ft^2$) |
| Steel Frame, 16 in. O.C. | x | x | | Gross Area ($ft^2$) |
| Steel Frame, 24 in. O.C. | x | x | | Gross Area ($ft^2$) |
| Solid Concrete or Masonry | | | | |
| Exterior Insulation | x | x | | Gross Area ($ft^2$) |
| Interior Insulation | x | x | | Gross Area ($ft^2$) |
| No Insulation | | | | Gross Area ($ft^2$) |
| Masonry Block with Empty Cells | | | | |
| Exterior Insulation | x | x | | Gross Area ($ft^2$) |
| Interior Insulation | x | x | | Gross Area ($ft^2$) |
| No Insulation | | | | Gross Area ($ft^2$) |
| Masonry Block with Integral Insulation | | | | |
| w/ Additional Exterior Insulation | x | x | | Gross Area ($ft^2$) |
| w/ Additional Interior Insulation | x | x | | Gross Area ($ft^2$) |
| w/ No Additional Insulation | | | | Gross Area ($ft^2$) |
| Log (5 to 16-in. diameters) | x | | | Gross Area ($ft^2$) |
| Structural Insulated Panels | | x | | Gross Area ($ft^2$) |
| Insulated Concrete Forms | | x | | Gross Area ($ft^2$) |
| Other | | | x | Gross Area ($ft^2$) |
| Basement and Crawl Space Walls[a] | | | | |
| Solid Concrete or Masonry | x | x | | Gross Area ($ft^2$) |
| Masonry Block with Empty Cells | x | x | | Gross Area ($ft^2$) |
| Masonry Block with Integral Insulation | x | x | | Gross Area ($ft^2$) |
| Wood Frame | x | x | | Gross Area ($ft^2$) |
| Insulated Concrete Forms | | x | | Gross Area ($ft^2$) |
| Other | | | x | Gross Area ($ft^2$) |
| Floors | | | | |
| All-Wood Joist/Truss | x | x | | Gross Area ($ft^2$) |
| Slab-On-Grade[b] | | x | | Perimeter (ft) |
| Structural Insulated Panels | | x | | Gross Area ($ft^2$) |
| Other | | | x | Gross Area ($ft^2$) |
| Windows, Skylights, Doors | | | | |
| Windows | | | x | Assembly Area ($ft^2$) |
| Skylights | | | x | Assembly Area ($ft^2$) |
| Doors | | | x | Assembly Area ($ft^2$) |

(a) The user is required to enter the wall height, depth below grade, and depth of insulation on the wall for basement and crawl space constructions, as well as the depth below inside grade for crawl space walls.
(b) The user is required to enter the depth of the installed insulation.

**Table 5.2**. MEC and IECC Building Component Requirements

| Component Description | MEC/IECC Requirement | 1992 MEC Figure Number | 1993 and 1995 MEC Figure Number | 1998 and 2000 IECC Figure Number |
|---|---|---|---|---|
| Ceilings | Roof/Ceilings | Fig. 2 | Fig. 2 | Fig 502.2 (2) |
| Stress-Skin Ceiling Panels | Roof/Ceilings | Fig. 2 | Fig. 2 | Fig 502.2 (2) |
| Wood- or Metal-Frame Walls | Walls | Fig. 1 | Fig. 1 | Fig. 502.2 (1) |
| Concrete, Masonry, or Log Walls | Walls With Mass Credit | Fig. 1, Tables 502.1.2a,b, and c | Fig. 1, Tables 502.1.2a,b, and c | Fig. 502.2 (1) Fig. 502.1.1 (1998 IECC) |
| Stress-Skin Wall Panels | Walls | Fig. 1 | Fig. 1 | Fig. 502.2.1.1.2 (2000 IECC) |
| Windows and Glass Doors | Walls | Fig. 1 | Fig. 1 | Fig. 502.2 (1) |
| Skylights | Roof/Ceilings | Fig. 2 | Fig. 2 | Fig. 502.2 (2) |
| Opaque Doors | Walls | Fig. 1 | Fig. 1 | Fig. 502.2 (1) |
| Floor Over Unheated Spaces | Floor Over Unheated Spaces | Fig. 6 | Fig. 4 | Fig. 502.2 (4) |
| Floor Over Outdoor Air | Roof/Ceilings | Fig. 2 | Fig. 2 | Fig. 502.2 (2) |
| Heated Basements | Basement Walls | Fig. 8 | Fig. 6 | Fig. 502.2 (6) |
| Heated or Unheated Slab | Slab-On-Grade | Fig. 3 | Fig. 3 | Fig. 502.2 (3) |
| Heated Crawl Spaces | Crawl Space Walls | Fig. 7 | Fig. 5 | Fig 502.2 (5) |

## 5.3 Individual Component UA Calculations

To compute the whole-building UA, a UA must first be established for each component listed by the user (multiple entries of the same component type may be listed). In general, the $U_o$-factor for all components except glazing, doors and "other" assembly types is computed based on an insulation R-value entered by the user. For some components, R-values for cavity insulation and continuous insulation are entered separately. Many construction assumptions are defaulted (supplied by the software). The calculations used for each component $U_o$-factor and the assumptions used to arrive at these calculations are described in Appendix A. The following sections describe the inputs expected by the software for each calculation, and how the inputs are used in the UA calculation.

Table 5.3 lists the limitations on these inputs—if the user tries to enter a value outside the ranges specified in this table, RES*check* issues a warning message and restores the number to its previous value.

### 5.3.1 Ceiling UA

The $U_o$-factor for ceilings is computed based on the cavity insulation R-value and the continuous insulation R-value (if used), which are entered by the user. Section A.1 in Appendix A describes this computation.

**Table 5.3**. Input Ranges Allowed by RES*check* Software

| Type of Input | Allowable Range |
|---|---|
| Cavity Insulation R-Value | 0 – 60 |
| Continuous Insulation R-Value | 0 – 40 |
| Glazing and Door U-Factor | >0.0 – 2.00 (0.0 is invalid) |
| Basement Wall Height | 0 – 12 ft |
| Basement Insulation Depth | 0 – 12 ft |
| Basement Depth Below Grade | 0 – 12 ft |
| Slab Insulation Depth | 0 – 6 ft |
| Crawl Space Wall Height | 0 – 7 ft |
| Crawl Space Insulation Depth | 0 – 7 ft |
| Crawl Space Depth Below Grade | 0 – 7 ft |
| Crawl Space Inside Depth Below Grade | 0 – 7 ft |

### 5.3.2 Wall UA

The $U_o$-factor for all frame walls is based on the R-value of cavity insulation and the continuous insulation R-value (if used). Section A.2 in Appendix A describes this computation. If the user does not enter a continuous insulation (sheathing) R-value (or enters a value of 0.0), the software assumes a sheathing R-value of 0.83. This default value gives credit for some minimal type of sheathing material (such as plywood) under the siding. The continuous insulation is assumed to cover 80% of the building, with the other 20% being covered by structural sheathing (also defaulted to R-0.83).

### 5.3.3 Mass Wall UA

This section explains how the RES*check* software incorporates the credit the code gives to high-mass walls. Section A.2.3 of Appendix A explains how $U_o$-factors for common types of high-mass walls are calculated for the proposed building (i.e., "Your UA") in the software.

In most locations, the code allows walls having a heat capacity greater than or equal to 6 Btu/ft$^2$·°F to have a higher $U_o$-factor than low-mass wood- or metal-frame walls (see Tables 502.1.2a-502.1.2c of the MEC; Tables 502.1.1(1)-502.1.1(3) of the 1998 IECC; and Tables 502.2.1.1.2(1)-502.2.1.1.2(3) of the 2000 and 2003 IECC). Masonry or concrete walls weighing at least 30 lb/ft$^2$ and solid-wood walls weighing at least 20 lb/ft$^2$ are eligible for this credit (the area to be considered is the exterior surface area of the mass wall). In the software, eligible mass wall components receive this credit as an increase in the code building UA (the mass wall required $U_o$-factor is greater than the low-mass wall required $U_o$-factor). Brick veneers or log walls constructed of logs less than 7 in. thick currently do not receive this credit.

The $U_o$-factor for all mass walls except log walls is based on the R-value of the insulation, the type of mass wall (solid concrete or block masonry), and the location of the insulation (exterior or interior). For log walls, the $U_o$-factor is based on the thickness of the logs plus any additional insulation that might be used. (The area considered is the exterior surface area of the mass wall.) Section A.2.3 in Appendix A describes the computation for determining mass wall $U_o$-factors. The methodology used to incorporate the increase in wall $U_o$-factor allowable for high-mass walls into the RES*check* software is discussed below.

#### 5.3.3.1 Determine Opaque Wall Requirement

The net opaque wall requirement ($U_w$) is used to determine the amount of credit given for mass walls. As shown in Equation (5.1), the $U_w$ for mass walls is determined from the low-mass wall $U_o$ requirement from Figure 1 of the MEC or Figure 502.2(1) of the IECC and the wall, window, and door components the user has entered.

$$U_w = \frac{U_{o_{MEC}} \text{ x } A_o - U_g \text{ x } A_g - U_d \text{ x } A_d}{A_w} \qquad (5.1)$$

where $U_w$ = opaque wall requirement
$U_{o_{MEC}}$ = gross wall requirement from Figure 1 in the MEC or Figure 502.2(1) in the IECC
$A_o$ = sum of the areas of all wall, door, and window components
$U_g$ = proposed glazing U-factor (the "$U_g$ x $A_g$" term may be expanded to include several glazing components)
$A_g$ = total glazing area
$U_d$ = proposed door U-factor (the "$U_d$ x $A_d$" term may be expanded to include several door components)
$A_d$ = total door area
$A_w$ = net opaque wall area, including mass and other (nonmass) wall components.

#### 5.3.3.2 Determine Gross Wall UA

Once the $U_w$ requirement is determined, the adjusted $U_w$ requirement for mass walls ($U_{w_{ADJUSTED}}$) is obtained from Tables 502.1.2a-502.1.2c of the MEC; Tables 502.1.1(1)-502.1.1(3) of the 1998 IECC; and Tables 502.2.1.1.2(1)-502.2.1.1.2(3) of the 2000 IECC. The $U_w$ requirement is given as the top row of each of these three tables. The adjusted $U_w$ is determined from these tables by reading down the column that the $U_w$ falls into to the row with the proper HDD. If the $U_w$ falls outside the range of the tables (0.04 to 0.20 in the MEC and 1998 IECC; 0.04 to 0.24 in the 2000 IECC), the $U_w$ adjustment for the closest $U_w$ in the table is used. This adjusted $U_w$ will be higher than the $U_w$ determined from Equation (5.1) for all but very cold climates. Note that the code tables have $U_w$ requirements in discrete steps of 0.02. When the $U_w$ falls between columns in the table, the $U_{w_{ADJUSTED}}$ is found by interpolation.

The $U_o$-factor used for the mass walls in increased by the difference between $U_{W_{ADJUSTED}}$ and $U_w$:

$$\text{NEW MASS WALL Uo} = U_{O_{MEC}} + (U_{W_{ADJUSTED}} - U_w) \qquad (5.2)$$

where $U_{O_{MEC}}$ = gross wall requirement (from MEC Figure 1 or IECC Figure 502.2(1))

$U_{W_{ADJUSTED}}$ = opaque mass wall requirement from tables

$U_w$ = opaque wall requirement before adjusting (from Equation 5.1).

### 5.3.4 Floor-Over-Unheated-Space UA

The $U_o$-factor for floors over unheated spaces is based on the R-value of the cavity and/or continuous insulation. Section A.3 in Appendix A describes this computation.

### 5.3.5 Basement Wall UA

The basement wall code requirement applies only to the net basement wall area (not including basement windows and/or doors).

In determining compliance with the basement wall U-factor requirements, Footnote 5 in Table 502.2.1 of the MEC and Footnote e in Table 502.2 of the IECC specifies that the basement wall U-factor calculation be based on the R-values of only the wall components and surface air films. Adjacent soil is not considered when computing the basement wall U-factor. However, because the soil will affect annual energy consumption, RES*check* accounts for the heat flow through the adjacent soil in the proposed building. Note that the code building U-factor requirement for basement walls is also adjusted for soil resistance, so that the heat transfer from the proposed building basement wall and the code building basement wall are consistently calculated. Section A.4 in Appendix A describes the basement wall U-factor computation. The software uses the R-value of the insulation, the wall height, the depth below grade, and the depth of the insulation as inputs into this computation.

Section 502.2.1.6 of the 1992 MEC and Section 502.2.6 of the 1993 and 1995 MEC state the following:

> The exterior walls of basements below uninsulated floors shall have a transmittance value not exceeding the value given in Table No. 502.2.1 to a depth of 10 feet below the outside finish ground level, or to the level of the basement floor, whichever is less.

Section 502.2.1.6 of the IECC contains similar text.

It appears that the code does not allow for or give any credit to basement walls insulated only part way down the wall. However, note that the insulation depth requirement is given in relation to Table 502.2.1, where the basement wall U-factor requirement appears. This presentation implies that the insulation depth requirement is intended to clarify the U-factor requirement for basement walls.

The basement wall with insulation only part way down can be considered to be two “assemblies” (the top part insulated and the bottom part not insulated), with a distinct UA for each assembly. This situation is permissible if the total heat loss for the entire building (the overall UA) remains the same or is reduced; i.e., if this lack of insulation at the bottom of the basement wall is adequately compensated for by extra insulation in any other part of the building envelope. Therefore, the software allows for and gives credit to basement walls insulated from the top of the wall to any depth (i.e., full basement wall insulation is not required). The basement UA for the code building is calculated assuming the insulation goes the full depth of the basement wall.

### 5.3.6 Crawl Space Wall UA

As with basements, a footnote in the code specifies crawl space wall U-factor requirements that are based on the resistance of only the wall components and surface air films. Adjacent soil is not considered, although it impacts the heat flow. However, when computing the U-factor of crawl space wall components, the software accounts for the heat flow through the adjacent soil for the same reason given above for basement walls. Section A.5 in Appendix A describes this computation. The software uses the R-value of the insulation, the wall height, the depth below grade, the depth below inside grade, and the depth of the insulation as inputs into this computation.

### 5.3.7 Slab-On-Grade Floor UA

If a slab-on-grade floor component (referred to as "slab") is selected, the user is required to enter the slab floor perimeter. RES*check* computes an F-factor for slab assemblies based on the R-value of the slab insulation and the depth of the insulation. An F-factor is the heat loss rate through the slab per foot of perimeter (Btu/ft·h·°F). Section A.6 in Appendix A describes this computation. For the proposed building, the user may enter any insulation depth from 0 to 6 ft. If the insulation will actually extend beyond 4 ft, the user does not receive any additional credit toward compliance. For the code building, the depth is either 2 ft (for locations with less than 6000 HDD) or 4 ft (for locations with equal to or more than 6000 HDD).

The code specifies requirements for slab floors in terms of the R-value of the slab insulation and the depth of the insulation. To directly compare the slab F-factor computed by RES*check* with the required R-value as specified by the code, the code R-value requirement is converted to an equivalent F-factor. For the code building, the code R-value requirement and the required insulation depth are used as inputs into the RES*check* slab F-factor calculation (Section A.6 in Appendix A). For the proposed building, the insulation R-value and depth of insulation entered by the user are the inputs into the RES*check* slab F-factor calculation.

## 5.4 Solar Heat Gain Compliance

In addition to meeting the UA compliance some locations must also meet solar heat gain coefficient (SHGC) compliance for the fenestration components of a building. This requirement will be in effect when the heating degree days (base 65) is less than 3500 and the selected code is 1998 IECC, 2000 IECC, or one of the state-based codes that are based on either of these codes.

To meet SHGC compliance the area-weighted average SHGC for a proposed building must be less than or equal to 0.40 as documented in the 1998-2002 IECC codes. The user is responsible for entering the SHGC value for each window, skylight, and/or glass door. The SHGC for each assembly type is area-weighted then averaged for the building as a whole.

All SHGC required codes allow adjustments to be made to the area-weighted average SHGC when overhang projections exist and/or, in the case of the Georgia 2004 code, when a shade screen exists. An overhang projection is represented as the ratio of width of the overhang (from exterior of wall to edge of overhang) over height as measured from the bottom of the overhang to the bottom of the fenestration component.

The adjustment to SHGC for overhang projections is based on work developed by the Technical Evaluation Committee for ASHRAE Special Project 53, under subcontract to PNNL in 1985-1988. The underlying data source was the ARES database. This work produced a set of multipliers specific to eight orientations along with a regression analysis based simplified formula. The relative orientation of the component with respect to “North” is first determined in order to select the correct set of coefficients to apply to the simplified multiplier formula. With the selected coefficients applied along with the glazing component projection factor, a multiplier results that can be applied to the component proposed SHGC. Note that projection factors do not apply to skylights.

The multipliers and formula to be applied to the projection factor are:

$$\text{multiplier} = \exp(A * \text{atan}(PF)) + M0 - 1$$

where the multipliers MO and A vary by orientation as follows:

| Orientation | M0 | A |
|---|---|---|
| N | 1.033182 | -0.0908 |
| NE/NW | 1.121773 | -0.4656 |
| E/W | 1.162932 | -0.7521 |
| SE/SW | 1.232682 | -1.0165 |
| S | 1.323909 | -1.3817 |

The adjustment process will occur when a request for the building average adjusted SHGC is requested. The process will loop through all applicable glazing components and for each in turn, compute the projection factor multiplier, factor in the shade screen multiplier depending on its specification then compute the adjusted area-weighted proposed SHGC and sum this into a running total that is then divided by the total fenestration area when all components have been processed.

## 5.5 Weather Data Used in the Software

The RES*check* software can be set up so the user can select from a list of cities or a list of counties in each state. The “cities” version contains HDD and CDD values for over 22,000 cities. The HDD values are used to determine the requirements for that city, as well as the high-efficiency heating and cooling equipment credit (see Section 6.0). The CDD value is only used to restrict the cooling efficiency credit from some California coastal locations (see Section 6.0). The “counties” version requires the user to select a county, not a city.

The cities’ weather data included with the software comes from the Populated Places database which is part of the Geographic Names Information System of the U.S. Geological Survey (USGS 2000) The methodology for selecting locations to include in the software was principally determined on population estimates. More specifically, if a location had a “<1” designator (which indicates low or unknown population) then it was not included in the final list of locations. A complete discussion of the methodology can be found in the supporting document addressing Weather/Location analysis and selection.

# 6.0 Equipment/Envelope Trade-Off

This section describes the methodology for trading increased heating or cooling efficiency for lowered envelope efficiency used in the RES*check* software. The insulating efficiency of the building envelope is measured, in all cases, by the overall coefficient of thermal transmission, $U_o$.[(a)]

For both AFUE and SEER trade-offs, the method identifies the appropriate relaxation in the required $U_o$[(b)] for a given improvement in equipment efficiency so that the overall energy consumption of a building complying via the trade-off is equal to or less than that of a building complying with the code. We refer to this condition of balance between a code-complying building and a modified-efficiency building as energy neutrality. The code allows such trade-offs if energy neutrality is preserved in terms of *site* energy consumption. All trade-offs are therefore designed to satisfy the following equation:

$$\frac{HeatLoad_{std}}{AFUE_{std}} + \frac{CoolLoad_{std} \times 3.413}{SEER_{std}} = \frac{HeatLoad_{mod}}{AFUE_{mod}} + \frac{CoolLoad_{mod} \times 3.413}{SEER_{mod}} \quad (6.1)$$

where the std subscript refers to a building built to minimally meet the code criteria and the mod subscript refers to a building with modified features. If a heat pump is used, the measure of heating efficiency is HSPF instead of AFUE. Note that heating and cooling loads are adjusted for on-site equipment efficiencies but not for generation and transmission efficiencies.

Envelope insulation levels, glazing solar characteristics, glazing orientation, and other factors determine the heating and cooling loads. These loads are met by heating and cooling equipment assumed to have efficiencies (AFUE or SEER) consistent with NAECA minimums for the standard case and as installed for modified cases (42 USC 6291 et seq).

Determining the appropriate $U_o$ credit that should be granted for a particular increase in HVAC efficiency is somewhat complicated. For example, the effect of higher HVAC efficiency on cooling energy consumption is easily approximated by simple multiplication, but the effect of changing the $U_o$ is more complicated to estimate. The $U_o$ affects both heating and cooling loads in nonlinear ways.

Our approach to solving these problems was to evaluate the energy consumption of a hypothetical building with envelope $U_o$-factors just meeting the minimum code envelope criteria and with HVAC efficiencies equal to the NAECA minimums. We modified (improved) the HVAC efficiency, and then incrementally adjusted the other building features to find the $U_o$ increase that would just balance the total

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(a) Throughout this discussion, we use the term "$U_o$" as it is defined in the code–the overall *conductive* thermal transmission coefficient of a house. This coefficient excludes, for example, the effects of mechanical ventilation and natural air infiltration. This distinction is important when interpreting the allowable changes in $U_o$.

(b) Note that the "required" $U_o$ is really an implied requirement based on an aggregation of the individual building component $U_o$-factor requirements of the code. The overall $U_o$ used in developing trade-offs is computed as the area-weighted average of the component $U_o$-factors of a prototype house that approximates average U.S. construction.

energy consumption. We did this analysis for a range of climates and aggregated the results, to the extent possible, to obtain simple relationships that builders and code enforcement officials can easily use to determine compliance with the code.

In general, the resulting trade-off equation looks like the following:

$$\beta = \frac{\left(\dfrac{U_{o,\,adjusted} - U_{o,\,standard}}{U_{o,\,standard}}\right)}{\left(\dfrac{EFF_{adjusted} - EFF_{standard}}{EFF_{standard}}\right)} \tag{6.2}$$

where $U_{o,standard}$ = $U_o$-factor implied by code prescriptive criteria
$U_{o,adjusted}$ = $U_o$-factor allowed with higher equipment efficiency
$EFF_{standard}$ = NAECA minimum equipment efficiency
$EFF_{adjusted}$ = actual (higher) installed equipment efficiency
$\beta$ = trade-off ratio.

The parenthesized term in the denominator of Equation (6.2) can be thought of as the fractional (percentage) increase in HVAC efficiency (either AFUE or SEER) being proposed by a builder. The $\beta$ coefficient, which is the primary result of our efficiency trade-off analysis, adjusts that fractional increase in heating and cooling efficiency to give the appropriate fractional increase in $U_o$ that will result in equivalent overall (heating plus cooling) energy consumption. Rearranging Equation (6.2) gives the adjusted $U_o$ requirement for a proposed HVAC efficiency increase:

$$U_{o,\,adjusted} = U_{o,\,standard} \text{ x } \left[1 + \beta \text{ x} \left(\frac{EFF_{adjusted} - EFF_{standard}}{EFF_{standard}}\right)\right] \tag{6.3}$$

A $\beta$ term of one indicates a one-to-one correspondence between a percentage improvement in equipment efficiency and an allowable percentage increase in the envelope $U_o$. Section 6.1 describes the calculation of $\beta$ for both heating and cooling equipment.

## 6.1 Background and Assumptions

The trade-off procedures were developed using assumptions made for a prototype building and its estimated energy consumption based on a particular climate zone.

### 6.1.1 Select Prototype Building

We developed all trade-off procedures using a prototype building designed to exemplify typical construction practices in the United States. The single-family prototype building described in Section 5.2.3 was used with a window area equal to 15% of the gross wall area. The dimensions of the prototype approximate the average characteristics of new buildings rather than any particular building.

Changing the prototype has only a small effect on the resulting trade-off ratios. In developing the trade-off ratios, we considered only the crawl space foundation type, for which $U_o$ calculations are the simplest. This simplification is acceptable because the trade-off methodology is cast in terms of *percentage change* in the overall $U_o$, minimizing the differences in influence between various component types. Note that the shading coefficient is fixed at 0.88, regardless of the window U-factor. We assumed the building was built with good air-sealing practices, but without an air infiltration barrier, heat recovery ventilator, or other special infiltration-control measures. Although the average air infiltration rate varies by location because of temperature and wind dependencies, it is between roughly 0.35 and 0.5 air changes per hour (ACH). $U_o$-factors for the components vary by climate zone (see Section 6.2.3).

### 6.1.2 Estimate Energy Consumption

In estimating the energy consumption of our prototype building, we used the residential energy database contained within the Automated Residential Energy Standard (ARES) software (Lortz and Taylor 1989). The ARES database was developed from a large number of parametric simulations using DOE-2, a large hourly building energy simulation program (LBNL and LANL 1980). The database is based on simulations for 45 primary locations in the United States and is extended to an additional 836 locations using carefully selected HDD and CDD ratios as load multipliers.

Given building dimensions, component $U_o$-factors, glazing properties, and window orientations, ARES returns annual heating and cooling loads for a specified location (city). These loads are adjusted by the heating and cooling efficiencies, respectively, and then summed to obtain the total site energy consumption. This total is preserved by the trade-off methodologies.

In our development of trade-off procedures, we used data from all of the 881 ARES locations. These data covered a wide range of U.S. climates and provided a large enough sample to allow identification of meaningful functional relationships between climate parameters (e.g., degree-days, which are used by the code to define envelope requirements for a location) and the trade-off allowances.

### 6.1.3 Select Climate Zones

The RES*check* compliance tools define 19 climate zones in the United States. These zones (defined in terms of HDD, base 65°F) were selected to provide a wide range of U.S. climates and to coincide with important change points in the code requirements. Table 6.1 shows the zone definitions and the total number of ARES cities by climate zone.

## 6.2 Develop Equipment Efficiency Trade-Off

We used the same procedure used in the previous section to develop trade-off allowances for increased AFUE and SEER, using the following steps:

1. For each climate zone, identify a baseline building configuration that just meets the code requirements; calculate its overall coefficient of conductive heat transfer ($U_o$).

**Table 6.1**. ARES Cities Available for Each Climate Zone

| Climate Zone | HDD, Base 65°F, Range | Number of ARES Cities Available |
|---|---|---|
| 1 | 0-499 | 16 |
| 2 | 500-999 | 26 |
| 3 | 1000-1499 | 23 |
| 4 | 1500-1999 | 57 |
| 5 | 2000-2499 | 57 |
| 6 | 2500-2999 | 81 |
| 7 | 3000-3499 | 67 |
| 8 | 3500-3999 | 43 |
| 9 | 4000-4499 | 44 |
| 10 | 4500-4999 | 52 |
| 11 | 5000-5499 | 67 |
| 12 | 5500-5999 | 77 |
| 13 | 6000-6499 | 87 |
| 14 | 6500-6999 | 71 |
| 15 | 7000-8499 | 84 |
| 16 | 8500-8999 | 11 |
| 17 | 9000-12999 | 17 |
| 18 | 13000 - 13999 | 0 |
| 19 | 14000 + | 1 |

2. Calculate the total annual energy consumption of the baseline prototype in each of the 881 ARES cites, assuming NAECA minimum HVAC efficiencies.

3. For each of several possible increased HVAC efficiencies, identify how much the prototype's $U_o$ can be relaxed (increased) while keeping total annual energy consumption at or below that of the baseline prototype.

4. For each HVAC efficiency level, calculate the ratio of the fractional $U_o$ change to the fractional efficiency change, referred to as the trade-off ratio.

Each step is described below, with a presentation of the results for AFUE and SEER trade-offs.

### 6.2.1 Identify MEC Baseline

The first step in developing allowable $U_o$ increases in trade for HVAC efficiency improvements was to identify the baseline MEC requirements for each MEC climate zone and design a package of component options that minimally meet the 1992 MEC requirements when applied to our prototype. Although numerous building configurations will meet the 1992 MEC requirements in each zone, we selected only one configuration to serve as the baseline. Because the final trade-off procedure is designed in terms of percentage changes, this baseline is a reasonable simplification.

Table 6.2 shows the baseline packages used in the various climate zones. Each package has a maximum window area equal to 15% of the floor area, equally distributed on the four cardinal orientations. Note that the selected packages do not necessarily represent the minimum possible complying packages for the zones–other combinations of ceiling, wall, floor, and window options may exist that are less expensive to build, yet still comply with the code's $U_o$ requirement. Because our results are expressed in terms of allowable percentage changes, it is not crucial that the base case building exactly match the code's criteria–only that it be close.

### 6.2.2 Calculate Baseline Energy Consumption

We calculated annual heating and cooling loads for the base case building using the ARES energy database (Lortz and Taylor 1989). These loads were then directly divided, respectively, by the NAECA-minimum AFUE and SEER. We assumed, in all cases, that heating is provided by a gas furnace and cooling by an electric, direct-expansion air conditioner.

### 6.2.3 Identify Adjusted $U_o$

We identified the adjusted $U_o$ that ensures neutrality in a relatively simple manner. Because we intended to generalize the $U_o$ increase justified by a given HVAC efficiency increase, we did not constrain the $U_o$-factors of individual building components to correspond to discrete products. For example, we allowed the wall $U_o$-factor to correspond to something between R-13 and R-19, although no readily available products may exist that would result in the $U_o$-factor. Because different buildings will have different complying combinations of ceiling, wall, and floor insulation and window $U_o$-factors, it was not crucial that our analysis land on any particular combination.

**Table 6.2**. MEC Baseline Prototype Configurations

| Zone | Ceiling R-Value | Wall R-Value | Crawl Space R-Value | Window U-Factor | Overall $U_o$ |
|---|---|---|---|---|---|
| 1 | 13 | 11 | 11 | 1.07 | 0.136 |
| 2 | 11 | 11 | 11 | 0.75 | 0.120 |
| 3 | 13 | 11 | 11 | 0.75 | 0.117 |
| 4 | 19 | 11 | 11 | 0.70 | 0.108 |
| 5 | 19 | 13 | 11 | 0.60 | 0.099 |
| 6 | 19 | 13 | 19 | 0.55 | 0.088 |
| 7 | 19 | 13 | 19 | 0.50 | 0.085 |
| 8 | 30 | 13 | 13 | 0.45 | 0.082 |
| 9 | 30 | 13 | 19 | 0.45 | 0.077 |
| 10 | 30 | 13 | 19 | 0.40 | 0.074 |
| 11 | 30 | 13 | 19 | 0.35 | 0.071 |
| 12 | 38 | 15 | 19 | 0.35 | 0.068 |
| 13 | 38 | 15 | 26 | 0.35 | 0.064 |
| 14-19 | 38 | 19 | 30 | 0.40 | 0.061 |

To adjust the $U_o$ for a given HVAC efficiency change, we constrained all building components to change *together* in searching for an energy-neutral configuration. We established a reasonable upper boundary on the possible U-factor (lowest conceivable R-value) of each building component. We then incrementally changed all component $U_o$-factors by the same fraction *f* of the difference between the baseline $U_o$-factor and the reasonable upper limit, and calculated the resulting total annual energy consumption. We applied a simple nonlinear minimization algorithm to identify the value of *f* that achieved total consumption most nearly equal to that of the baseline. Thus, the adjusted $U_o$ was based on a house with slightly less insulation in the ceiling, walls, and floors, and with windows having a slightly higher U-factor. This procedure avoided problems of the differential impact of similar $U_o$-factor changes in ceilings and walls, for example.

The above procedure was applied independently for AFUE and SEER changes. We analyzed AFUE values of 80% through 100% (increases of 2.5% to 28.2% over the NAECA minimum) and SEER values of 11 through 14 (increases of 10% to 40% over the NAECA minimum). These values roughly represent the range of commonly available products. However, we observed no significant correlation between the magnitude of the efficiency increase and the resulting trade-off ratios.

## 6.2.4 Identify Trade-Off Ratios and HDD Relationships

### 6.2.4.1 Heating

For each of the ARES cities and each of several AFUE levels, we calculated the trade-off ratio according to Equation (6.2). Figure 6.1 shows a scatter plot of the results. Note that the trade-off ratio exceeds 1.0 for much of the United States. This result implies, for example, that a 10% increase in the AFUE justifies more than a 10% increase in the $U_o$. This apparently counterintuitive result stems from the code definition of $U_o$ that excludes the effects of infiltration. An AFUE increase affects energy use resulting from both the conductive loads and the infiltration loads. A change in insulation level affects only the conductive loads. If the trade-off ratio was defined in terms of the total building UA, including infiltration effects, we would expect the trade-off ratio to be less than 1.0.[a]

If the trade-off ratio is defined in terms of the total building UA (assuming an average infiltration rate of 0.35 ACH), the ratio asymptotically approaches 1.0 in the very cold locations, as expected [see Footnote (a)]. A few ratios exceeding 1.0 remain because the actual ACH implicit in the ARES energy database, based on DOE-2's calculations that include both temperature and wind effects, is not known exactly (LBNL and LANL 1980). The building tightness features were selected so that average air

(a) We would expect a ratio less than 1.0 because the heating load is a nonlinear function of the home's UA, which is because changing the UA changes a home's balance temperature—the outdoor temperature below which the home needs heat to maintain its temperature above the thermostat setpoint. Changing the balance point changes the appropriate base temperature to which degree-days must be calculated to accurately estimate energy consumption. In effect, changing the UA changes heating loads in two ways that compound one another—changing the UA changes the rate of heat loss from the building during heating hours and changes the number of heating hours. Thus, a certain percentage increase in the UA should result in a larger percentage increase in heating loads.

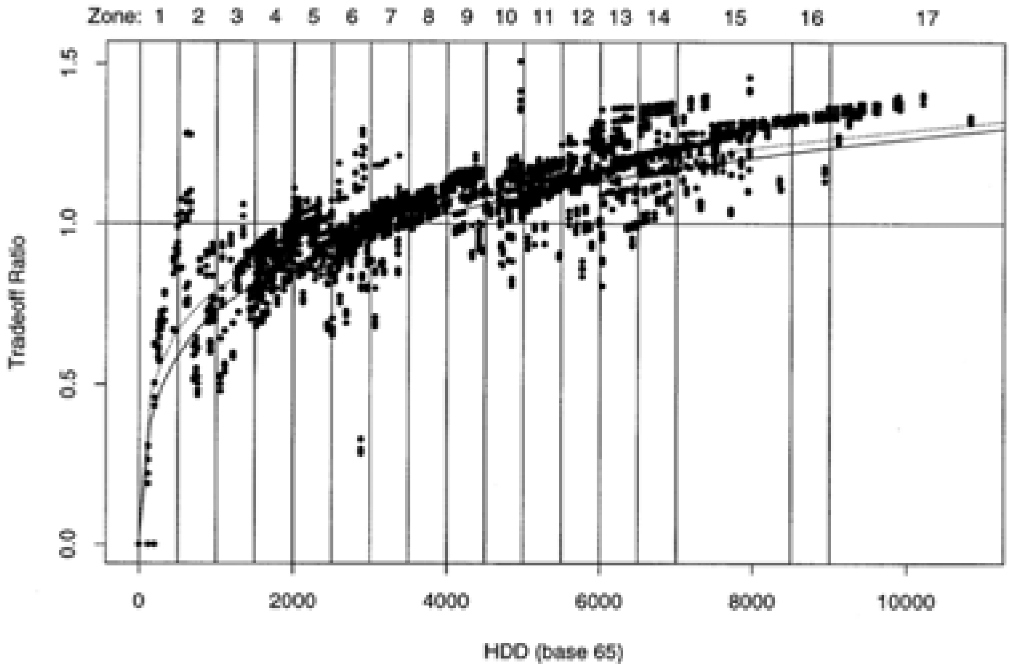


**Figure 6.1**. Heating Trade-Off Ratio vs. Heating Degree-Days

exchange rates would be close to 0.35 for most locations, but the rates are higher in many locations because the driving forces (e.g., wind, temperature difference) vary with climate.

A clear trend exists with respect to HDDs, although some scatter exists because of differences in solar, wind, summer temperature, and humidity characteristics between locations. The dotted line drawn through the points in Figure 6.1 is based on a linear regression of the trade-off ratio against a polynomial in the logarithm of HDDs:

$$\text{Trade-Off Ratio} = 0.0526 + 0.0225 \times \ln(\text{HDD} + 1) + 0.0122 \times [\ln(\text{HDD} + 1)]^{-2} \quad (6.4)$$

The regression predicts the adjusted $U_o$ requirement with an $R^2$ of 0.94.[a] The solid line is discussed in Section 6.2.5.

#### 6.2.4.2 Cooling

Figure 6.2 shows a similar scatter plot for the cooling trade-off ratio. The cooling ratio dramatically exceeds 1.0 in the very warm climates. This ratio is expected because an increase in air- conditioning efficiency impacts the total cooling load, only a small fraction of which is due to conductive heat gain through the building envelope. Increasing the $U_o$-factor in such cooling-dominated climates has little effect on overall cooling loads. The increase has a greater effect on heating loads, but the trade-off ratio

(a) An $R^2$ of 0.94 indicates that Equation (6.4) (and the dotted line plotted in Figure 6.1) is a good fit to the data points shown.

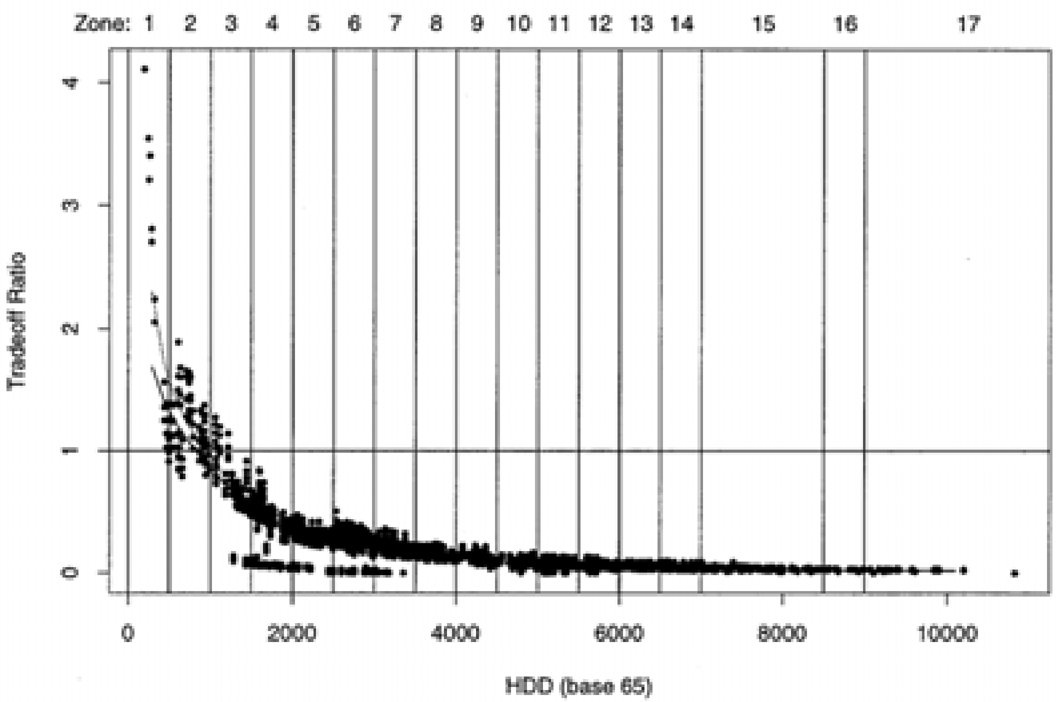


**Figure 6.2**. Cooling Trade-Off Ratio vs. Heating Degree-Days

can greatly exceed 1.0 where the heating loads are very small compared to the cooling loads. In practice, any advantages derived from increasing the $U_o$-factor to improve the cooling ratio are realized only in Hawaii and southern portions of Florida.

Note that the cooling trade-off ratio drops rapidly with increasing HDDs. In locations where heating dominates the loads, very little $U_o$ degradation is justified by an increase in SEER. The cloud of zero-ratio points near 1500 to 3000 HDD represents coastal cities of California. The Pacific influence on these cities gives them unusually small cooling loads relative to their heating loads. These coastal locations are clearly exceptions to the cooling trade-off ratio curve fit (shown by the line in Figure 6.2). These locations are treated as exceptions (county by county) in the various RES*check* trade-off materials. These locations are assigned the cooling trade-off ratio corresponding to Zone 17 (see below) in the software and receive no credit in the prescriptive packages and the trade-off approaches (the trade-off approach does not have any equipment/envelope trade-offs).

The dotted line drawn through the points on Figure 6.2 represents a nonparametric curve fit through the data. The fit is defined by a sequence of data pairs (i.e., HDD, trade-off ratio), so no equation for the line can be shown. Using the data pairs and linear interpolation between adjacent pairs, the fit predicts the adjusted $U_o$ requirement with an $R^2$ of 0.77. If data on additional climate variables (e.g., solar gains, humidity, and wind) were available for the ARES cities, a better-fitting equation could be developed. However, because the MEC recognizes only HDD in determining $U_o$ requirements, such an equation would have dubious value.

### 6.2.5 Aggregate Zones

To simplify implementing the trade-off procedure, it is often necessary to hold the trade-off ratio fixed within a particular climate zone or code jurisdiction. We produced such ratios for each of the 19 climate zones. A problem arose with the variation of trade-off ratios within a climate zone. We biased our selection of zonal ratios so that the resulting number of buildings in a zone that did not meet the code was minimized or at least guaranteed to be significantly smaller than the number of buildings that met or exceeded the code's base requirements. Some buildings did not meet the code for two reasons. First, the curve fits shown by the dotted lines in Figures 6.1 and 6.2 represent the average $U_o$ change justified by an efficiency increase as a function of HDD, but scatter clearly exists above and below the curves. Thus, in some locations the fit gives too much credit for efficiency improvements while in other locations with similar degree-days it gives too little credit. Second, the actual number of HDDs varies within each climate zone.

To address the first problem, we conducted a second regression analysis that gave more weight to the lower trade-off ratios than to the higher trade-off ratios. The ratios are weighted so that the lowest ratio in each climate zone gets 100% influence and the highest gets none. The weight for each city between the extremes was assigned linearly with respect to the percentile in which the city fell, resulting in the lowest 50% of the ratios having 75% of the influence on the fitted curve. The resulting regression equation for heating is

$$\text{Trade-Off Ratio} = 0.0148 + 0.0019 \times \ln(\text{HDD} + 1) + 0.0145 \times [\ln(\text{HDD} + 1)]^2 \qquad (6.5)$$

Equation (6.5) is shown as the solid line in Figure 6.1. We developed a second cooling curve in a similar manner. As before, the cooling curve fit was based on a nonparametric regression so no equation describing the curve fit exists. The cooling curve is shown as the solid line in Figure 6.2.

To account for varying degree-days within a zone, we based our zonal trade-off ratios on takeoffs from the regression curves at the "conservative" ends of each zone; i.e., we obtained the heating ratios by evaluating Equation (6.5) at the lower end of each zone's HDD range. We obtained cooling ratios by a takeoff from the solid line in Figure 6.2 at the upper end of each zone's HDD range. Note that the cooling ratios primarily affect the low-HDD climates. The results of these takeoffs are the zonal ratios we established as the primary implementation of our HVAC efficiency trade-off procedure (shown in Table 6.3).

**Table 6.3**. Zonal Trade-Off Ratios

| Zone | Heating Trade-Off Ratio | Cooling Trade-Off Ratio |
|---|---|---|
| 1 | 0.01 | 1.32 |
| 2 | 0.59 | 0.87 |
| 3 | 0.72 | 0.52 |
| 4 | 0.81 | 0.33 |
| 5 | 0.87 | 0.26 |
| 6 | 0.92 | 0.22 |
| 7 | 0.96 | 0.15 |
| 8 | 1.00 | 0.13 |
| 9 | 1.03 | 0.08 |
| 10 | 1.06 | 0.05 |
| 11 | 1.09 | 0.05 |
| 12 | 1.11 | 0.05 |
| 13 | 1.13 | 0.04 |
| 14 | 1.15 | 0.03 |
| 15 | 1.17 | 0.02 |
| 16 | 1.22 | 0.02 |
| 17-19 | 1.24 | 0.02 |

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# Appendix A

# Envelope Component $U_o$-Factor Calculations

# Appendix A

# Envelope Component $U_o$-Factor Calculations

Appendix A documents the assumptions and equations used in calculating the envelope component $U_o$-factors for the RES*check*™ compliance software, prescriptive packages, and trade-off worksheet (DOE 1995d, 1995c, and 1995b) for the 1992, 1993, and 1995 editions of the Model Energy Code (MEC) (CABO 1992, 1993, and 1995) and the 1998, 2000, and 2003 editions of the International Energy Conservation Code (IECC) (ICC 1998, 1999, and 2003). Envelope components consist of ceilings, above-grade walls, floors over unheated spaces, basement and crawl space walls, and slab-on-grade foundations.

The code[(a)] generally presents envelope component requirements in $U_o$-factors. The $U_o$-factor is a measure of the rate of conductive heat transfer per unit area of any material(s). For simplicity, the prescriptive package requirements are given in terms of R-values of insulating materials. The RES*check* software allows the user to specify most components in terms of R-values. The trade-off worksheet includes tables that allow the user to quickly ascertain an envelope component $U_o$-factor based on a building description and the R-value of the insulating materials. Specifying inputs and requirements in terms of R-value is advantageous because insulation R-values correspond to the products purchased by builders and inspected by code officials.

Several details of the envelope component construction can impact envelope component $U_o$-factors. To convert insulation R-values to overall component $U_o$-factors, assumptions must be made about the typical construction of the envelope components. Note that construction materials and techniques often vary from those assumed here and described below, but these differences will generally not have a significant impact on the resulting $U_o$-factors.

The general equation for calculating heat flow through building envelope components is

$$U_o = [U_1 \times \text{Area}_1 + U_2 \times \text{Area}_2 + ...] / [\text{Area}_1 + \text{Area}_2 + ...] \qquad \text{(A.1)}$$

where the subscripts identify different series of materials that present a different path of heat transfer; e.g., $\text{Area}_1$ is the area between the framing and $\text{Area}_2$ is the area of the framing. The U-factor is the inverse of the sum of all the material R-values for each path of heat transfer and includes the insulating value of surface air films. Equation (A.1) is sufficiently accurate unless any of the construction material is highly conductive (e.g., steel framing).

As an example, for envelope components with wood frame construction, Equation (A.1) becomes

(a) The term, "the code" in this Appendix refers to the 1992, 1993, and 1995 editions of the MEC and the 1998 and 2000 editions of the IECC.

$$U_o = \frac{Area_{STUDS} / \sum R_{FRAMING\ PATH} + Area_{INSULATION} / \sum R_{INSULATION\ PATH}}{Area_{STUDS} + Area_{INSULATION}} \quad (A.2)$$

## A.1 Ceilings

Two common types of roof/ceiling construction are ceilings separated from roofs by an attic space and ceilings without attics (flat, vaulted, or cathedral). Because of construction differences, the $U_o$-factors for these two ceiling types are slightly different for equal insulation R-values. Prior to Version 3.2 of the RES*check* compliance materials, no differentiation was made between ceilings with and without attics because the $U_o$-factor for the two types of roof/ceiling construction is sufficiently close. All ceiling U-factors were calculated using the ceilings-with-attic construction as described in this section. A comparison of $U_o$-factors for ceilings with and without attics is given in Section A.1.1.

RES*check* 3.2 and later versions include the distinction between ceilings with and ceilings without an attic, primarily to improve clarity for the user as to which type of ceiling assembly they should select. Some code officials reported confusion from users about how to enter ceilings without attics, and some users were selecting the raised-truss option for ceilings without attics. Therefore, we modified the software to include the following ceiling options:

- Flat Ceiling or Scissor Truss
- Cathedral Ceiling (no attic)
- Raised or Energy Truss
- Structural Insulated Panels (SIPs)
- Other

Additionally, the software displays an illustration of a raised-truss ceiling if the user selects that option. The illustration helps clarify the definition of a raised-truss ceiling.

### A.1.1 Flat Ceiling or Scissor Truss; Raised or Energy Truss

This section describes the algorithm used for flat ceilings and scissor trusses, as well as raised-truss ceilings. In versions prior to RES*check* 3.2, this same algorithm was used for ceilings with and without attics, entered in the software as an *All Wood Joist/Rafter/Truss* assembly. Refer to Section A.1.2 for the algorithm used for cathedral ceilings in RES*check* 3.2 and later versions.

The analysis assumed the use of blown fiberglass insulation, although batt insulation in ceilings is also common. Insulation was assumed to cover the ceiling joists so that “voids” were negligible. Equivalent batt and blown insulation R-values achieve similar $U_o$-factors, so the assumption of insulation type has little effect. Ceiling joists or rafters were assumed to be at 24 in. on center (O.C.), occupying 7% of the ceiling area for both ceiling types (ASHRAE 1989).

The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) recommends an attic ventilation rate of 0.5 cfm/ft$^2$ of ceiling area to control moisture (ASHRAE 1989). A fully vented attic was assumed with a still-air film resistance above the insulation and a 1-in. space between the insulation and the roof near the eaves for ventilation (the venting negates the R-value of the roof materials). A prefabricated truss system was assumed because this system is most common in new residential construction (Anderson and McKeever 1991). For truss members, 2x4 framing (DeCristoforo 1987) and a roof slope of 4/12 were assumed. Table A.1 shows the heat flow paths for ceilings, and Equation (A.3) uses these results to compute the final $U_o$-factor of the ceiling component.

**Table A.1**. Heat Flow Paths for Ceilings

| Description | R-Value at Joists | R-Value at Insulation |
|---|---|---|
| Percentage of Ceiling Area | 7% | 93% |
| Attic Air Film | 0.61 | 0.61 |
| Batt or Blown Insulation | Rij | Ric |
| Sheathing | Rs | Rs |
| Joists | 4.38 | -- |
| 1/2-in. Drywall | 0.45 | 0.45 |
| Inside Air Film | 0.61 | 0.61 |
| **Total Path R-Value** | **6.05 + Rij + Rs** | **1.67 + Ric + Rs** |

$$\text{Ceiling } U_o = \frac{0.07}{6.05 + \text{Rij} + \text{Rs}} + \frac{0.93}{1.67 + \text{Ric} + \text{Rs}} \tag{A.3}$$

where Rij = the effective overall R-value of the insulation above the ceiling joists as computed by Equation (A.5).
Ric = the effective overall R-value of the ceiling cavity insulation between joists as computed by Equation (A.4).
Rs = the rated R-value of the insulating sheathing (if any).

The effective insulation R-value may be less than the rated R-value because of limited space at the eaves. Equations (A.4) and (A.5) account for the limited space for insulation at the eaves, which can be alleviated by raising the trusses or using an oversized truss. For a standard truss, the space available at the eaves was assumed to be 3.86 in. A standard truss was assumed in determining the prescriptive packages. For a raised truss, the space available at the eaves was assumed to be 15.86 in. (3.86 in. + 12.0 in.). Equation (A.4) shows how the effective overall R-value of the ceiling cavity insulation (Ric) is calculated. The effective insulation R-value is equal to the rated R-value if adequate space for the full insulation thickness exists at the eaves.

$$\text{Ric} = \frac{\text{Ric}_{\text{nominal}}}{1 + \left(\frac{\text{yic}_{\text{full}}}{\text{roof height}}\right) \ln\left(\frac{\text{yic}_{\text{full}}}{\text{yic}_{\text{eave}}}\right) - \left(\frac{\text{yic}_{\text{full}} - \text{yic}_{\text{eave}}}{\text{roof height}}\right)} \tag{A.4}$$

where $\text{Ric}_{\text{nominal}}$ = the rated R-value of the cavity insulation.
$\text{yic}_{\text{full}}$ = the full thickness in inches of the cavity insulation

= $Ric_{nominal}$ / 2.5 (for blown fiberglass).

$yic_{eave}$ = the thickness in inches of the cavity insulation at the eaves. The space available at the eaves is assumed to be 3.86 in. for a standard truss. If $yic_{full}$ is greater than 3.86 in., $yic_{eave}$ is set to 3.86 in. For a raised truss, the space available is assumed to be 15.86 in. (3.86 in. + 12.0 in.). If $yic_{full}$ is greater than 15.86 in., $yic_{eave}$ is set to 15.86 in.

roof height = the maximum height in inches at the center line of the house. A 56-in. height was assumed, which corresponds to a 28-ft roof with a rise of 1 ft for each 3 ft across.

Equation (A.5) shows how the effective overall R-value of insulation is calculated for the insulation above the ceiling joists (Rij). Equation (A.5) is the same as Equation (A.4), except 3.5 in. is subtracted from the full insulation depth to account for the insulation displaced by the 2x4 joist. If the truss is not raised, the height of the insulation at the eaves cannot be greater than 0.36 in. (3.86 in. - 3.5 in.). If the truss is raised, the height of the insulation above the eaves cannot be greater than 12.36 in. (15.86 in. - 3.5 in.).

$$Ric = \frac{Ric_{nominal}}{1 + \left(\frac{yij_{full}}{\text{roof height}}\right) \ln\left(\frac{yij_{full}}{yij_{eave}}\right) - \left(\frac{yij_{full} - yij_{eave}}{\text{roof height}}\right)} \qquad (A.5)$$

where $Rij_{nominal}$ = the R-value of the insulation above the joist, which is the rated insulation R-value ($Ric_{nominal}$) minus the joist height (assumed to be 3.5 in.) x the resistance (assumed to be 2.5°F·ft$^2$h/Btu·in.).

= $Ric_{nominal}$ – (3.5 x 2.5)

$yij_{full}$ = the full thickness of the insulation above the joist (in inches).

= ($Ric_{nominal}$ / 2.5) – 3.5.

$yic_{eave}$ = the thickness (in inches) of the insulation above the joists at the eaves. The space available at the eaves is assumed to be 0.36 in. for a standard truss (3.86 in. – 3.5 in.). If $yij_{full}$ is greater than 0.36 in., $yij_{eave}$ is set to 0.36 in. For a raised truss, the space available is assumed to be 12.36 in. (15.86 in. – 3.5 in.). If $yij_{full}$ is greater than 12.36 in., $yij_{eave}$ is set to 12.36 in.

roof height = the maximum height in inches at the center line of the house. A 56-in. height was assumed, which corresponds to a 28-ft roof with a rise of 1 ft for each 3 ft across.

Table A.2 shows some $U_o$-factors for ceilings calculated using this methodology. These $U_o$-factors are used in the calculations to determine the prescriptive packages.

### A.1.3 Cathedral Ceiling (no attic)

For ceilings without attics in RES*check* 3.2 and later versions, the analysis assumed a fully vented ceiling with a still-air film resistance above the insulation. Batt insulation was assumed because vaulted ceilings typically have inadequate space for blown insulation. The rafters were modeled as 2x8 or 2x10 studs at 24 in. O.C. However, the effective thickness of the rafters was set equal to the thickness of the

**Table A.2**. Sample $U_o$-Factors for Ceilings

| Nominal R-Value | Average Insulation R-Value (Ric) | Insulation R-Value Above Joists (Rij) | $U_o$-Factor of Ceiling Including Framing |
|---|---|---|---|
| 11 | 11.0 | 2.2 | 0.082 |
| 19 | 18.5 | 9.2 | 0.051 |
| 30 | 27.3 | 15.9 | 0.035 |
| 38 | 32.5 | 19.1 | 0.030 |
| 38 + Raised Truss | 38.0 | 29.2 | 0.025 |
| 49 | 38.0 | 22.2 | 0.026 |
| 49 + Raised Truss | 48.6 | 39.9 | 0.020 |

insulation because heat flows directly out the side of the wood beyond the depth of the insulation. Table A.3 shows the heat flow paths for ceilings without attics, and Equation (A.6) uses these results to compute the final $U_o$-factor of the ceiling component.

$$Ceiling\,U_o = \frac{0.07}{1.67 + Rr + Rs} + \frac{0.93}{1.67 + Ri + Rs} \qquad (A.6)$$

where Rr = the R-value of the wood rafters, which was assumed to be the thickness of the cavity insulation multiplied by 1.25. The thickness of the batt cavity insulation was assumed to be equal to the R-value of the cavity insulation (Ri) divided by 3.0.
= 1.25 x (Ri ÷ 3.0).
Ri = the rated R-value of the cavity insulation.
Rs = the rated R-value of the insulating sheathing if any.

### A.1.2 Comparison of $U_o$-Factors for Ceilings With and Without Attics

As described above, all $U_o$-factors underlying the RES*check* materials prior to Version 3.2 were based on buildings containing an attic space (i.e., a flat ceiling and a sloped roof). For typical construction, the

**Table A.3**. Heat Flow Paths for Ceilings Without Attics

| Description | R-Value at Rafters | R-Value at Insulation |
|---|---|---|
| Percentage of Ceiling Area | 7% | 93% |
| Ceiling Air Film | 0.61 | 0.61 |
| Batt Insulation | -- | Ri |
| Sheathing | Rs | Rs |
| Rafters | Rr | -- |
| 1/2-in. Drywall | 0.45 | 0.45 |
| Inside Air Film | 0.61 | 0.61 |
| **Total Path R-Value** | **1.67 + Rr + Rs** | **1.67 + Ri + Rs** |

overall ceiling $U_o$-factors for buildings with and without attics are very close. The two ceiling types were offered as separate options in RES*check* 3.2 and later versions primarily for clarification rather than computational accuracy.

Table A.6 compares $U_o$-factors for ceilings with and without attics as calculated using the methodologies described in Sections A.1.1 and A.1.2. This table shows that, for insulation R-values commonly used in ceilings without attics, the difference in the $U_o$-factors between the two construction types is small.

### A.1.4 Structural Insulated Panels

At the time of this report, we were unable to find studies or reports on roof construction of structural insulated panels (SIP). An approximate roof SIP adjustment is made by using the wall correction factors. For a discussion of the algorithms used for wall, ceiling, and floor SIPs, refer to Section A.2.5.

### A.1.5 Steel-Frame Joist/Rafter Assembly Ceilings

Section 502.2.1.2 of the 2003 IECC includes steel-frame joist/rafter assembly ceilings. Because of the high conductivity of the steel framing members, a correction factor is applied to the cavity insulation R-values (Ric) to more accurately account for the metal stud conductivity. The correction factors used are shown in the following two tables. Applying a correction factor to cavity insulation, the steel-frame ceiling $U_o$-factors are the inverse of the sum of the ceiling layer R-values as determined and shown by Equation (A.7). When the cavity R-value falls between the stated R-values of Tables A.4 and A.5 (ICC 2003, Table 502.2.1.2), a linearly interpolated correction factor will be computed.

$$\text{Steel-Frame Ceiling } U_o = \frac{1.0}{1.67 + \text{Rs} + (Fcor * Ric)} \tag{A.7}$$

where Rs = the R-value of the insulating sheathing.

Fcor = Correction factors for Roof/Ceiling assemblies as given by Table 502.2.1.2 (ICC 2003, page 27)

Ric = Cavity insulation between ceiling members

**Table A.4. Correction Factors for Steel Framed Roof / Ceiling Joist / Rafter Assemblies (16-in. framing spacing)**

| Member Size | R-19 | R-30 | R-38 | R-49 |
|---|---|---|---|---|
| 2 x 4 | 0.90 | 0.94 | 0.95 | 0.96 |
| 2 x 6 | 0.70 | 0.81 | 0.85 | 0.88 |
| 2 x 8 | 0.35 | 0.65 | 0.72 | 0.78 |
| 2 x 10 | 0.35 | 0.27 | 0.62 | 0.70 |
| 2 x 12 | 0.35 | 0.27 | 0.51 | 0.62 |

**Table A.5. Correction Factors for Steel Framed Roof / Ceiling Joist / Rafter Assemblies (24-in. framing spacing)**

| Member Size | R-19 | R-30 | R-38 | R-49 |
|---|---|---|---|---|
| 2 x 4 | 0.95 | 0.96 | 0.97 | 0.97 |
| 2 x 6 | 0.78 | 0.86 | 0.88 | 0.91 |
| 2 x 8 | 0.44 | 0.72 | 0.78 | 0.83 |
| 2 x 10 | 0.44 | 0.35 | 0.69 | 0.76 |
| 2 x 12 | 0.44 | 0.35 | 0.61 | 0.69 |

**Table A.6. Heat Flow Path for Steel framed Joist / Rafter Ceilings**

| Description | R-Value at Insulation |
|---|---|
| Attic Air Film | 0.61 |
| Batt or Blown Insulation | Ric |
| Sheathing | Rs |
| Joists | -- |
| ½-in. Drywall | 0.45 |
| Inside Air Film | 0.61 |
| **Total Path R-Value** | **1.67 + Ric + Rs** |

### A.1.6 Steel-Frame Truss Assembly Ceilings

For steel-framed truss ceiling assemblies the correction factor applied to cavity insulation is 0.864 as indicated in Equations 5-7 - 5-9 of the IECC 2003. The "Total Path R-value" (excluding cavity and sheathing R-values) is dependent on the user-provided sheathing R-value. Specifically, the conditions shown in Table A.7 will be applied.

**Table A.7. Construction material R-Values for Steel framed Truss Ceilings (excluding cavity and sheathing R-values)**

| Sheathing R-value | BOA |
|---|---|
| < 3.0 | 0.33 |
| >= 3.0 and less than 5.0 | 1.994 |
| >= 5.0 | 2.082 |

$$\text{Steel-Frame Ceiling } U_o = \frac{1.0}{\text{BOA} + \text{Rs} + (0.864 * Ric)} \qquad \text{(A.8)}$$

where Rs = the R-value of the insulating sheathing.
BOA= Balance of assembly R-values (construction materials) as determined by Table A.7
Ric = Cavity insulation between ceiling members

## A.2 Walls

This section describes the calculation of wall $U_o$-factors, excluding windows and doors.

### A.2.1 Wood-Frame Walls

Wall materials were assumed to be plywood siding, plywood and/or foam insulation sheathing on the framing exterior, batt insulation, wood framing, and 1/2-in. gypboard on the interior. Walls with rigid foam insulation were assumed to have plywood sheathing for 20% of the wall area to account for structural support at corners. In the prescriptive packages, walls with insulation R-values equal to or less than R-15 were modeled as having 2x4 studs at 16 in. O.C. and walls with insulation R-values greater than R-15 were modeled as having 2x6 studs at 16 in. O.C.

The 1992 MEC references the *1985 ASHRAE Handbook: Fundamentals* (CABO 1992; ASHRAE 1985). The 1993 MEC references the *1989 ASHRAE Handbook: Fundamentals* (CABO 1993; ASHRAE 1989). The percentage of wood-frame walls that constitute the framing area cited by these documents is the same and was used for the wood-frame wall calculations in the 1992 and 1993 RES*check* materials. Based on the assumptions in the ASHRAE handbooks, the 16 in. O.C. translates to a framing percentage of 15% of the opaque wall area and the 24 in. O.C. translates to a framing percentage of 12% of the opaque wall area. The 1995 MEC and later editions of the code reference the *1993 ASHRAE Handbook: Fundamentals* (CABO 1995; ASHRAE 1993). The 1993 ASHRAE handbook contains higher wood-frame wall framing percentages─25% of the opaque wall area for 16-in. O.C. framing and 22% of the

**Table A.8**. Comparison of $U_o$-Factors for Ceilings With and Without Attics

| **Batt Insulation R-Value** | **$U_o$-Factor for Ceilings With Attics** | **$U_o$-Factor for Ceilings Without Attics** | **Difference Between Construction Types** |
|---|---|---|---|
| 19 | 0.051 | 0.052 | 2% |
| 30 | 0.035 | 0.034 | 3% |

opaque wall area for 24-in. O.C. framing. Wall construction heat flow paths are shown in Table A.9. Equation (A.9) shows how opaque wall $U_o$-factors are calculated for the 1992 and 1993 MEC, and Equation (A.10) shows how opaque wall $U_o$-factors are calculated for the 1995 MEC and the 1998, 2000, and 2003 IECC (ICC 1998, 1999, 2003). Table A.10 shows wall $U_o$-factors for 16-in. O.C. walls and common insulation R-values. These $U_o$-factors are used in the calculations to determine the prescriptive packages.

For the 1992 and 1993 MEC:

$$\text{Wall } U_o = \left[\frac{0.15 \text{ or } 0.12}{1.97 + Rs + Rw} + \frac{0.85 \text{ or } 0.88}{1.97 + Rs + Ri}\right] 0.80 + \left[\frac{0.25 \text{ or } 0.12}{1.97 + 0.83 + Rw} + \frac{0.85 \text{ or } 0.88}{1.97 + 0.83 + Ri}\right] 0.20 \quad \text{(A.9)}$$

For the 1995 MEC, and 1998 and 2000 IECC:

$$\text{Wall } U_o = \left[\frac{0.25 \text{ or } 0.22}{1.97 + Rs + Rw} + \frac{0.75 \text{ or } 0.78}{1.97 + Rs + Ri}\right] 0.80 + \left[\frac{0.25 \text{ or } 0.22}{1.97 + 0.83 + Rw} + \frac{0.75 \text{ or } 0.78}{1.97 + 0.83 + Ri}\right] 0.20 \quad \text{(A.10)}$$

where Rs = the R-value of the insulating sheathing (entered in the software as continuous insulation). If no insulating sheathing is indicated, the sheathing is assumed to be plywood with an R-value of 0.83. If insulating sheathing is used, only 80% of the net wall is assumed to be covered by the insulating sheathing. The other 20% is assumed to be covered with plywood (R-value = 0.83).

Rw = the R-value of the wood framing members. The R-value of the wood framing members was assumed to be R-4.38 for 2x4 construction and R-6.88 for 2x6 construction.

Ri = the rated R-value of the cavity insulation.

**Table A.9**. Heat Flow Paths for Wood-Frame Walls

| Description | R-Value at Studs | R-Value at Insulation |
|---|---|---|
| Outside Air Film | 0.25 | 0.25 |
| Plywood Siding | 0.59 | 0.59 |
| Sheathing | Rs | Rs |
| Wood Studs | Rw | -- |
| Insulation[a] | -- | Ri |
| 1/2-in. Gypboard | 0.45 | 0.45 |
| Inside Air Film | 0.68 | 0.68 |
| **Total Path R-Value** | **1.97 + Rs + Rw** | **1.97 + Rs + Ri** |
| (a) If the nominal R-value is less than R-11, R-0.9 is added to account for the air space. | | |

**Table A.10**. Sample $U_o$-Factors for 16-in. O.C. Wood-Frame Walls

| Batt Insulation R-Value | Sheathing Insulation R-Value | Framing R-Value | 1992 and 1993 MEC Wall $U_o$-Factor[a] | 1995 MEC, 1998 and 2000 IECC Wall $U_o$-Factor[a] |
|---|---|---|---|---|
| 11 | 0.83 | 4.38 | 0.083 | 0.089 |
| 13 | 0.83 | 4.38 | 0.075 | 0.082 |
| 19 | 0.83 | 6.88 | 0.055 | 0.060 |
| 21 | 0.83 | 6.88 | 0.051 | 0.057 |
| 19 | 4 | 6.88 | 0.047 | 0.055 |
| 19 | 5 | 6.88 | 0.046 | 0.054 |
| 19 | 7 | 6.88 | 0.043 | 0.052 |
| (a) Wall $U_o$-factors calculated for compliance with the 1995 MEC and 1998 and 2000 IECC are higher than those for the 1992 and 1993 MEC because of the higher assumed wood framing area. | | | | |

## A.2.2 Steel-Frame Walls

Equation (A.1), which calculates heat loss rates through parallel paths of heat transfer (i.e., framing and insulation), is not accurate for steel-frame walls because of the high conductivity of the steel studs. Combined stud/insulation R-values (Re), which more accurately account for the metal stud conductivity, were calculated from Table 502.2.1b of the 1995 MEC (CABO 1995). Table A.11 shows these combined stud/insulation R-values, which are referred to as equivalent R-values. Given these equivalent R-values, the steel-frame wall $U_o$-factors are the inverse of the sum of the wall layer R-values as shown in Table A.12 and Equation (A.11).

**Table A.11**. Equivalent R-Values for Steel-Frame Walls

| Nominal R-Value of Insulation | Equivalent R-Value (16-in. framing spacing) | Equivalent R-Value (24-in. framing spacing) |
|---|---|---|
| 0.0 - 10.9 | 0.0 | 0.0 |
| 11.0 - 12.9 | 5.5 | 6.6 |
| 13.0 - 14.9 | 6.0 | 7.2 |
| 15.0 - 18.9 | 6.4 | 7.8 |
| 19.0 - 20.9 | 7.1 | 8.6 |
| 21.0 - 24.9 | 7.4 | 9.0 |
| 25.0+ | 7.8 | 9.6 |

**Table A.12**. Heat Flow Paths for Steel-Frame Walls

| Description | R-Value |
|---|---|
| Outside Air Film | 0.25 |
| Plywood Siding | 0.59 |
| Sheathing | Rs |
| Equivalent R-Value[(a)] | Re |
| 1/2-in. Gypboard | 0.45 |
| Inside Air Film | 0.68 |
| **Total Path R-Value** | **1.97 + Rs + Re** |
| (a) If the nominal R-value is less than R-11, R-0.9 is added to account for the air space. | |

$$\text{Steel-Frame Wall } U_o = \frac{1.0}{1.97 + Rs + Re} \qquad \text{(A.11)}$$

where Rs = the R-value of the insulating sheathing. If no insulating sheathing is indicated, the sheathing is assumed to be plywood with an R-value of 0.83. The entire wall was assumed to be covered with insulation sheathing.

Re = the equivalent R-value, determined by the rated cavity insulation R-value and the spacing of the framing members. Table A.11 lists the equivalent R-values used.

### A.2.3 Mass Walls

RES*check* 3.0 uses the same three mass wall types for above-grade mass walls, basement walls, and crawl space walls. Table A.13 lists these wall types and gives the R-value assigned to that uninsulated wall type in RES*check*. The following sections describe how these assembly types were chosen, how their uninsulated wall R-values were assigned, and how the $U_o$-factors for the entire mass wall assemblies are calculated for the proposed building in the RES*check* software. This section does not address how the

MEC requirements for high-mass walls are calculated. Section 5.3.3 of this document explains how the software incorporates the credit the MEC gives to high-mass walls.

RES*check* also includes an option for log walls, which are also considered mass walls (see Section A.2.4).

**Table A.13**. RES*check* Mass Wall Types and R-Values

| Mass Wall Type | Uninsulated Wall R-Value |
|---|---|
| Solid Concrete or Masonry | R-1.6 |
| Masonry Block with Empty Cells | R-1.8 |
| Masonry Block with Integral Insulation | R-2.4 |

### A.2.3.1 Selection of Mass Wall Types

In looking at the small differences between the three mass wall R-values given in Table A.13, it is arguable whether the three mass wall options are necessary. They could be combined into a single category as was done in previous versions of RES*check*. However, input received from Wisconsin state officials indicated a concern with users incorrectly entering the R-value of masonry core inserts under the *Cavity R-Value* field. Offering the *Masonry Block with Integral Insulation* option helps alleviate this confusion in the software and gives some credit to builders using the insulated block. When *Masonry Block with Integral Insulation* is selected, the software further issues a warning message that informs users NOT to enter the R-value of the inserts because they are already accounted for. Using these three options more closely aligns RES*check* with the COM*check*-EZ options because these same mass wall types and their definitions match those used for COM*check*-EZ. However, COM*check*-EZ distinguishes between wall thickness, with walls <8” and walls >8” being separate assemblies.

Wisconsin officials further expressed concern that their builders using filled blocks were not receiving enough credit. Wisconsin builders are apparently using blocks with R-values of up to R-5. While our conclusions did not justify generically assigning an R-5 to filled block products, RES*check* does support an “Other” wall category that can be used to enter these and other specialty mass wall products that substantially exceed the default R-values assigned.

As discussed in the following sections, differences in concrete wall characteristics (such as thickness, density, and web characteristics) generally have less than an R-1 impact, but clearly some of the systems described in the section entitled, “Other Wall R-Values,” have a more significant impact. Direct support for these specialty products is not provided in RES*check*. More detailed coverage of these options would allow users to more accurately model mass wall types. Not including these options could make it more difficult for builders to use the specialty products and does not help support the more energy-efficient products mentioned. However, adding these options would complicate the software for other users. Concrete above-grade exterior walls only comprise about 4.4% of residential construction, with most of this construction in the south (DOE 1995a). Specialty systems would comprise an even smaller percentage. Making RES*check* more complex in an attempt to address the needs of this small percentage and all of the other variations on mass walls is not advised. Again, the “Other” wall option can be used.

Another difficulty in directly supporting specialty products is determining the R-value to assign to those products. In some cases, manufacturer-reported values for some specialty products may be inflated. As an example, ICON block inserts were reported by the manufacturer to have a system R-value of 5.8, but tests revealed a measured R-value of only 3.5 (*Energy Design Update* 1993). High-mass products may report an "effective" R-value that gives a substantial credit for thermal mass, while the credit for thermal mass is provided elsewhere in the code (and in RES*check*) and should not be included in the R-value.

#### A.2.3.2 Solid Concrete or Masonry Wall R-Value

*Solid Concrete or Masonry* wall types are defined as solid precast or poured-in-place concrete as well as concrete masonry units (CMUs) with grouted cells having grout in 50% or more of the CMU cells. The R-value of grouted masonry more closely resembles solid concrete than masonry with empty cells.

According to Martha Van Geem of Construction Technology Laboratories, Inc., 144 lb/ft$^2$ concrete is by far the most common in residential construction.[a] For basements, the nominal thickness of plain concrete walls should be 8 in. or more for walls 7 ft. or more below grade.[b] Tables A.14 and A.15 show R-values for solid concrete of various densities and thicknesses from ASHRAE Standard 90.1R, Appendix A (ASHRAE 1996) and U-factors for stone and gravel or stone aggregate concretes from the *1997 ASHRAE Handbook: Fundamentals* (ASHRAE 1997, page 24.7), respectively.

The variation of R-value over common ranges of density and thickness is less than R-1. This small variance does not merit breaking down the wall assembly categories further by density or thickness.

Using the ASHRAE 1997 handbook as the primary reference, Solid Concrete and Masonry assembly types for both above-grade and below-grade walls assume an 8-in. wall and are assigned an R-value of R-1.6 for the uninsulated wall. This value includes air films of R-0.25 + R-0.68.

**Table A.14**. R-Values (U-Factors) from Standard 90.1R

| Density (lb/ft$^3$) | Solid Concrete | |
|---|---|---|
| | **6-in. Thickness** | **8-in. Thickness** |
| 85 | R-2.3 (0.44) | R-2.7 (0.37) |
| 115 | R-1.5 (0.65) | R-1.8 (0.57) |
| 144 | R-1.2 (0.81) | R-1.4 (0.74) |

---

(a) Assumptions and equivalent R-values for solid concrete constructions based on a personal communication with Martha Van Geem, Construction Technology Laboratories, Inc. Calculation of concrete wall based on energy calculations and data.

(b) See *Building Foundation Design Handbook*, Table 7-11, page 184 (Labs et al. 1998).

**Table A.15**. U-Factors from ASHRAE 1997 Fundamentals Handbook

| Density (lb/ft$^3$) | Stone and Gravel or Stone Aggregate Concretes | | |
|---|---|---|---|
| | R-Value per in. | Median R-Value for 8 in. | R-Value with Air Films (0.25+0.68) |
| 130 | 0.08-0.14 | 0.88 | 1.81 |
| 140 | 0.06-0.11 | 0.68 | 1.61 |
| 150 | 0.05-0.10 | 0.60 | 1.53 |

### A.2.3.3 Masonry Block with Empty Cell Wall R-Value and Masonry Block with Integral Insulation Wall R-Value

*Masonry Block with Empty Cells* is defined as CMUs with at least 50% of the CMU cells free of grout.

*Masonry Block with Integral Insulation* is defined as CMUs with integral insulation such as perlite or rigid foam inserts.

Bruce Wilcox indicated that 8-in. medium-weight, partially-grouted CMU was commonly used for residential construction.[(a)] Kosny and Christian (1995) report that "normal-weight" (120-to-144 lb/ft$^2$) blocks are by far the most common. Steve Szoke indicated the high end of medium-weight blocks are common, and suggested using ungrouted as a default.[(b)] Tables A.16 and A.17 show the R-values and U-factors from ASHRAE Standard 90.1R (ASHRAE 1996) and U-factors from the *1997 ASHRAE Handbook: Fundamentals* (ASHRAE 1997).

**Table A.16**. R-Values and U-Factors (including air films) from Standard 90.1R

| Density (lb/ft$^3$) and Thickness | Solid Grouted | Partial Grouted, Cells Empty | Partial Grouted, Cells Insulated | Unreinforced, Cells Empty | Unreinforced, Cells Insulated |
|---|---|---|---|---|---|
| **85** | | | | | |
| 6 in. | R-1.8 (0.57) | R-2.2 (0.46) | R-2.9 (0.34) | R-2.5 (0.40) | R-5.0 (0.20) |
| 8 in. | R-2.0 (0.49) | R-2.4 (0.41) | R-3.6 (0.28) | R-2.7 (0.37) | R-6.6 (0.15) |
| **115** | | | | | |
| 6 in. | R-1.5 (0.66) | R-1.9 (0.54) | R-2.4 (0.41) | R-2.2 (0.46) | R-3.8 (0.26) |
| 8 in. | R-1.7 (0.58) | R-2.1 (0.48) | R-2.8 (0.35) | R-2.3 (0.43) | R-4.8 (0.21) |
| **135** | | | | | |
| 6 in. | R-1.4 (0.73) | R-1.7 (0.60) | R-2.0 (0.49) | R-1.9 (0.53) | R-2.9 (0.35) |

(a) Assumptions and equivalent R-values for block masonry constructions were based on a personal communication with Bruce Wilcox, Berkeley Solar Group.

(b) Assumptions and equivalent R-values for block masonry constructions were based on a personal communication with Stephen Szoke, Portland Cement Association.

| | | | | | |
|---|---|---|---|---|---|
| 8 in. | R-1.5 (0.65) | R-1.8 (0.55) | R-2.4 (0.42) | R-2.0 (0.49) | R-3.6 (0.28) |

**Table A.17**. U-Factors from ASHRAE 1997 Fundamentals Handbook

| Type | Normal Weight Aggregate (sand and gravel), 8 in. | |
|---|---|---|
| | **R-Value of Block Only** | **R-Value with Air Films (0.25+0.68)** |
| Empty | 0.97-1.11 | 1.90-2.04 |
| Perlite Fill | 2.0 | 2.93 |
| Vermiculite Fill | 1.37-1.92 | 2.30-2.85 |

Kosny and Christian (1995) report 2-core 12-in. blocks have an R-value of slightly less than R-2 (apparently this R-value does not include air films).

Over common densities, the density and thickness does not make much difference—less than R-1. Insulated cells do not have a significant impact, particularly when grouting is used, suggesting that it is not important to allow the user to specify these inputs. However, RES*check* 3.0 **does** include an option for *Masonry Block with Integral Insulation* for reasons sited in the previous section entitled, "Selection of Mass Wall Types."

We used the Standard 90.1R table to establish default values because the table covers the variety of concrete blocks. The software currently assumes an 8–in. 135-lb/ft$^3$ block with partial grouting based on a recommendation by Bruce Wilcox and because assuming partial grouting is more conservative than assuming no grouting. The software option for *Masonry Block with Empty Cells* allows for up to 50% grouting. R-1.8 is used for this option, based on *Partial Grouted, Cells Empty* in the Standard 90.1R table. R-2.4 is used for *Masonry Block with Integral Insulation*, based on *Partial Grouted, Cells Insulated* in the Standard 90.1R table. These values include air films of R-.25 + R-.68.

#### A.2.3.4 Other Wall R-Values

Several mass walls types could be classified as specialty products. The following results from Kosny and Christian (1995) describe specialty mass wall products, some of the features of these products, and their impact on R-value.

**Improved Block Design with Insulation Fill:** A "cut web" design with 12-in. normal-density block has an R-value of R-5.4, more than double the R-value of a 2-core 12-in. block. A similar multicore block is rated at R-3.5 if the core is left uninsulated and R-6.8 if the core is insulated. Self-locking blocks with continuous insulation in the middle (like a sandwich) have tested R-values of about R-8 to R-10. Product literature for one such product (Thermalock) reports R-14 for 8-in. blocks, R-18 for 10-in. blocks, and R-24 for 12-in. blocks. Supposedly, these products are to be installed with no thermal bridge by mortar, but we do not know if this type of installation is typical.

**Density:** Density is more-or-less bimodal. The most commonly used heavy concrete has densities ranging from about 120 to 140 lb/ft$^3$. Other products, such as autoclaved aerated concrete (e.g., hebel block) (*Environmental Building News* 1996), lightweight expanded clay aggregate, and expanded polystyrene bead concrete, have much lower densities. Table A.18 shows the density and R-value of specialty products.

**Table A.18**. Density and R-Value of Specialty Products

| | **Density** | **R-Value per in.** |
|---|---|---|
| Expanded Shale, Clay, and Slate Concrete | 80-100 | 0.27 to 0.40 |
| Lightweight Expanded Clay Aggregate Concrete | 28-40 | 0.90 to 1.07 |
| Wood Concrete | 28-40 | 0.41 to 0.90 |
| Autoclaved Aerated Concrete | 30-40 | 0.95 |
| Expanded Polystyrene Bead Concrete | 25-70 | 0.89 (30 $lb/ft^3$) |

**Mortar Joints:** Kosny and Christian (1995) report that mortar has little effect on hollow, normal-weight, 2-core, 12-in. blocks–the R-value is reduced by less than 1%. If the cores are insulated, the mortar can result in a 2% to 5% reduction in R-value. Kosny and Christian report the mortar joint covers 4% to 10% of the total wall vertical area and assume an R-value of 0.2 per in. The use of mortar in any concrete walls with high R-values (insulation inserts, low-density concretes) can cause a major decrease to the R-value if it establishes a bridge across the insulation.

#### A.2.3.5 Mass Wall $U_o$-Factors

$U_o$-factors for mass walls are determined by adding an R-value for the uninsulated wall and the insulation system (which accounts for air films and other materials). For exterior insulation, the insulation was assumed to cover the entire wall. Equation (A.12) computes the U-factor of a mass wall with interior and/or exterior insulation. For interior insulation, an interior furring system was assumed. Table A.19 lists equivalent R-values for interior furring and insulation systems.

**Table A.19**. Effective R-Values for Interior Furring Systems[(a)]

| Nominal R-Value | Thickness of Framing (in.) | Effective R-Value |
|---|---|---|
| 0 | 0.75 | 1.4 |
| 1 | 0.75 | 1.4 |
| 2 | 0.75 | 2.1 |
| 3 | 0.75 | 2.7 |
| 4 | 1.0 | 3.4 |
| 5 | 1.5 | 4.4 |
| 6 | 1.5 | 4.9 |
| 7 | 2.0 | 5.9 |
| 8 | 2.0 | 6.4 |
| 9 | 2.5 | 7.4 |
| 10 | 2.5 | 7.9 |
| 11 | 3.5 | 9.3 |
| 12 | 3.5 | 9.8 |
| 13 | 3.5 | 10.4 |
| 14 | 3.5 | 10.9 |
| 15 | 3.5 | 11.3 |
| 16 | 5.5 | 13.6 |
| 17 | 5.5 | 14.2 |
| 18 | 5.5 | 14.7 |
| 19 | 5.5 | 15.3 |
| 20 | 5.5 | 15.8 |
| 21 | 5.5 | 16.3 |

(a) The framing thickness varies with R-value. All values include 0.5-in. gypsum wallboard on the inner surface (interior surface resistances not included). The framing was assumed to be 24-in. on-center, and the insulation was assumed to fill the furring space. The framing was assumed to have an R-value of 1.25/in.

$$\text{Mass Wall } U_o = \frac{1}{\text{Reff} + \text{Rwall} + \text{Rcont}} \quad \text{(A.12)}$$

where Reff = the effective R-value of an interior furring and insulation system as determined by the rated R-value of the cavity insulation.

Rwall = the R-value of the uninsulated wall (as determined in the previous sections).

Rcont = the rated R-value of the exterior continuous insulation.

### A.2.4 Log Walls

The proposed U-factor calculation for log walls has been updated in REScheck 3.7 Release 1 to address the concern over the lack of mass wall credit for 5-in and 6-in diameter log walls. To make the calculation for log wall density more accurate, a separate specific gravity (SG) is now available and used to calculate conductivity, R-value, and heat capacity for each wood species listed in Table A.20. This distinction makes it possible for some species of wood with 5-in and 6-in nominal diameters to receive mass wall credit in the software and is based on the work of the ICC log wall standard consensus process.

Using the known green specific gravity (Gu), as shown in Table A.20, the density and conductivity for each species are calculated. The moisture constant (a) is calculated from the Moisture Content at Fiber Saturation (MCfs) and the Moisture Content of Service (MCs) which varies by climate zone. This is used to calculate the specific gravity (G) for each species in Equation A.14 [Equation 3-5 from the Wood Handbook FPL-GTR-113 (USDA 1999)].

$$a = (MCfs - MCs)/MCfs \qquad (A.13)$$

Where

MCfs for each species is determined by Table 304.2.1 (a) of the ICC IS-Log Standard (ICC 2005)

MCs varies by climate zone based on the IECC 2004/2006 climate zones.
MCs = 10% for Dry climate
MCs = 13% for Moist climates
MCs = 15% for Marine climates
MCs = 14% for Warm-Humid climates
MCs = 12% for all other climates

$$G = Gu / (1 - (0.265 \cdot a \cdot Gu)) \qquad (A.14)$$

Where

Gu is given in Table A.1 for each species
a is calculated based on Equation A.13

The proposed thermal addition to the ICC IS-Log committee also includes improved methods for calculating the R value of log walls based on the Wood Handbook (USDA 1999) Equation 3-7. Thermal conductivity is calculated as shown in equation A.15.

$$k = G ( B + C(MCs) ) + A \qquad (A.15)$$

where A = 0.129 (Specific gravity greater than 0.30)
B = 1.34 (Design temperature at 75 F)
C = 0.028 (Moisture content less than 25%)

Table A.20 shows the calculated conductivity based on equation A.13 and the assumed specific gravity for the species.

**Table A.20.** The calculated conductivity and assumed specific gravity for species found in the revised RES*check* are shown.

| Wood Species Group | Species Label | Specific Gravity (Gu) | Calculated k for Dry Climate (Btu-in/(h-ft2-F) | Calculated k for Moist Climate Btu-in/(h-ft2-F) | Calculated k for Warm-Humid Climate Btu-in/(h-ft2-F) | Calculated k for Marine Climate Btu-in/(h-ft2-F) |
|---|---|---|---|---|---|---|
| White Cedar (WC) | WC | 0.3 | 0.6422 | 0.664316 | 0.671607 | 0.678857 |
| Red Cedar (RC) | RC | 0.31 | 0.660297 | 0.683031 | 0.690522 | 0.697971 |
| Western Red Canadian Cedar (WRC-N) | WRC-N | 0.31 | 0.650231 | 0.669576 | 0.675904 | 0.682174 |
| Western Red Cedar (WRC) | WRC | 0.31 | 0.650231 | 0.669576 | 0.675904 | 0.682174 |
| Sugar Pine (SUP) | SUP | 0.34 | 0.714999 | 0.739532 | 0.747606 | 0.75563 |
| Incense Cedar (IC) | IC | 0.35 | 0.73337 | 0.758485 | 0.766747 | 0.774956 |
| Eastern White Pine (EWP) | EWP | 0.35 | 0.73337 | 0.758485 | 0.766747 | 0.774956 |
| Western White Pine (WWP) | WWP | 0.35 | 0.73337 | 0.758485 | 0.766747 | 0.774956 |
| White Fir (WF) | WF | 0.37 | 0.770321 | 0.796571 | 0.805201 | 0.813771 |
| W. Spruce-Pine-Fir (WSPF) | WSPF | 0.37 | 0.770321 | 0.796571 | 0.805201 | 0.813771 |
| E. Spruce-Pine-Fir (ESPF) | ESPF | 0.38 | 0.788901 | 0.815706 | 0.824514 | 0.83326 |
| Eastern Softwoods (ESW) | ESW | 0.38 | 0.788901 | 0.815706 | 0.824514 | 0.83326 |
| Eastern Spruce (ES) | ES | 0.38 | 0.788901 | 0.815706 | 0.824514 | 0.83326 |
| Western Softwoods (WS) | WS | 0.38 | 0.788901 | 0.815706 | 0.824514 | 0.83326 |
| Hem-Fir (HF) | HF | 0.39 | 0.807552 | 0.834901 | 0.843884 | 0.852803 |
| Lodgepole Pine (LPP) | LPP | 0.39 | 0.807552 | 0.834901 | 0.843884 | 0.852803 |
| Ponderosa | PP | 0.39 | 0.807552 | 0.834901 | 0.843884 | 0.852803 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Pine (PP) | | | | | | |
| Red-Canadian Pine (RP-N) | RP-N | 0.39 | 0.807552 | 0.834901 | 0.843884 | 0.852803 |
| Yellow Cedar (YC) | YC | 0.42 | 0.863932 | 0.892856 | 0.902346 | 0.911761 |
| Red Pine (RP) | RP | 0.42 | 0.863932 | 0.892856 | 0.902346 | 0.911761 |
| Baldcypress (CYP) | CYP | 0.43 | 0.882869 | 0.912299 | 0.92195 | 0.931524 |
| Douglas Fir-Larch (DFL) | DFL | 0.45 | 0.918526 | 0.948129 | 0.957818 | 0.96742 |
| Loblolly Pine (LBP) | LBP | 0.47 | 0.959346 | 0.990697 | 1.000961 | 1.011135 |
| Shortleaf Pine (SLP) | SLP | 0.47 | 0.959346 | 0.990697 | 1.000961 | 1.011135 |
| Mixed Southern Pine (MSP) | MSP | 0.48 | 0.97865 | 1.010455 | 1.020864 | 1.031179 |
| Southern Pine (SP) | SP | 0.48 | 0.972637 | 1.002473 | 1.012211 | 1.021849 |
| Tamarack (TAM) | TAM | 0.49 | 0.998029 | 1.030278 | 1.040827 | 1.051279 |
| Longleaf Pine (LLP) | LLP | 0.54 | 1.096057 | 1.13036 | 1.141558 | 1.152642 |
| Slash Pine (SHP) | SHP | 0.54 | 1.096057 | 1.13036 | 1.141558 | 1.152642 |
| Red Oak (RO) | RO | 0.57 | 1.155799 | 1.191199 | 1.202741 | 1.214156 |
| White Oak (WO) | WO | 0.62 | 1.256948 | 1.29394 | 1.305974 | 1.317865 |

For a wall to receive the Mass Wall credit in the IECC, the wall must have a heat capacity (HC) of 6 Btu/ft$^2$ F. Assuming the specific heat of wood (c) is 0.39 Btu/lb-F, the heat capacity is calculated from the species density as shown in Equation A.16.

$$D = 62.4 \cdot [G / (1+ (0.009 \cdot G \cdot MCs))] \cdot (1+ MCs/100) \quad (A.16)$$

Where

D is log density (lb/ft$^3$) based on section 302.2.3.7 of ICC IS-LOG

$$HC = D \cdot c \cdot (Nd/12) \quad (A.17)$$

Where

D is log density (lb/ft$^3$) based on section 302.2.3.7 of ICC IS-LOG

c is specific heat 0.39 lb-F for all species

Nd is the Nominal Width of the log wall in inches

## A.2.5 Structural Insulated Panels

### A.2.5.1 Wall Panels

SIPs typically have ½-in. fiberboard sheathings and an EPS foam core. Panels have an edge stiffener, which also is used as the nailing strip for connections. Corners and window/door openings all require the foam core be replaced with wood framing members. RES*check* instructs users to provide the manufacturer-reported R-value of the SIP panel in the continuous R-value field. Manufacturer-reported R-values are typically clear-wall R-values–they do not include connections and framing effects.

For SIP panels, Oak Ridge National Laboratory (ORNL) has reported the difference between the clear-wall R-value and overall wall R-value as 12.5% (ASHRAE 1998). The ORNL Whole-Wall Thermal Performance Calculator estimates the whole-wall R-value to be 88.3% of the clear-wall R-value in a typical single-family dwelling (an 11.7% difference) (ORNL 2001).

From these results, we adopted an adjustment factor of 12.5% for use in RES*check* for calculating the overall R-value of SIP exterior walls, which is the more conservative of the two results. Because the manufacturer-reported R-values do not include air films, we assumed the heat flow paths shown in Table A.21.

**Table A.21**. Assumed Heat Flow Paths for Wall Panels

| **Description** | **R-Value** |
|---|---|
| Outside Air Film | 0.25 |
| Wall Panels | Rm * 0.875 |
| 1/2-in. Gypboard | 0.45 |
| Inside Air Film | 0.68 |
| Total Path R-Value | 1.38 + (Rm * 0.875) |
| Rm = the manufacturer's reported R-value. | |

### A.2.5.2 Floors Panels

No studies or reports are available for floor construction of SIP panels. An approximate floor adjustment is made using wall correction factors listed in the Whole-Wall Thermal Performance Calculator for stress-skin walls. The only heat flows listed in this table considered applicable to the floor are the clear-wall (42.42 Btu/h·ºF) and wall/floor (1.86 Btu/h·ºF) heat flows. Adding these heat flows gives 44.28 Btu/h·ºF, which is approximately 96% of the clear-wall heat flow. Therefore, an adjustment of 4% is warranted.

The floor joists consist of ½-in. fiberboard web. Based on the percentage of joist web area of a typical 4-x 8-ft panel, the fiberboard web comprises about 1% of the floor area. The adjustment factor is increased by 1% to account for the heat flow through the webs, which are not a factor in wall construction.

Assuming that the RES*check* user provides a clear-wall R-value of the stress-skin floor panel, a total adjustment factor of 5% was adopted for use in calculating the overall R-value of SIP floors (a 4% adjustment plus 1% for the webs).  Because the manufacturer-reported R-values do not include air films, we assumed the heat flow paths shown in Table A.22.

#### A.2.5.3 Roof Panels

No studies or reports are available for roof construction of SIP panels. An approximate roof adjustment is made using wall correction factors listed in the Whole-Wall Thermal Performance Calculator for stress-skin walls. A conservative approach assumes that the window, door, and corner framing of the walls are analogous to the roof ridge framing in the ceilings. If the heat flow through the wall/floor framing is removed from consideration, the total heat flow from this table would be 46.21 Bth/h·ºF (48.07 - 1.86). This heat flow is approximately 92% of the clear-wall heat flow, so an adjustment of 8% is warranted. An additional 1% was added for the wood portion of the joist members, as was done for floors.

Assuming that the RES*check* user provides a clear-wall R-value of the stress-skin ceiling panel, a total adjustment factor of 9% was adopted for use in calculating the overall R-value of SIP ceilings (an 8% adjustment plus 1% for the webs). Because the manufacturer-reported R-values do not include air films, we assumed the heat flow paths shown in Table A.23.

**Table A.22**. Assumed Heat Flow Paths for Floor Panels

| Description | R-Value |
|---|---|
| Unheated Space Air Film | 0.92 |
| Floor Panels | Rm * 0.95 |
| Carpet and Pad | 1.23 |
| Inside Air Film | 0.92 |
| Total Path R-Value | 3.07 + (Rm * 0.95) |
| Rm = the manufacturer’s reported R-value. | |

**Table A.23**. Assumed Heat Flow Paths for Roof Panels

| Description | R-Value |
|---|---|
| Ceiling Air Film | 0.61 |
| Roof Panels | Rm * 0.91 |
| 1/2-in. Drywall | 0.45 |
| Inside Air Film | 0.61 |
| Total Path R-Value | 1.67 + (Rm * 0.91) |
| Rm = the manufacturer’s reported R-value. | |

### A.2.6 Insulated Concrete Forms

Insulated concrete Forms (ICFs) consist of two rigid-board insulation sheathings that serve as a permanent form for poured-in-place concrete walls. The insulation sheathings are connected by plastic or metal links that keep the sheathings in position and also serve as stirrups or reinforcements for the concrete wall. RES*check* instructs users to provide the manufacturer-reported R-value of ICFs in the continuous R-value field. Manufacturer-reported R-values are typically clear-wall R-values–they do not include connections and framing effects.

The ORNL tests (ASHRAE 1998), show that the difference between the clear-wall R-value and the overall wall R-value is 9.5%. These ORNL calculations take into account the additional framing in corners, window/door frames, and wall/roof and wall/floor interfaces. A typical ICF wall analyzed using the ORNL Whole-Wall Thermal Performance Calculator shows that the whole-wall R-value is 89% of the clear-wall R-value (an 11% difference) (ORNL 2001).

Assuming that the RES*check* user provides a clear-wall R-value of an ICF construction, an adjustment factor of 11% was adopted for use in determining the overall effective R-value, which is the more conservative of the two results. Tables A.24 and A.25 lists the R-values used to calculate the overall effective R-Value for above- and below-grade ICF walls.

**Table A.24**. Above-Grade ICF Walls

| Description | R-Value |
|---|---|
| Outside Air Film | 0.25 |
| ICF Clear Wall | Rm * 0.89 |
| 1/2-in. Gypboard | 0.45 |
| Inside Air Film | 0.68 |
| Total Path R-Value | 1.38 + (Rm * 0.89) |
| Rm = the manufacturer's reported R-value. | |

**Table A.25**. Below-Grade ICF Walls

| Description | R-Value |
|---|---|
| ICF Clear Wall | Rm * 0.89 |
| Inside Air Film | 0.68 |
| Total Path R-Value | 0.68 + (Rm * 0.89) + Soil Impact |
| Rm = the manufacturer's reported R-value. | |

## A.3 Floors Over Unheated Spaces

### A.3.1 All-Wood Joist/Truss

We assumed that floors over unheated spaces are constructed of batt insulation, wood framing, a ¾-in. wood subfloor, and carpet with a rubber pad. The floor joists were modeled as 2x10 studs at 16-in. O.C. (DeCristoforo 1987) occupying 10% of the floor area. The effective depth of the joists for the thermal calculation was set equal to the depth of the insulation. This thickness was used because heat flows directly out of the sides of the joists beyond the depth of the insulation. Table A.26 shows the heat flow paths for floors over unheated spaces, and Equation (A.18) uses these results to compute the final floor component $U_o$-value. Table A.27 shows some $U_o$-factors for floors over unheated spaces as calculated by this methodology. These $U_o$-factors are used in the calculations to determine the prescriptive packages.

$$Floor\ U_o = \frac{0.1}{4.01 + Rj} + \frac{0.9}{4.01 + Ri} \qquad (A.18)$$

where Rj = the R-value of the wood joists, which was assumed to be the thickness of the cavity insulation multiplied by 1.25. The thickness of the batt cavity insulation was assumed to be equal to the R-value of the cavity insulation (Ri) divided by 3.0.

= 1.25 x (Ri ÷ 3.0).

Ri = the rated R-value of the cavity insulation.

**Table A.26**. Heat Flow Paths for Floors Over Unheated Spaces

| Description | R-Value at Joists | R-Value at Insulation |
|---|---|---|
| Percentage of Floor Area | 10% | 90% |
| Unheated Space Air Film | 0.92 | 0.92 |
| Insulation | -- | Ri |
| Joists | Rj | -- |
| Carpet and Pad | 1.23 | 1.23 |
| ¾-in. Wood Subfloor | 0.94 | 0.94 |
| Inside Air Film | 0.92 | 0.92 |
| Total Path R-Value | 4.01 + Rj | 4.01 + Ri |

**Table A.27**. Sample $U_o$-Factors for Floors Over Unheated Spaces

| Batt R-Value | $U_o$-Value of Floor Including Framing |
|---|---|
| 0 | 0.250 |
| 11 | 0.072 |
| 13 | 0.064 |
| 19 | 0.047 |
| 30 | 0.033 |

### A.3.2 Structural Insulated Panels

No studies or reports were found for floor construction of SIPs. An approximate floor SIP adjustment is made by using the wall correction factors. For a discussion of the algorithms used for wall, ceiling, and floor SIPs, refer to Section A.2.5.

### A.3.3 Steel-Frame

Section 502.2.1.3 of the 2003 IECC includes steel-frame floors over unheated spaces. Because of the high conductivity of the steel framing members, a correction factor is applied to the cavity insulation R-values (Ric) to account for the metal stud conductivity. The correction factors shown in the following two tables are used. Applying a correction factor to cavity insulation, the steel-frame floor $U_o$-factors are the inverse of the sum of the floor layer R-values as determined and shown by Equation (A.19). When cavity R-value falls between the stated R-Values of Table A.28 (ICC 2003, Table 502.2.1.3a) and Table A.29 (ICC 2003, Table 502.2.1.3b), a linearly interpolated correction factor is computed. Cavity insulation credit is limited by the framing member size as indicated by "NA" in Tables A.28 (ICC 2003, Table 502.1.1.3a) and A.29 (ICC 2003, Table 502.2.1.3b). The user is permitted to enter higher R values, but an information message will be presented to indicate that the maximum R value credit will be that defined in Tables A.28 (ICC 2003, Table 502.1.1.3a) and A.29 (ICC 2003, Table 502.2.1.3b).

**Table A.28 Correction Factors for Steel Framed Floor Assemblies (16-in. framing spacing)**

| Member Size | R-19 | R-30 | R-38 |
|---|---|---|---|
| 2 x 6 | 0.70 | NA | NA |
| 2 x 8 | 0.35 | NA | NA |
| 2 x 10 | 0.35 | 0.27 | NA |
| 2 x 12 | 0.35 | 0.27 | 0.24 |

**Table A.29 Correction Factors for Steel Framed Floor Assemblies (24-in. framing spacing)**

| Member Size | R-19 | R-30 | R-38 |
|---|---|---|---|
| 2 x 6 | 0.78 | NA | NA |
| 2 x 8 | 0.44 | NA | NA |
| 2 x 10 | 0.44 | 0.35 | NA |
| 2 x 12 | 0.44 | 0.35 | 0.32 |

**Table A.30. Heat Flow Paths for Steel framed Floor Assemblies (Over Unheated Spaces)**

| Description | R-Value at Insulation |
|---|---|
| Unheated Space Air Film | 0.92 |
| Insulation | Ric |
| Sheathing | Rs |
| Joists | -- |
| Carpet and Pad | 1.23 |
| ¾-in. Wood Subfloor | 0.94 |
| Inside Air Film | 0.92 |
| Total Path R-Value | 4.01 + Ri + Rs |

$$\text{Steel-Frame Floor } U_o = \frac{1.0}{4.01 + Rs + (Fcor * Ric)} \qquad (A.19)$$

where Rs = the R-value of the insulating sheathing.
Fcor = Correction factors for floor assemblies as given by Table 502.2.1.3 of ICC 2003
Ric = Cavity insulation between ceiling members

Note: Floors over outside air are evaluated the same as Ceilings/Roofs as stated in Section 502.2.1.3 of the 2003 IECC.

## A.4 Basement Walls

The methodology for calculating heat loss through basement walls was adapted from the *1993 ASHRAE Handbook: Fundamentals* (ASHRAE 1993, p. 25.10-25.11). Both the proposed and required UA calculations take into account the effect of the soil surrounding below-grade walls.

The soil R-value is computed for each 1-ft increment of wall below grade, based on the user's *Wall Height* and *Depth Below Grade* inputs. Table A.24 gives the heat loss factors for an uninsulated wall as given in the 1993 ASHRAE handbook (ASHRAE 1993). The combined R-value of the uninsulated wall and air-films in the ASHRAE values was determined to be approximately R-1.6. Column D of Table A.31 gives the R-value attributed to the soil at each 1-ft. increment after the wall R-value of R-1.6 has been deducted.

### A.4.1 Proposed UA Calculation

To compute the proposed UA, the foundation dimensions and insulation characteristics are obtained from the user.

- height of wall
- depth below grade
- depth of insulation
- R-value of insulation
- wall area.

The “depth of insulation” refers to the distance the insulation extends vertically from the top of the foundation wall downward. No additional credit is given for insulation depths greater than the height of the wall.

The basement perimeter is also used in the UA calculation and is estimated from Equation (A.20).

$$\text{Perimeter} = \frac{\text{Wall Area}}{\text{Wall Height}} \quad \text{(A.20)}$$

The proposed wall UA is calculated as:

$$\text{proposed UA} = \sum_{n}^{i=1} \left( \frac{1}{\text{wall R-value[i]} + \text{soil R-value[i]}} \right) * \text{area[i]} \quad \text{(A.21)}$$

where wall R-value[i] = the R-value of the wall assembly for increment i, based on the wall type and the insulation configuration.

soil R-value[i] = the R-value of the soil for increment i, based on the depth below grade of increment i (see Table A.31).

area[i] = the perimeter times the height, which is 1 for a complete increment, but may be a fraction of 1, depending on the configuration.

n = the wall height, rounded up to the nearest whole number.

Equation (A.21) is calculated separately for the above-grade UA (in which case the soil R-value is 0) and the below-grade UA. The total building UA is the sum of these separate calculations. For partial increments, the area is adjusted to reflect only the area under consideration. For example, if the user defines a wall 1.5 ft above-grade, then the above-grade portion is computed based on two increments, with the second increment having only one-half the area of the first increment (perimeter * 0.5). Likewise, partial increments are computed if the user’s depth of insulation does not fall in whole-number increments, in which case the wall R-value may vary over the increment. Table A.31 gives the soil R-values used in Equation (A.21), based on the depth of the increment under consideration.

**Table A.31**. Soil R-Values

| A | B | C | D |
|---|---|---|---|
| **Depth Below Grade (ft)** | **Heat Loss (Btu/ft$^2$•h•°F) for Uninsulated Wall** | **R-Value of Uninsulated Wall and Soil (1 / B)** | **R-Value of Soil Only (C – 1.6)** |
| 0-1 | 0.410 | 2.439 | 0.839 |
| 1-2 | 0.222 | 4.505 | 2.905 |
| 2-3 | 0.155 | 6.452 | 4.852 |
| 3-4 | 0.119 | 8.403 | 6.803 |
| 4-5 | 0.096 | 10.417 | 8.817 |
| 5-6 | 0.079 | 12.658 | 11.058 |
| 6-7 | 0.069 | 14.493 | 12.893 |
| 7-8 | 0.061 | 16.393 | 14.793 |
| 8-9 | 0.055 | 18.182 | 16.582 |
| 9-10[(a)] | 0.049 | 20.408 | 18.808 |
| (a) Depths below 10 ft assume the 9-to-10-ft soil R-value. | | | |

### A.4.2 Required UA Calculation

The MEC does not consider the surrounding soil in determining the basement wall $U_o$-factor requirements (Table 502.2.1, Footnote 5 in the 1992 and 1993 MEC [CABO 1992, 1993]; Table 502.2.1a, Footnote 5 in the 1995 MEC [CABO 1995]; Table 502.2, Footnote ‘e’ in the 1998 and 2000 IECC [ICC 1998 and 1999]. To directly compare the required $U_o$-factor specified by the code (which does not include soil) to the proposed building $U_o$-factor (which does include soil), the code requirement is adjusted to include the impact of the soil.

The required wall UA is calculated as:

$$\text{required UA} = \sum_{n}^{i=1} \left( \frac{1}{\frac{1}{\text{MEC U}_o} + \text{soil R-value}[i]} \right) * \text{area}[i] \qquad \text{(A.22)}$$

where MECU$_o$ = the MEC/IECC basement wall $U_o$ requirement for the given location.

soil R-value[i] = the R-value of the soil for increment i, based on the depth below grade of increment i (see Table A.31).

area[i] = the perimeter times the height, which is 1 for a complete increment, but may be a fraction of 1, depending on the configuration.

n = the wall height, rounded up to the nearest whole number.

## A.4.3 Wall R-Value Calculations

### A.4.3.1 Solid Concrete and Masonry Block Basement Walls

Table A.32 shows the R-values used for uninsulated solid concrete and masonry block walls. The uninsulated wall R-value assigned to these three wall types is the same as is used for above-grade mass walls. Refer to Section A.2.3 for the derivation of these values.

**Table A.32**. Basement Wall Types and R-Values

| Mass Wall Type | Uninsulated Wall R-Value |
|---|---|
| Solid Concrete or Masonry | R-1.6 |
| Masonry Block with Empty Cells | R-1.8 |
| Masonry Block with Integral Insulation | R-2.4 |

The insulated wall R-value is

$$\text{Basement Wall Rval} = \text{Reff} + \text{Rwall} + \text{Rcont} \qquad \text{(A.23)}$$

where Reff = the effective R-value of an interior furring and insulation system as determined by the rated R-value of the cavity insulation (see Table A.19).
Rwall = the R-value of the uninsulated wall (see Table A.32).
Rcont = the rated R-value of the continuous insulation.

### A.4.3.2 Wood-Frame Basement Walls

Wood-frame basement wall R-values are established similarly to above-grade wood-frame walls (see Section A.2.1). Due to differences in the code-referenced ASHRAE standards, the 1992 and 1993 MEC (CABO 1992, 1993) framing factors are different from the framing factors used by the 1995 MEC (CABO 1995) and the 1998 and 2000 IECC (ICC 1998 and 1999).

Table A.33 gives the assumed heat flow paths for basement wood-frame walls. Equation (A.24) gives the wall $U_o$ for the 1992 and 1993 MEC, and Equation (A.25) gives the wall $U_o$ for the 1995 MEC and 1998 and 2000 IECC. In both cases, 2x6 16-in. O.C. construction is assumed. A wall R-value is obtained by inverting the results of these equations.

For the 1992 and 1993 MEC:

$$\text{Basement Wall } U_o = \left[ \frac{0.15}{9.03 + \text{Rcont}} + \frac{0.85}{2.15 + \text{Rcavity} + \text{Rcont}} \right] \qquad \text{(A.24)}$$

For the 1995 MEC and 1998 and 2000 IECC:

$$\text{Basement Wall } U_o = \left[ \frac{0.25}{9.03 + \text{Rcont}} + \frac{0.75}{2.15 + \text{Rcavity} + \text{Rcont}} \right] \tag{A.25}$$

**Table A.33**. Heat Flow Paths for Wood-Frame Basement Walls

| Description | R-Value at Studs | R-Value at Insulation |
|---|---|---|
| Outside Air Film | 0.25 | 0.25 |
| Plywood | 0.77 | 0.77 |
| Continuous Insulation | Rcont | Rcont |
| Wood Studs | 6.88 | -- |
| Cavity Insulation | -- | Rcavity |
| 1/2-in. Gypboard | 0.45 | 0.45 |
| Inside Air Film | 0.68 | 0.68 |
| Total Path R-Value | 9.03 + Rcont | 2.15 + Rcont + Rcavity |

#### A.4.3.3 Insulated Concrete Forms

For ICF walls, the depth of insulation is assumed to be the same as the wall height. Below-grade ICF wall R-values are calculated as:

$$\text{ICF R-value} = 0.68 + \text{Rm} \times 0.89 \tag{A.26}$$

where Rm = the manufacturer's reported R-value, as entered by the user. (Refer to Section A.2.6 for additional information on ICFs.)

#### A.4.3.4 Other Basement Walls

For *Other* wall types, the depth of insulation is assumed to be the same as the wall height. The user must enter and be prepared to justify an assembly U-factor. The wall R-value is

$$\text{Other Wall R-value} = \frac{1}{\text{Assembly U-factor}} \tag{A.27}$$

### A.4.4 Required Basement $U_o$ in Locations Without Requirements

Basement wall requirements in the MEC and IECC do not apply to locations with HDD <1500. In RES*check*, however, the user may receive credit for insulating basement walls in these locations. In this case, the requirement is assumed to be an uninsulated wall of the type selected by the user, with some exceptions.

## A.5 Crawl Space Walls

The methodology for calculating heat loss through crawl space walls is identical to that described above for basement walls.

The crawl space wall calculation requires the same inputs as the basement wall calculation. In computing the code building UA, these same inputs are used except for the insulation R-value. For the code building, the required UA is derived from Equation (A.22), except that the MEC $U_o$ used in this equation comes from the crawl space wall requirement rather than the basement wall requirement.

For crawl space walls having an inside ground surface 12 in. or more below the outside finished ground surface, the code only requires the insulation to extend 12 in. below the outside grade. In this case, the code building in the UA comparison is assumed to be fully insulated above outside grade and insulated to 12 in. below outside grade.

For crawl space walls having an inside ground surface less than 12 in. below outside grade, the code requires the insulation extend downward vertically and inward horizontally a total distance of 24 in. from the outside grade surface. In this case, it is necessary to account for the horizontal insulation required by the code in the RES*check* software (DOE 1995d). The *1989 ASHRAE Handbook: Fundamentals* does not provide an estimate of the effect of horizontal insulation on the heat loss through the crawl space floor (ASHRAE 1989). Therefore, the horizontal insulation is accounted for in the UA calculation by assuming both the insulation and the wall extend down vertically 24 in. below the outside grade. In the UA calculation, this assumption increases the area of the crawl space wall beyond the actual vertical wall area. This vertical insulation assumption, when the insulation is actually horizontal, is reasonable because the length of the heat flow path through the soil to bypass the insulation is about the same in either case. The same assumption is made for both the code building and the proposed building.

## A.6 Slab-On-Grade Floors

To calculate foundation heat losses, heat loss values for slabs were taken from Huang et al. (1988).[(a)] In this methodology, the heat loss unit for below-grade foundations is in terms of linear feet of perimeter (F-factor) instead of square feet of surface area ($U_o$-factor). A $U_o$-factor is multiplied by a surface area and degree-days to obtain the total heat loss. An F-factor is multiplied by a perimeter length and degree-days to obtain the total heat loss. These F-factors are shown in Table A.34. The F-factors are given in the referenced paper for insulation both on the exterior and interior of the foundation wall. The F-factors vary only slightly by insulation placement, so the average of the exterior and interior insulation placement was used. The same F-factors were used for heated and unheated slabs. Huang et al. (1988) did not present F-factors for insulation levels above R-10 for slab insulation 2-ft deep; therefore, F-factors were considered to be constant for insulation levels above R-10 for this configuration. Additionally, F-factors were considered to be constant for all insulation levels above R-20, regardless of insulation depth. This

(a) Sufficient data were not available from this source to model heat losses from common basement and crawl space insulation configurations, so this source was used only for slab-on-grade foundations.

assumption was deemed reasonable because little is gained by the additional insulation (above R-20, most of the heat loss occurs under and around the insulation).

In the RES*check* software, slab perimeters can be insulated to any depth up to 4 ft (DOE 1995d). To calculate heat loss for any combination of insulation depth and R-value, quadratic curves were fit through the data in Table A.34. The resulting quadratic Equation (A.28) gives the F-factor as a function of insulation depth. The applicable coefficients for Equation (A.28) are given in Table A.35 and are determined by the insulation R-value. R-values range from R-0 to R-20.

**Table A.34**. Slab-On-Grade Floor F-Factors

| Insulation R-Value | 2-ft Insulation Depth | 4-ft Insulation Depth |
|---|---|---|
| R-0 | 1.043 | 1.041 |
| R-5 | 0.804 | 0.744 |
| R-10 | 0.767 | 0.684 |
| R-15 | 0.767 | 0.654 |
| R-20 and Above | 0.767 | 0.636 |

$$\text{F-factor} = \text{intercept} + \text{coef 1} \times \text{depth} + \text{coef 2} \times \text{depth}^2 \qquad \text{(A.28)}$$

where depth = the distance the insulation extends downward (or downward and outward) in feet.

**Table A.35**. Coefficients for Slab F-Factor Equation (A.28)

| R-Value | intercept | coef 1 | coef 2 |
|---|---|---|---|
| R-0 | 1.042 | 0.0013 | -0.0004 |
| R-1 | 1.042 | -0.0967 | 0.0144 |
| R-2 | 1.042 | -0.1293 | 0.0188 |
| R-3 | 1.042 | -0.1459 | 0.0207 |
| R-4 | 1.042 | -0.1562 | 0.0217 |
| R-5 | 1.042 | -0.1635 | 0.0223 |
| R-6 | 1.042 | -0.1692 | 0.0227 |
| R-7 | 1.042 | -0.1739 | 0.0230 |
| R-8 | 1.042 | -0.1781 | 0.0233 |
| R-9 | 1.042 | -0.1819 | 0.0236 |
| R-10 | 1.042 | -0.1855 | 0.0240 |
| R-11 | 1.042 | -0.1836 | 0.0231 |
| R-12 | 1.042 | -0.1819 | 0.0222 |
| R-13 | 1.042 | -0.1805 | 0.0215 |
| R-14 | 1.042 | -0.1792 | 0.0208 |
| R-15 | 1.042 | -0.1780 | 0.0203 |
| R-16 | 1.042 | -0.1770 | 0.0197 |
| R-17 | 1.042 | -0.1760 | 0.0193 |
| R-18 | 1.042 | -0.1751 | 0.0188 |
| R-19 | 1.042 | -0.1743 | 0.0184 |

| | | | |
|---|---|---|---|
| R-20 | 1.042 | -0.1735 | 0.0180 |

## A.7 References


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# Appendix B

# Arkansas

# Appendix B

# Arkansas

The 2004 Arkansas Energy Code is based on the 2003 IECC with the release of RES*check* 3.6 Version 1a. The Arkansas code has no functional differences from the 2003 IECC, and is implemented in RES*check* to give exactly the same results with the exception of building-level SHGC compliance. However, the Arkansas implementation does require SHGC inputs where applicable (i.e., locations with heating degree days less than 3500).

# Appendix C

# Georgia

# Appendix C

# Georgia

The Georgia Residential Code is based on the 2000 IECC.

## C.1 Compliance Calculations

The Georgia code gives an R-2.75 credit for slabs with carpet or hardwood on plywood. The software assumes a continuous R-value of 2.75 to a depth of 2 ft. if the user selects this option. Otherwise, the software assumes zero insulation.

All SHGC required codes allow adjustments to be made to the area-weighted average SHGC when overhang projections exist and/or, in the case of the Georgia 2004 code, when a shade screen exists. An overhang projection is represented as the ratio of width of the overhang (from exterior of wall to edge of overhang) over height as measured from the bottom of the overhang to the bottom of the fenestration component. In the RES*check* 3.5 software the shade screen multiplier applied is 0.80 as per industry recommendation until additional research can be completed. This multiplier was adopted as being representative of the most conservative approximation. That is, solar heat gain can be reduced by at most 20%.

As per direction from Georgia state representatives, the shade screen adjustment must recognize half, full, or no shade screen specifications. No shade screens implies no adjustment is made. A full shade screen specification requires that a multiplier of 0.45 be applied to the component proposed SHGC. A half shade screen specification requires that only half the glazing component area be considered in the SHGC adjustment for shade screens. Note that shade screen adjustments do not apply to skylight or glass door components.

## C.2 Compliance Reports

Slab entries in the *Compliance Report* have an additional selection: *Other* or *w/ Carpet or Hardwood on Plywood*.

The *Inspection Checklist* differs in the following sections, as requested by the state: Air Leakage, Vapor Retarder, Duct Insulation, and Heating and Cooling Equipment Sizing. A decorating glazing exemption is also included.

# Appendix D

# Massachusetts

# Appendix D

# Massachusetts

The Massachusetts Energy Code is based on the 1995 MEC.

## D.1 Compliance Reports

The *Inspection Checklist* differs from the 1995 MEC in the following sections, as requested by the Massachusetts Energy Office: Vapor Retarders, Air Leakage, Duct Insulation, Duct Construction, Heating and Cooling Equipment Sizing.

# Appendix E

# Minnesota

# Appendix E

# Minnesota

The 2000 Minnesota Energy Code is based on the 1995 MEC.

## E.1 Calculations

The Minnesota code requirements are:

| Assembly | 1999 Minnesota Code | 2000 Minnesota Code (changed values only) |
|---|---|---|
| **1& 2 Family Assembly** | | |
| Roof/Ceiling | 0.026 | |
| Combined Wall (includes foundation windows/doors) | 0.11 (if foundation walls are >= R-10)<br>0.10 (if any foundation wall < R-10) | |
| Basement & Crawl Wall | R-10 | |
| Floors Over Unconditioned | 0.04 | 0.033 |
| Slab-On-Grade Uo | R-10 | |
| Slab-On-Grade Depth of Ins. | 60" (North/Zone 1)<br>42" (South/Zone 2) | |
| **Multifamily** | | |
| Wall | 0.145 (North/Zone 1)<br>0.148 (South/Zone 2) | 0.129<br>0.131 |

The minimum U-factor and maximum R-value limits are as follows. The U-factor limits are applied as area-weighted averages. The R-5 foundation minimum is applied as the sum of cavity and continuous insulation. Any combination of cavity plus continuous insulation meeting or exceeding R-5 will meet the requirement.

| Assembly | Minimum $U_o$ or Maximum R-Value |
|---|---|
| Skylights | 0.55 |
| Glazing | 0.37 for windows and glass doors (except foundation windows 5.6 ft2 or less)<br>0.51 for foundation windows 5.6 ft2 or less |
| Foundation Wall & Slab | R-5 (any combination of cavity + continuous) |
| Floors Over Unconditioned | 0.033 |

The engine has two additional boolean variables to distinguish between the Minnesota glazing types: *foundation* and *small*.

The Minnesota code for the slab *depth of insulation* extends to 60". Previously, the RES*check* slab calculations were only considered valid up to 48". The method for extending F-value calculation for depths beyond 48" are included in Appendix A. The depth of insulation range limits for all codes was extended to 72" in May 1996.

## E.2 Compliance Reports

Minnesota's *Inspection Checklist* is so different from the 1995 MEC checklist, the state provided its own file.

# Appendix F

# New Hampshire

# Appendix F

# New Hampshire

The New Hampshire Energy Code is based on the 1995 MEC (RES*check* 3.5.1 and 3.5.1a) and the 2000 IECC in RES*check* 3.5.1b+.

## F.1 Weather Data

New Hampshire uses a single HDD65 for their entire state, based on the value of Concord, NH. They do not support a cities or counties list.

# Appendix G

# New Jersey

# Appendix G

# New Jersey

The New Jersey Energy Subcode is based on the 1995 MEC.

# Appendix H

# New York

# Appendix H

# New York

The New York State Energy Conservation Construction Code is based on the 2001 IECC.

## H.1 Calculations

Electric Homes: The New York code requirements for electrically heated homes are given in the following table. The NY code requirements are given in the second column, primarily as R-values. Since code requirements based on R-value will vary with assembly type, the software instead enforces the roof, above-grade wall, and floor requirements as a U-factor based on the code R-values and assuming a specific construction type. he assumed construction type is also listed in the table:

| **Assembly** | **NY Single & Multifamily R-Value Requirement** | **Assumed Assembly Type** | **Corresponding U-value Requirement** |
|---|---|---|---|
| Roof/Ceiling | R-49 | Wood truss | 0.026 |
| Wall | R-26 | Wood-framed walls, 16"oc | 0.052 |
| Glazing U-Factor | 0.31 | | 0.31 |
| Floor Over Unheated | R-30 | Wood truss floor over unconditioned space | 0.033 |
| Basement Wall<br>Depth of Insulation | R-19<br>7 ft. below outside grade or to top of slab | | R-19[(a)] |
| Slab Edge<br>Depth of Insulation | R-15<br>4 ft. | | R-15 |

(a) The required U-factor varies with wall type, using the following equation:

$$\mathrm{Re}\,qUo = \frac{1}{effective(19) + uninsulatedWallRvalue}$$

where effective(19) = the effective R-value of a furring system with R-19 insulation. Refer to Appendix A for a table of effective R-values. This table lists the effective R-value of R-19 cavity insulation as R-15.3. uninsulatedWallRvalue = the R-value of the uninsulated wall. These R-values are listed in Appendix A, but are duplicated here for the three concrete/masonry wall types:

| Wall Type | Uninsulate Wall R-Value |
| --- | --- |
| Solid Concrete or Masonry | R-1.6 |
| Masonry Block with Empty Cells | R-1.8 |
| Masonry Block with Integral Insulation | R-2.4 |

Non-Electric Homes: The New York requirements for non-electric homes is the same as the IECC 2001, except for the depth of insulation requirement for foundation walls. For basement walls, the 2001 IECC requires insulation the full wall height or 10 ft. whichever is less. The New York basement wall depth of insulation requirements are from the top of the wall to the depth specified in the following table.

| HDD65 | Depth Below Grade (in.) |
| --- | --- |
| Up to 6000 | 24” |
| 6001-8000 | 48” |
| 8001 and up | 84” |

For crawl space walls, the 2001 IECC requirements depend on the configuration of the wall and its relation to the outside and inside grade. For New York, the depth requirement is a total minimum vertical or vertical and horizontal distance of 24” from the outside finish ground level.

## H.2 Compliance Reports

The *Inspection Checklist* differs from the 1995 MEC in the following sections, as requested by the state: Vapor Retarders, Duct Insulation, Duct Construction, Temperature Controls, Electric Systems, Fireplaces, and Service Water Heating.

# Appendix I

# SES/Pima County

# Appendix I

# SES/Pima County

The codes listed as Sustainable Energy Standard, Pima County for Locations < 4000 ft, and Pima County for Locations >= 4000 ft are based on the 2000 IECC. The two Pima County codes are identical to the 2000 IECC, except that they are based on a single HDD65 value (see Weather Data). The Sustainable Energy Standard has several modifications, as described below.

## I.1 Weather Data

The Pima county codes do not require a location file. The HDD value assigned is based on the code selected:

| **Code** | **HDD65** |
|---|---|
| 2000 IECC for locations < 4000 ft | 2100 |
| 2000 IECC for locations >= 4000 ft | 7000 |
| Sustainable Energy Standard | 7000 |

## I.2 Calculations

To force the engine to use the HDD65 values associated with each code, the GUI can set the HDD65 location variable directly. This will cause the engine's *use location file* variable to be set to FALSE. When the code is changed again, the *use location file* variable must be explicitly set back to TRUE, or the engine will not use HDD values based on location.

With respect to the solar heat gain calculations, the SES code will implement its own version (i.e., 0.39 and 0.5 depending on the orientation of the window) and the non-SES codes will implement the SHGC calculation that factors in projection factor impacts.

## I.3 Compliance Reports

The *Inspection Checklist* for the SES code differs from the 2000 IECC in the following sections, as requested by the jurisdiction: Heating and Cooling Equipment, Glazing, Plans, Air Leakage, Vapor Retarder, Duct Construction, Water Heating, Metering, Wood Burning Stoves and Fireplaces, Circulating Hot Water Systems, and Swimming Pools.

# Appendix J

# Vermont

# Appendix J

# Vermont

The 1997 Vermont Residential Building Energy Standards is based on the 1995 MEC.

## J.1 Weather Data

Vermont enhanced their list of cities and mapped all of them to the weather data for one of five locations: Burlington, Chelsea, Newport, St. Johnsbury, or Vernon.

## J.2 Calculations

The Vermont code requirements apply the following modifications to the MEC 1995 code requirements:

| **Code Requirement** | **Percentage of the 1995 MEC UA** |
|---|---|
| Single-Family Homes | Total UA 5% Below 1995 MEC |
| Multifamily Homes | Total UA 10% Below 1995 MEC |
| Log Wall Homes | Total UA 20% Above 1995 MEC |

## J.3 Compliance Reports

The *Inspection Checklist* differs from the 1995 MEC in the following sections, as requested by the state: Vapor Retarder, Domestic Hot Water, and Dampers.

# Appendix K

# Wisconsin

# Appendix K

# Wisconsin

The Wisconsin Uniform Dwelling Code is based on the 1995 MEC.

## K.1 Weather Data

Wisconsin uses counties and does not support a cities version. Their code is based on a single zone (Zone 15). You will not see changes in the Max. UA when switching locations, like you do for most codes. The locations were left in, however, because the heating loads calculation in the *Loads* folder varies by zone. Wisconsin has four zones, and the outdoor design temperatures used in the loads calculation vary for each of the four zones.

## K.2 Calculations

The Wisconsin code has the following requirements:

| | **Non-Electric** | **Electric** |
|---|---|---|
| Ceiling | 0.026 | 0.020 |
| Wall | 0.0110 | 0.080 |
| Basement | 0.091 | 0.091 |
| Crawl Space | 0.060 | 0.060 |
| Floor over unheated | 0.050 | 0.050 |
| Floor over outside air | 0.033 | 0.033 |
| Slab – Unheated | R-6.5 | R-10 |
| Slab – Heated | R-8.5 | R-10 |

## K.3 Compliance Reports

The *Inspection Checklist* differs from the 1995 MEC in the following sections, as requested by the state: Air Leakage, Ventilation, Vapor Retarder, Duct Insulation, Duct Construction, Temperature Controls, Humidity Control, Circulating Hot Water Systems, and Pipe Insulation.

# Appendix L

# AreaCalc

# Appendix L

# AreaCalc

## L.1 Introduction

### L.1.1 About AreaCalc

AreaCalc is an automated building take-off tool that can be used to assist builders, architects, contractors, and others in the building industry to perform area take-offs. AreaCalc was designed to work with the RES*check* software, although it may be used for other applications.

The AreaCalc software allows users to construct a library of commonly-used windows, skylights, and doors. Users can enter these components directly, or once the library is created, they can simply select an assembly from the library and enter the quantity to be installed in the building. The software computes the gross area of all assemblies.

AreaCalc may also be used to sum the areas of wall and ceiling components to compute a gross wall or ceiling area. The gross areas of ceilings, basement and crawl space walls, and floors may also be summed. The data input into AreaCalc can be automatically transferred to RES*check* by using the *Transfer Data to REScheck* option under the *Tools* menu.

### L.1.2 About This Report

This appendix is designed to explain the features, technical basis and the software development details for the AreaCalc software.

## L.2 Computations

The **Window/Wall Percent** is the ratio of total window area divided by the total wall area:

[(WINDOW_AREA / GROSS_WALL_AREA) * 100.0].

The **Area-Weighted Average U-Factor** is the total weighted U-factor divided by the total area of that component. The Total Weighted U-Factor is calculated by multiplying U-factor by the component area:

(WINDOW_AVERAGE_U_FACTOR = sumWeightedUFactorAvg / sumTotalArea) (applicable to windows/skylights only).

The **Area-Weighted Average SHGC** is the total weighted SHGC divided by total area of that component. Total Weighted SHGC is calculated by multiplying SHGC by the component area: (WINDOW_AVERAGE_ SHGC = sumWeighted SHGCAvg / sumTotalArea) (applicable to windows/skylights only).

The **Net Ceiling Area Total** is the total ceiling area minus the total skylight area:

(NET_CEILING_AREA = GROSS_CEILING_AREA - SKYLIGHT_AREA).

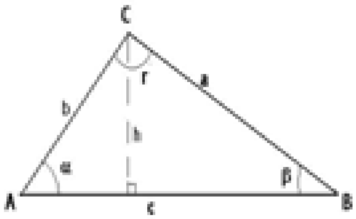
The **Net Wall Area Total** is the total wall area minus total window area minus total door area:

(NET_WALL_AREA = (GROSS_WALL_AREA)- (WINDOW_AREA)- (DOOR_AREA)).

The **Area Subtotal** (total of selected rows) is the sum of the areas of the selected rows that are in the library.

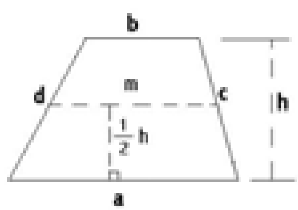
## L.3 Common Shapes, Dimensions, and Area Calculations

### L.3.1 Triangle



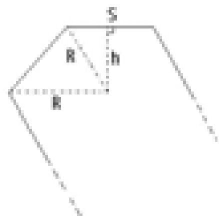

Area = (base X height)/2
Base = c; height = r;

### L.3.2 Trapezoid



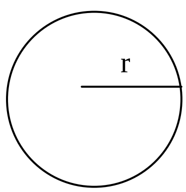

Area = (height)/2 X (width1 + width2)
Height = h; width1 = a; width2 = b;

### L.3.3 Hexagon




Area = (Perimeter X height)/2
Perimeter = number of sides X side length = 6 X s;
Height = h;

### L.3.4 Circle




Area = Π X Radius $^2$
Π = pie- constant – 3.17..;
Radius = r;

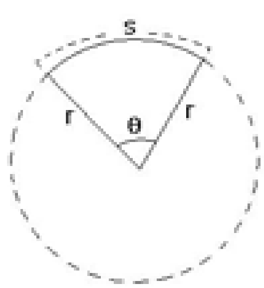
### L.3.5 Half Circle

Area= Area of circle /2;
Perimeter = (perimeter of circle/2) + diameter

### L.3.6 Quarter Circle

Area = Area of circle/4
Perimeter = (perimeter of circle/4) + (2 x radius)

### L.3.7 Sector of Circle (not implemented)




Area and Perimeter of the Sector of Circle

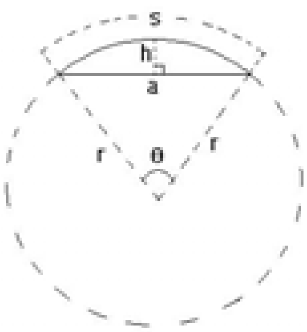
$\alpha = \frac{\theta \pi}{180}$ (rad)

$s = r\alpha$

Perimeter $= 2r + s$

Area $= \frac{1}{2} \alpha r^2$

### L.3.8 Segment of Circle (not implemented)




Area and Perimeter of the Segment of Circle

$$\alpha = \frac{\theta \pi}{180} \quad \text{(rad)}$$

$$a = 2\sqrt{2hr - h^2}$$

$$a^2 = 2r^2 - 2r^2 \cos\theta$$

$$s = r\alpha$$

$$h = r - \frac{1}{2}\sqrt{4r^2 - a^2}$$

$$\text{Perimeter} = a + s$$

$$\text{Area} = \frac{1}{2}\left[ sr - a\,(r - h) \right]$$

# APPENDIX J: HUD CLIMATE ZONE MAP

24 CFR §3280.506