Development of a Thermal Standard for Manufactured Homes

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Proposed thermal requirements were developed for manufactured (mobile) homes in response to legislation requiring the U.S. Department of Housing and Urban Development (HUD) to update its thermal standards for manufactured homes. A life-cycle cost minimization from the consumer's (owner's) perspective was used to establish the consumers optimum. The life-cycle cost analysis, the resulting maximum overall U-value, and the impact of the new requirements are discussed. Guidelines are suggested for developers of future standards.

Introduction

Proposed new U.S. Department of Housing and Urban Development (HUD) energy-efficiency standards were developed for manufactured homes (also known as mobile or HUD-code homes). These energy-efficiency standards were developed based on a cost-benefit analysis where the costs of energy efficiency measures (EEM) were balanced against the benefits of energy savings to yield the minimum total cost to the consumer. The new standard reduces the average building envelope U-value by about one-third, with a similar reduction in energy consumption. This energy-efficiency standard is preemptive of all other manufactured home standards and mandatory for the approximately 200,000 manufactured homes built annually in the United States. This paper outlines the development and characterizes the impact of the proposed manufactured home energy-efficiency standard. The last quarter of the paper focuses on recommendations to developers of future standards.

Methodology and Input Parameters Used in Development

Introduction

Congress passed the Housing and Community Development Act of 1987 (HCDA) requiring the U.S. Department of Housing and Urban Development to revise energy conservation standards for manufactured housing (HCDA 1987; CRH 1987; CRS 1987). HUD brought the Pacific Northwest Laboratory (PNL) under contract to assist in developing a revision to the energy conservation requirement in the HUD's existing Manufactured Home Construction and Safety Standards (MHCSS) (24 CFR 3280). The standard is documented in more detail in other reports (Conner et al. 1992; Conner and Taylor 1992; Lee and Conner 1992).

The approach used in developing the proposed standard revision was a cost-benefit analysis in which the costs of energy efficiency measures (EEMs) were balanced against the benefits of energy savings. The resulting optimum specified an overall level of energy conservation in terms of a building shell U-value (thermal transmittance) that ensured the lowest total of construction and operating costs to the owner of a manufactured home. This life-cycle cost optimization was performed for a large number of cities in the U.S. The resulting U-values were grouped into four zones with state boundaries, each zone having a specific U-value requirement.

Life-Cycle Cost Model and Energy Simulation

The Housing and Community Development Act of 1987 (HCDA 1987) and the accompanying conference reports (CRH 1987; CRS 1987) define the type of optimization method used to set the standard. (The Congressional Reports provided additional clarification of the HCDA and were treated as requirements.) By Congressional mandate, the optimization methodology should be chosen to "ensure the lowest total of construction and operating costs." (HCDA 1987). The methodology should "result in the lowest possible total cost taking into consideration down payment, financing, construction, and energy costs" (CRH 1987). The method was described as "a life cycle cost analysis" (CRS 1987).

Life-cycle cost (LCC) methods were used to compare the total long-run (present value) dollar costs of several alternatives, with the least cost alternative usually the preferred alternative. The LCC method sums the (discounted) costs and benefits of the investment, which, in turn, are calculated based on existing and forecasted economic parameters. For the analysis to be credible, the parameters must properly reflect present or expected market conditions.

The elements of the generic LCC method are shown below. All costs and benefits are computed in present value dollars.

Life-cycle cost = Initial investment + Energy costs
+ Maintenance costs - Resale value

The first element, the initial costs for the purchase and financing of manufactured home EEMs, is the primary cost. A reduction in the second element, energy costs, is the primary benefit of the standard.

Automated Residential Energy Standard

The use of software containing a life-cycle cost model, a cost-minimization model, and a building thermal energy simulation model can speed development of a building energy standard; all three of these functions are performed by the Automated Residential Energy Standard (ARES) (Lortz and Taylor 1989). The ARES software is a computer program developed for the U.S. Department of Energy (DOE) specifically for the development of residential energy conservation standards. Given a set of energy price, financial, economic, and EEM cost parameters for a building at a specific location, ARES identifies the set of EEMs that minimizes homeowners' total life-cycle cost. ARES removes the requirement for doing separate building energy simulations because simulation (actually a parameterization of a large database of simulations) is internal to ARES.

The Automated Residential Energy Standard generates an optimum set of EEMs for a home in a specific city using a specific heating system and energy type. ARES does not generate an optimum U-value for a group of cities or a climate zone. The aggregation of the individual optimum U-values into climate zone values is done as a separate series of steps that are described later.

Financial and Economic Parameters

Selection of a number of financial, economic, and energy price parameter values was necessary to develop the cost-effective manufactured housing standards.

Legislative Requirements Pertaining to Parameter Selection. Statutory requirements affected the selection of parameters. The standard was developed using "costs to the manufactured home owner" (CRH 1987). Therefore, all costs and benefits were calculated from the homeowner's perspective. The costs and benefits were considered for the "home over its estimated useful life" (CRH 1987). This is clarified as "the effective physical life of the structure" (CRS 1987). Therefore, the period of analysis was the manufactured home's physical lifetime.

Finance Parameters. Because most new manufactured homes purchased are financed, several financing parameters were required. Most of these parameters were established based on sources that surveyed the financing practices of the industry. A few of the parameters had to be established by querying experts. The finance parameters are the mortgage interest rate, loan term, down payment, points, and loan fees. A mortgage interest rate of 14% was selected for this analysis, based on rates in recent years. Based on studies of manufactured home financing (Gates 1986, p. 4; Foremost Insurance Group 1988, p. 18), a loan term of 14 years was selected. A down payment of 15% was used in the analysis (Gates 1986, p. 13). Based on personal communications with a number of experts, the points and loan fees imposed by the new EEMs were estimated to total 1%.

Economic Parameters. A discount rate, inflation rate, period of analysis, and property tax were required to define the new standard. The discount rate was most difficult to establish because there was no clear correct choice that most experts agreed on. (The discount rate also has a significant impact on the final result.)

- Discount Rate

  The discount rate is used to compute the present value of future dollars, as required by the life-cycle cost analysis. The discount rate is usually considered to reflect either the best alternative use of the consumer's funds or the more ambiguous measure of the consumer's preferences for spending their money in the present or future (time value of money).

  There were many alternatives on which a choice of discount rate could have been based. There are several alternative monetary investments for the consumer, including U.S. Savings Bonds, passbook savings accounts, and certificates of deposit (CDs). The interest rates on these investments vary, but in the aggregate range from about 3% to 9%.

  The consumer's "time value of money", or "implicit discount rate" is more difficult to determine. The consumer's implicit discount rate is usually imputed by examining consumer purchasing behavior when given a range of options at different prices and energy-efficiencies. This purchasing behavior demonstrates how much a consumer is willing to pay in the present for future energy savings. In practice, discount rates are difficult to determine, with an extremely wide range of discount rates having been reported (EPRI 1988). The rates also vary greatly across individuals and income levels. Often the consumer lacks sufficient information to compare options.

Another possible rate is the rate charged for other consumer debt, such as credit card purchases, because consumers show their willingness to pay this rate by using credit cards. However, considering the fact that many consumer pay off credit card bills before they are charged interest, and that many credit cards have a "grace period" between the consumer purchase and initiating the interest charge, the effective interest rate is hard to judge and may be significantly lower than the posted rate.

Another alternative "investment" for the consumer is prepayment of the mortgage. Using the criteria that the discount rate should be compared to the consumer's alternative investments, specifically "The discount rate should reflect the rate of return that will be foregone if the project in question is undertaken instead of the next best alternative investment opportunity of similar risk; that is, it should reflect the 'opportunity cost' of the project." (Ruegg and Petersen 1987, p. 17). This criterion requires selecting the consumer's best available rate of return with comparable risk, the prepayment of mortgage. The net rate available to the homeowner with a 14% manufactured home loan who deducts the interest from his taxes for an "investment" in mortgage prepayment would between 11.5% and 14% (nominal) or about 6.5% to 9% (real). The real discount rate of 7% (about 12% nominal, if the 4.9% inflation rate is added) was used in the analysis because it is within this range and was the rate generally used for Federal energy life-cycle cost analyses (7% in the Energy Security Act of 1980).

- Inflation Rate

  The inflation rate is used to convert between nominal and real rates used in this analysis. The mortgage interest rate is a nominal rate. The energy escalation rates, described later in this section, are real rates. A recent DOE base-case forecast of the long-range gross national product (GNP) implicit price deflator is 4.9% (Energy Information Administration 1989, p. 54), which was used as the inflation rate for this analysis.

- Period of Analysis

  The statutory requirements for development of the standard set the "estimated useful life" (CRH 1987) as the period for the life-cycle cost analysis. This period is clarified as the "effective physical life of the structure" (CRS 1987). Because the standard applies to new manufactured homes, the estimated life was that of a newly constructed home. The average useful life for new manufactured homes that are continuously occupied has been most recently estimated at about 33 years (Gates 1986); this value was used in the analysis.

Energy Prices

Both current energy prices and energy price escalation rates were required for the analysis. The average residential energy price used in each state for electricity, distillate fuel oil, liquid petroleum gas (LPG), and natural gas was available from an Energy Information Agency (EIA) report, State Energy Price and Expenditure Report (EIA 1988), which was updated for inflation.

Energy prices can be volatile and projection of future energy prices is difficult. Because the useful life of a manufactured home typically exceeds 30 years, the analysis is relatively insensitive to temporary changes in energy prices, so only long-term energy prices need to be projected. The selection of energy prices was restricted to published projections by the Federal government. The residential energy escalation rates (real) were adapted from a report prepared for the Federal Energy Management Program (FEMP) [National Institute of Standards and Technology (NIST) 1988]. The energy escalation rates for the 33-year period of analysis averaged: electricity 0.0% (constant); fuel oil, 2.5%; natural gas, 2.0%; and LPG, 2.3%. Another DOE source for energy escalation rates projects similar but higher energy price escalation rates (EIA 1989, p. 47).

Energy Efficiency Measures

A life-cycle cost analysis requires the definition of specific EEM options. EEMs are considered alternative construction options that can be compared to determine the most cost-effective package of options that, in turn, provides the basis for the proposed new standard. The law and accompanying documents set requirements that affect the selection of the EEMs reported here. The standard was to be developed using "costs to the owner of a manufactured home" (CRH 1987). Therefore, all costs and benefits were calculated as retail cost to the homeowner. The requirement concerning design was clarified in the Congressional Report (CRH 1987) by requiring separate consideration of single- and double-wide homes. Therefore, the distinction between EEM characteristics for single- and double-wide homes was made when appropriate.

Energy Efficiency Measure Characteristics Required

Energy efficiency measure option characteristics were determined for all manufactured home components. These components included ceilings, walls, floors, windows, and doors. Special considerations, which are discussed later, applied to space conditioning equipment, ducts, and infiltration. For each component, a list of EEM options and associated characteristics (if appropriate) was produced, including EEM option description, cost, U-value, and lifetime.

Obtaining defensible EEM cost data is a common problem for standards developers. Common cost estimation manuals do not include the EEM level resolution needed for standards development; the manuals usually do not include any data allowing calculation of the cost of windows or HVAC equipment. Cost data for the EEMs used in the manufactured home analysis came primarily from national surveys of manufactured-home manufacturers. Most EEM cost data came from two surveys, a 1987 survey performed by PNL for HUD (Lee and Conner 1992) and a study done for the Bonneville Power Administration (BPA) (Harkreader et al. 1987). A telephone survey of manufacturers was also conducted in 1988 to collect data on window characteristics and costs (Lee and Conner 1992).

Analysis of Energy Efficiency Measure Cost and Characteristics Data

A set of candidate EEMs was selected for use in the analysis based on the manufacturer surveys. These measures constituted the possible options included in the life-cycle cost optimization. An incremental cost was defined for each measure. The overall U-values for walls, floors, and ceiling assemblies were calculated assuming constructions currently used in the industry. The window and door U-values were defined based on ASHRAE sources.

The first step in the analysis of the EEM ceiling, wall, and floor cost data was to distinguish between the cost of adding insulation (additional R-value) and the construction changes (for example, going from 2x4 to 2x6 wall studs) that would be required at some point to allow for higher R-values. Once the ranges in which no construction changes occurred were determined, the costs per change in unit R-value (equivalent to the cost of incremental insulation) were calculated. To estimate the incremental cost of an EEM, the change in R-value from one EEM to the next was multiplied by the cost per unit R-value change and the prototype component area to produce the component cost. If a construction change was required, the cost of the construction change was also included. With variations, this method was used to determine the ceiling, wall, and floor costs for each EEM.

Determining Energy Efficiency Measure Options

The legislative requirement to consider the "factory construction techniques of manufactured homes" (HCDA 1987) was interpreted to mean consideration of only those EEMs used commercially by a portion of the manufactured home industry. Operationally, we translated this guideline to the requirement that, to include an EEM in our analysis, at least four manufacturers must have reported in our surveys that a specific EEM option was offered in one of their homes. Although consistent with our interpretation of the statutory requirement, the requirement that EEMs be in current commercial use rather than technically feasible eliminated a number of EEMs that have been demonstrated to be technically feasible by demonstration programs (e.g., higher levels of floor insulation, low-e windows), such as those sponsored by BPA (Onisko 1986; Riewer 1988).

Window costs were estimated based on the manufacturer window survey described previously. A regression analysis was performed to calculate the incremental cost for each window characteristic separately.

The incremental costs of doors were estimated using the survey data and regression analysis.

Table 1. EEM Options

Ceilings: R-11, 14, 19, 21, 22, 28, 30, 33, 38
Walls: R-7, 11, 13, 14, 19
Floors: R-7, 11, 14, 18, 22
Windows: single-pane: aluminum (al.); al. and tint; al. & storm; double-pane: al.; al., thermal break; al., storm; wood; vinyl
Door: metal; metal and storm; metal and thermal break; metal, thermal break and storm; wood; wood and storm

The life-cycle cost analysis included the cost of replacing EEMs in the year that they are projected to be replaced. Insulation (51 years), windows (30 years), and storm doors and windows (15 years) lifetimes were based on a Minnesota Department of Energy and Economic Development report (MDEED 1984).

The use of high-efficiency heating and air conditioning equipment (usually referred to as HVAC equipment) was a possible EEM option. However, in contrast to the higher R-value EEMs described previously, higher efficiency space conditioning appliances were not considered because there was no explicit requirement to consider them in the law, the standard was an overall U-value, and the National Appliance Energy Conservation Act of 1987 (NAECA) (Public Law 100-12, March 17, 1987) sets minimum efficiency standards that will apply to manufactured homes. Although the NAECA does not limit HUD's authority to require higher equipment efficiency (it does limit state and local authority), the NAECA does provide a single appliance efficiency standard for the United States and this was deemed sufficient as a base requirement. The NAECA minimums were assumed for the analysis. The efficiencies were: electric furnace, 100%; fossil fuel furnace, 75% annual fuel utilization efficiency (AFUE); heat pump, 6.6 heating season performance factor (HSPF) and 9.7 seasonal energy efficiency ratio (SEER); and air conditioner, 9.7 SEER.

The law required that the standard "provide for alternative practices that result in net estimated energy consumption equal to or less than the specified standard" (HCDA 1987). As part of the compliance with this provision, the standard included a method of giving manufacturers credit for HVAC systems that exceed the NAECA requirements; the alternative allowed homes a higher U-value such that the increased U-value allowed would balance the efficiency savings from the increased heating/cooling efficiency.

Infiltration and Ducts

Energy efficiency measures that would lower infiltration were considered, but rejected based on several concerns. Currently many new manufactured homes are relatively airtight, so further tightening might have significant negative impacts on occupant health. The recommendation of ventilation standards to mitigate health effects of very low levels of infiltration was difficult based on the current state-of-the-art, and would require further study. There were also practical concerns with measuring infiltration rates and assigning responsibility in the event of noncompliance. No specific requirement was present in either the legislation or the Congressional Report to include infiltration EEMs in the standard. For these reasons, no infiltration control EEMs were considered.

Required insulation levels for external ducts were developed in a different manner than the requirements for other components. ARES did not perform duct insulation optimization and an ARES-type model for duct insulation was not readily available. Duct insulation requirements for the proposed standard were set based on the ASHRAE (1989 ASHRAE Fundamentals, p. 32.12), the ANSI/ASHRAE Standard 90A-1980, and the Model Energy Code [Council of American Building Officials (CABO) 1989, 503.9.1], all of which define a criterion for determining a required insulation level as:

$$R = \Delta T / 15(\text{hr} \times {}^\circ\text{F} \times \text{ft}^2/\text{Btu})$$

where ΔT is the design temperature differential between duct air and duct surface. These were applied to the HUD zones based on MHCSS specified design temperatures and ASHRAE climate data (ASHRAE 1989a, p. 24.4 to 24.15). After rounding to the nearest common commercial value for insulation, the requirements became R-4 for the new zone 1 and R-8 in all other zones. The existing HUD standard requires R-4 insulation on external ducts (24 CFR 3280.715(a)(6) and (7)). To address practical concerns of insulation compression, this R-value standard was expressed as a nominal R-value installed per manufacturer's specification.

Optimum U-Values and U-Value Zones

The statutory requirements for the standard expected that HUD would establish "maximum transmission heat loss coefficients (U-values) in a number of climate zones" (CRH 1987). Current HUD requirements are also defined as overall U-value maximums for zones. The overall U-value (U_o) computation includes the contribution of each building component -- ceilings, walls, floors, and windows -- with the U-value (U) of each component weighted by area (A).

This section describes the creation of the new maximum U-value zones. This process started with ARES producing separate U-value optimums for each city, energy/equipment type, and prototype (single- and double-wide). These were aggregated in a series of steps to U-values for four zones in the U.S., which are shown later. Separate U-value requirements were expected for single- and double-wide homes (CRH 1987); however, as discussed below, the requirements for single- and double-wide homes were very similar and, therefore, were merged.

Initially, prototype single- and double-wide homes using five specific types of (HVAC) equipment and energy were optimized by ARES. The five energy types for which optimum U-values were produced for each city were natural gas, LPG, oil, electric resistance, and electric heat pump. In all cases, an electric air-conditioning system was included. The two manufactured home prototypes (single-wide home and double-wide home), were optimized separately. Rather than selecting a few cities to represent the U.S, all 881 cities available in ARES were used. This provided a density of locations such that any point in the U.S. was close to a city for which an optimum U-value was produced.

After the production of the 8,810 U-values (881 cities for five HVAC/energy types for both single- and double-wide homes), the individual U-values were aggregated to U-value zones in four steps. First, individual city U-values were extrapolated into state U-values. Next, single-wide and double-wide U-values were combined into U-values for all homes. In the third step, separate HVAC equipment and energy types were aggregated into U-values for all equipment/energy types based on the frequency with which each type of equipment was present in each region. Consideration was given to establishing separate fossil fuel and electric U-values, but the combination of all system types was selected as preferable for a number of reasons, including simplicity and continuity with the existing HUD standard.

The final step in creation of the maximum U-values was the creation of zones. The Congressional Report (CRH 1987) specifies the creation of "climate zones" in which a specific U-value applies. Since the homes can be shipped over wide areas and the destination is not always known when the home is built, the standard needed to define large zones with well-defined boundaries. Therefore, all U-value zones were defined as collections of states and the U-values defined at the city level were aggregated into state U-values. A mathematical technique was used to group states with similar U-values into U-value zones. The mathematical technique, called "hierarchial clustering", defined groups of states such that the difference between each state's U-value to the mean U-value in its zone was minimized. The "clustering" technique provided a quick and objective method of grouping states into zones. The single criterion for definition of the zones was the similarity in U-values. Four zones were selected as representing the range of U-value optimums found in the U.S. The U-value applicable to each zone was defined as the sales weighted average of the U-values for all states in that zone. The proposed four zones and the U-value requirement associated with each is shown in Figure 1.

Comparison to Other Standards

There are several existing standards that can be used for comparison to the revised HUD standard:

- HUD's Title VI (regulates most manufactured homes)
- HUD Title II-E (30-year loan, requires that the home include land)
- HUD's Minimum Property Standards (MPS)

Two groups have also circulated proposed new energy standards for comment by their members and the public:

- Manufactured Housing Institute's (MHI) Manufactured Home Construction and Safety Standards Consensus Committee (Levy 1989)
- American Society of Heating Refrigerating and Air-Conditioning Engineers, SPC 90.2 on Residential Energy Standards (ASHRAE 1989b).

The various standards are not directly comparable. The different standards are defined in terms of several geographical zones (groups of states) or based on various ranges of heating degree days. The simplest basis for comparison is to look at the national average U-value required by each standard. The estimated national average maximum U-value (home sales weighted by state) in each standard is shown in Table 2. As the table shows, the revision proposed by the revised standard is significantly more stringent than any of the existing HUD standards. It is interesting to note that all three recently proposed standards (those from HUD, MHI, and ASHRAE) would require U-values well below the three current HUD standards (Title VI, Title II-E, and MPS), supporting HUD's revision of the standard. The revised standard is closest to that proposed by ASHRAE.

Life-Cycle Savings, Mortgage Costs, and Energy Savings

The approximate costs and benefits of the proposed standard were compared to current construction practice as distinguished from HUD Title VI requirements. The average home currently has a U-value somewhat less than the Title VI requirements because some new homes are built with U-values at least moderately below the Title VI maximum. Based on home manufacturers' reports of their most commonly produced model, the mean current-practice new manufactured home in the U.S. has an

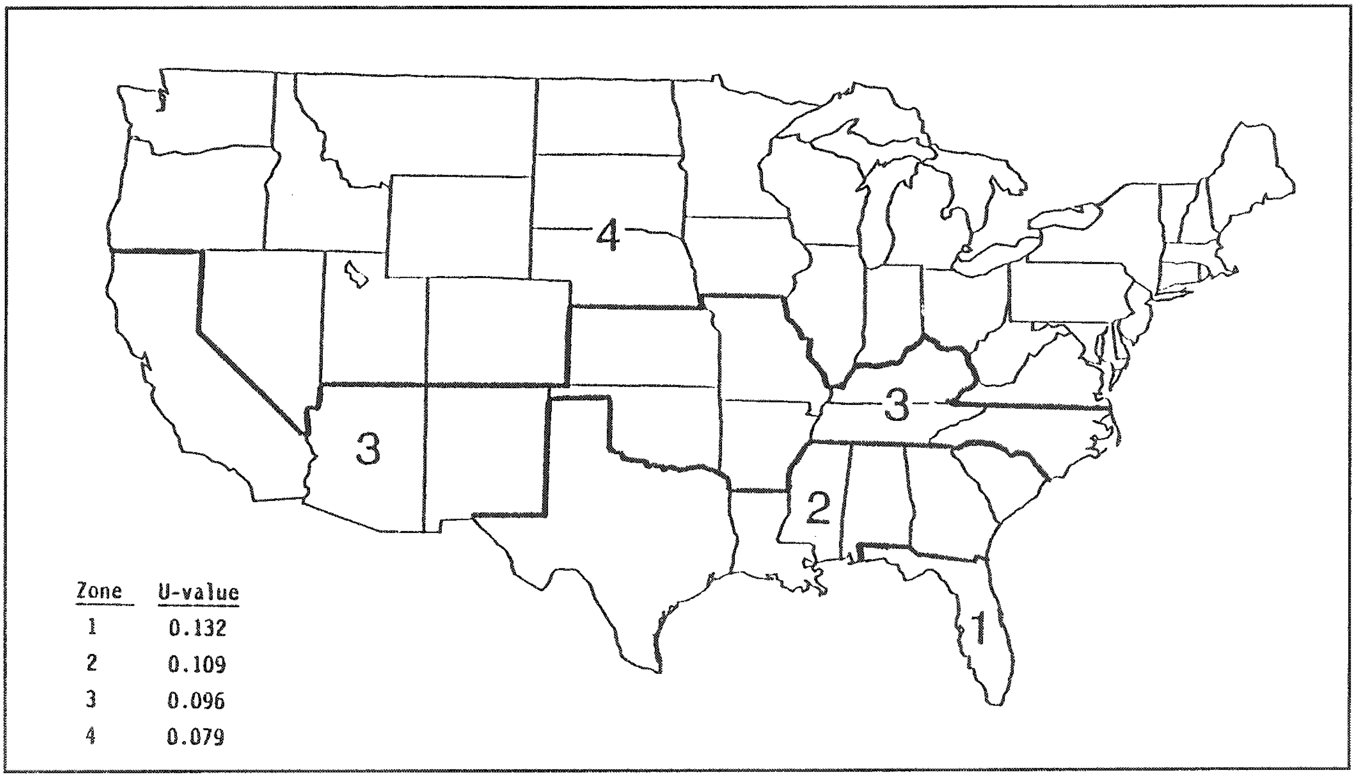

Figure 1. U-Value Zones[(a)]

(a) Hawaii is zone 1. Alaska is zone 4.

Table 2. Average National U-Value for Selected Standards

Average U-value	Standard
0.145	HUD Title VI
0.125 to 0.140	Estimated current practice
0.125 to 0.135	HUD Minimum Property Standards
0.127	HUD Title II-E
0.111	MHI MHCSS Consensus Committee
0.098	Revision proposed by HUD
0.092	ASHRAE 90.2P Residential Standard

approximate U-value between 0.140 and 0.125. The average additional cost per current-practice home to meet the proposed standard would be in the range of $800 to $1100. The average present value of the projected energy savings was calculated to be 2 to 2.5 times the added construction cost of meeting the standard. The aggregate national net present value (costs minus benefits) of the proposed standard compared to current practice was estimated to be $300 million for each year's production of homes. [This value would be about $400 million (per year) if all homes were assumed to be built to the current standard.]

The cost and benefits of the proposed standard, relative to the Title VI standard, were also estimated. The national average (sales-weighted) increase in the mortgage payment was $10/month. Note that after 14 years, the mortgage is paid off while the energy savings continue. The present value of the incremental costs (primarily the mortgage and financing costs) of the standard averaged about $1200. Nationally, the first year savings in energy costs averaged $18/month, which slowly escalates over the home lifetime. The monthly savings in energy costs exceeds the monthly mortgage payment increase in all states. The present value of the energy savings averaged $3200. The net present value, including both costs and benefits, is the most important figure from the homeowner's perspective. The net present value from the proposed standard averaged $2000 per home.

The approximate insulation R-values required by the existing Title VI requirements are compared to the new requirements in Table 3. The old zone 1 (southern half of the U.S.) includes most of the new zones 1, 2, and 3. The old zone 2 (Northern half of continental U.S.) is approximately equivalent to the new zone 4. The old zone 3 (not shown) is Alaska and contained only about 0.05% of the home sales. Recall that the standards prescribes only an overall maximum U-value, not the specific R-values by component. The actual R-values required for a specific home are dependent on the home design and construction and are particularly sensitive to the window area.

There are a number of significant social benefits from the standard that are not reflected in the net present value ($300 million for each year's production of homes). These benefits result from the standard's positive impacts that are external to the market valuation of manufactured home energy efficiency from the consumer's perspective, referred to as "externalities" by economists. For example, the market does not properly value the high marginal cost of the new utility generation/distribution construction that would be necessary if not for the more energy-efficient manufactured homes. Also, the use of average energy prices in the residential energy market underestimates the higher than average capacity costs associated with heating and cooling loads. A major externality to the energy market is the environmental impact of energy use. This environmental impact includes the emission of CO_2, SO_2, NO_x, and particulates during the generation of electricity and the burning of fossil fuels. Although these "environmental externalities" are difficult to value, they are clearly large. The present value of environmental externalities were estimated to be between $50 million and $200 million for each year's production of homes. These positive social impacts of the revised standard were not included in the optimization that developed the revised standard, but they are clearly significant national benefits.

Table 3. Comparison of Existing and New Requirements in Terms of R-Value

Existing Requirement	New Requirement
Zone 1 (about 63% of homes)	Zone 1 (11% of homes, Florida)
Ceiling R-11	Ceiling R-14
Walls R-7	Walls R-11
Floor R-7	Floor R-11
Windows Any	Windows Any
	Zone 2 (28% of homes)
	Ceiling R-19
	Walls R-14
	Floor R-14
	Windows Single with Storm
	Zone 3 (29%, of homes)
	Ceiling R-22
	Walls R-19
	Floor R-19
	Windows Single with Storm
Zone 2 (about 37% of homes)	Zone 4 (about 31% of homes)
Ceiling R-14	Ceiling R-22
Walls R-11	Walls R-19
Floor R-7	Floor R-19
Windows Single/storm	Windows Double-Pane Vinyl

Alternative Methods of Compliance

Two alternative methods of compliance are suggested for inclusion in the proposed standard. These methods "provide for alternative practices which result in net estimated energy consumption equal or less than the specified standard" (HCDA 1987). The first alternative method allows a trade-off between U-value and HVAC efficiency, as was noted earlier. An equation for this calculation is included in the standard. The second alternative allows a calculation or simulation of energy use to show that a home meets the energy use implicit in the U-value standard. The characteristics of an acceptable calculation are also suggested. Although a calculation could be used with any home, it requires significantly more effort and is intended only for use with innovative designs that are not adequately characterized by a U-value.

U-Value Calculation Method

The manufactured home standard is described in terms of an overall U-value (U_o), which manufacturers must calculate for each model of home they make. In the process of developing the standard, it became clear that the methodology for calculation of the U_o was vague and ambiguous. Because enforcement of the standard requires a clear definition of the required calculation, a manual defining the calculation was written (Conner and Taylor 1992). The manual also includes heating load and cooling load calculations. The methods were adapted from the ASHRAE Handbook, 1989 Fundamentals. The Handbook defines methods for use in all types of buildings, therefore it is necessarily more general than this manual. The Handbook leaves many application-specific choices to the professional applying its methods. The Handbook does not contain (or claim to contain) methods specifically for manufactured homes. The manual for the proposed standard clarifies ambiguities and specifies calculations which must be used for determining compliance with HUD's requirements related to manufactured home U_o, heating load and cooling load.

Suggestions to Developers of Future Standards

Based on our experience in developing this and other standards, we make the following suggestions to future standards developers.

Characteristics of a Usable Standard

A standard must be carefully written and easily understood to be useful. Regardless of what the specific requirements are, we suggest the following guide lines for creating a usable standard:

- Keep it simple.
- Shorter is better.
- Limit the need for additional support materials.
- Choose a form whose compliance is easily verified in both the plan/ specification stage and in the field. Plan evaluation should take less than 15 minutes. Field verification should add little time to existing routine inspections. Presume that the builder, plan/ specification reviewer, and the field verifier cannot talk with each other.
- Any data, methodology, or technology required to demonstrate compliance must be readily available.
- Requirements must be specific. Compliance or non-compliance should be clear to all parties. Clearly distinguish between mandatory requirements and suggestions.

Who Is Your Audience?

The standards developer writes for two very different audiences:

- those who review and evaluate the new standard
- those who apply the new standard.

The first audience includes policy makers, public officials, trade groups, special interest groups (e.g., environment, energy, consumer, Congressional oversight), and professional organizations. To them the standard represents an opportunity to make something happen (or prevent something from happening), to change and improve (or worsen) a situation. This group needs clearly written development documentation; including the methodology, assumptions, and input data. In principle they should be ale to reproduce the numerical values and specific requirements in the standard from the written documentation. Because the written documentation may be extensive, include an executive summary and relegate the details (large tables, related discussions, etc.) to the appendixes or reference separate reports.

Those who use the standards have different needs. Those who must comply with or enforce a standard need a standard that is usable, as described in the section above. Developers should be conscious that few people belong to both groups, and that text that meets the needs of one group will probably not meet the needs of the other group.

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