Update of Energy Efficiency Requirements for Manufactured Homes

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ABSTRACT

Energy-efficiency requirements were developed for manufactured (mobile) homes, which are regulated by the U.S. Department of Housing and Urban Development (HUD). A life-cycle cost analysis from the homeowner's perspective was used to establish parameters for a least-cost home in a large number of cities. Economic, financial, and energy-efficiency measures for the life-cycle cost analysis were selected. The resulting energy-efficiency levels were aggregated to the existing HUD zones and expressed as a maximum overall home U-value (U_o, or thermal transmittance) requirement for the building envelope. The proposed revised standard's costs, benefits, and net value to the consumer were quantified. This analysis updates a similar effort completed in 1992, which was the basis for the existing HUD code U_o requirement.

Introduction and Background

In 1987 Congress passed legislation that required the U.S. Department of Housing and Urban Development to revise energy-efficiency standards for manufactured housing. HUD contracted with the Pacific Northwest National Laboratory (PNNL)[1] to assist in developing a revision to the energy-efficiency requirements in the HUD's existing Manufactured Home Construction and Safety Standards (MHCSS) (24 CFR 3280). These energy-efficiency requirements are expressed as a maximum overall home U-value (U_o, or thermal transmittance) requirement for the building envelope. The HUD requirements currently in effect are based on a PNNL analysis completed in 1992 (Conner et al. 1992, Conner and Freeborne 1992).

Many changes have occurred in the decade since the analysis, which resulted in the existing-energy efficiency requirements in the MHCSS. The cost of energy-efficient window frames has been reduced. The price of low emissivity (low-E) glass has dropped dramatically. The use of vinyl windows has greatly expanded. Low-E glazing is standard for some manufacturers (PATH 1999). Mortgage interest rates have dropped. Single-wide manufactured homes, predominate in 1992, have given way to double-wide homes that often compete directly with site-built homes. Together these factors suggested the need to update the 1992 analysis to evaluate the least cost, energy-efficient building envelope requirements based on current economic parameters.

HUD has delegated MHCSS development to the National Fire Protection Association (NFPA). NFPA maintains its version of the MHCSS as the Standard on Manufactured Housing, NFPA 501 (NFPA 2003). This analysis supports a change proposal submitted to the NFPA 501 Committee, with the expectation that the updated NFPA 501 would eventually become the MHCSS. The energy-efficiency requirements for manufactured homes fall under the NFPA

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Mechanical Technical Subcommittee for Manufactured Housing. The specifications for overall U-values presented in this paper may be modified by the NFPA code development process.[2]

Methodology

The approach used in developing both the existing MHCSS thermal envelope requirements and this proposed revision was a cost-benefit analysis that balanced the costs of energy-efficiency measures (EEM) against the benefits of energy savings. The motivation for this approach is documented by the original development process (Conner et al. 1992). The resulting least-cost EEMs were used to define a minimum level of energy efficiency in terms of an overall building shell U-value (U_o). A U_o requirement for large geographical zones is used in the MHCSS.

Several major activities were required to develop the U_o requirements proposed here. A life-cycle cost (LCC) model was required to determine the least-cost EEM investment. EEM options, including each EEM's cost (mortgage, fees, payments) and U-value, were required as inputs. The calculation also required definition of the financial, economic, and fuel price parameters. Initially, separate minimum cost U_o levels were defined for homes with different heating fuel/equipment types in many U.S. cities. These separate U_o levels were aggregated into large geographical zones in which a specific U_o requirement applies.

Both the current HUD standard and the proposed revised standard were developed with the Automated Residential Energy Standard (ARES) software[3]. ARES implements an LCC methodology for residential energy-efficiency decisions based on a simulation database. Given a set of fuel price, financial, economic, and EEM cost parameters for a building at a specific location, ARES identifies the set of EEMs that minimizes the homeowner's total costs.

Input Parameters

Several financial, economic, and fuel price parameters were required for the LCC analysis. The intent was to identify the best source for each parameter. Most values are commonly reported statistics, traceable to published sources. It should be noted that some values vary across time, location, markets, institutions, circumstances, and individuals. If multiple sources for a parameter were identified, an attempt was made to choose the best source, with a bias towards the most recent and best documented sources.

Finance and Economic Parameters

This analysis assumed a new manufactured home purchased by the owner with financing. Several parameters affecting the cost and duration of the loan were defined for the analysis. These parameters are the mortgage interest rate, loan term, down payment, points, and loan fees. A discount rate, inflation rate, and period of analysis also needed to be established.

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[2] Congress created the Manufactured Housing Consensus Committee (MHCC) in 2000 (PL 106-569). The MHCC acts on the revisions of NFPA 501 and may also make changes to the specifications determined in this analysis.

[3] ARES is documented in Lortz and Taylor (1989).

Mortgage rate. A mortgage interest rate of 10% was selected. This rate represents a blended rate combining direct financing (through a lending institution) and indirect financing (through a home dealership). Between 75% and 80% of manufactured homes are financed indirectly (PATH 2000, NAHBRC 1998, Conwell 1999). Indirect financing rates are often reported as a percentage above traditional mortgage rates, typically 1 to 4% above direct (site-built) rates (AHS 2001, MHI 2003b, PATH 2000). The American Housing Survey (US Census 2001) reports that the long-term historical average rate for direct loans for site-built homes is near 8%. Freddie Mac's average for last 10 years is near 7.5%. Therefore an interest rate of 10% was selected was to represent the average historical long-term interest rate for financing manufactured homes. There is a trend towards lower cost financing and multi-section homes. Over time these trends will lower the least-cost U_o.

Loan term. A loan term of 15 years was selected as representative. The average loan term was estimated by several sources to range between 13 and 30 years (AHS 2001, NAHBRC 1998, MHI 2000, PATH 2000). The 15-year term is consistent with the American Housing Survey (US Census 2001) median reported for all manufactured homes.

Down payment. A down payment of 10% was used. Most of the literature reported (or assumed) a down payment of approximately 10% (NAHBRC 1998, MHI 2000, PATH 2000).

Points and loan fees. A value of 1% of the mortgage was retained from the 1992 work. There is little information about typical manufactured home loan points and fees.

Discount rate (alternative investment rate). To sum costs and benefits in future years as a present value, a discount rate needs to be established. Six methods of determining discount rates are discussed in the 1992 analysis (Conner et al. 1992). Paying off part of the mortgage early represents a reasonable and often available alternative investment for the consumer. Mortgage prepayment was also used as the discount rate for this analysis, which is 10%.

Inflation rate. The inflation rate is used to convert between nominal and real rates used in this analysis. The Council of Economic Advisors (2002) projects a long-term inflation rate of 2.3% annually, which was chosen for this analysis

Period of analysis and building lifetime. The 1992 analysis used the "physical life of the structure" (CRS 1987) as the period of analysis. Some suggested the first owner's (buyer's) time in their new home as the period for analysis. However, this analysis represents the interests of all the consumers who live in the house, because energy-efficiency features last much longer than the average occupant. If the first owner recoups the investment on resale, then the first owner's interests are also represented by higher energy efficiency resulting from the longer period of analysis. Although the value is difficult to define, energy efficiency adds value on resale indicating that the first homebuyer recoups much of their investment on resale[4]. A high resale value also makes the exact period of analysis less important.

[4] For example: NADA's Manufactured Housing Appraisal Guide Jan-April 2003 Part 3 Page 31, double section Super Good Cents/Natural Choice home with R-19 walls, R-33 floor, R-38 ceiling and R-5 doors with vinyl frames and low-E glass have an additional resale value of $1990 after year five and beyond. Although not stated, the "base" home would presumably be a home built to the existing MHCSS minimum requirements.

A 30-year lifetime with no resale value was selected for this analysis. The average useful life for new manufactured homes that are continuously occupied is estimated by two sources as 45 and 57.5 years (Eckman 2002, Meeks 1998). The longer lifetime would have increased the cumulative energy savings of the EEMs, but is moderated by the effect of the discount rate in reducing the value of benefits that far into the future.

Property tax rate. A property tax rate of 1% was assumed for this analysis. Property taxes vary widely from state to state and within a state. The median tax rate reported by the American Housing Survey (US Census Bureau 2001) for all manufactured homes is 1%.

Income tax rate. The marginal income tax rate paid by the homeowner affects the value of the mortgage tax deduction. However, most owners of the manufactured homes do not itemize their income tax deduction, so no benefit for mortgage tax deduction was assumed in the analysis.

Fuel price parameters. Both current fuel prices and fuel price escalation rates were required for this analysis. The average residential fuel price used in each state for electricity, distillate fuel oil, liquid petroleum gas (LPG) and natural gas were taken from the Energy Information Agency (2003a, 2003b, 2003c) The summer (air conditioning) and winter (heating) variation in electricity rates was accounted for.

The "real" annual residential fuel price escalation rates are projected for 25 years for the residential sector by fuel type as: -0.2% for electricity, 0.4% for fuel oil, 0.4% for natural gas, and 0.5% for LPG (Fuller and Boyles 2003).

Energy-Efficiency Measures

Selecting the least cost energy-efficiency measures (EEM) required defining the specific EEM options. The manufactured home components covered included ceilings, walls, floors and windows. For each component, a list of EEM options and associated characteristics was produced, including EEM U-value, cost and lifetime.

HUD's Uo is defined as the home's thermal shell and does not include infiltration or the required mechanical ventilation. Therefore, air leakage control and ventilation improvements, which may be very cost effective, are not dealt with here.

Energy-Efficiency Measure Cost and Characteristics

Because it was more obtainable than manufactured home cost data, cost estimations were based partly on site-built cost data. According to the industry—"Depending on the region of the country, construction cost per square foot for a new manufactured home averages from 10 to 35% less than a comparable site-built home" (MHI 2003). This implies EEM construction costs for manufactured homes are usually lower than costs for site-built homes. Therefore, overall costs reported here are likely biased towards a higher price, which makes the analysis results more conservative. All costs reported here are the incremental costs for each EEM option above the price of the lowest level. Except when noted in this report, the calculation of U-values for each EEM is described in 1992 report (Conner et al. 1992, Appendix B).

Table 1 shows the EEM options for the ceiling. Cost data is based on an assumed cost of $5 per bag for cellulose, with a manufacturer markup of 1.85 and a dealer markup of 1.34.[5]

Table 1. Ceiling EEM Options

R-Value	Cost $/ft^2	U-Value
11	0.00	0.091
22	0.15	0.046
33	0.32	0.033
38	0.40	0.030

The wall insulation cost data used in this analysis was a combination of the R.S. Means (2001) data and the California *Database for Energy Efficient Resources* (DEER) (Xenergy 2001). Costs for changing from 2-by-4 to 2-by-6 framing to accommodate R-19 or R-21 insulation are included. The R.S. Means costs are $0.14/ft^2 for the R-19 insulation instead of R-11 insulation and $0.37/ft^2 for additional framing cost for R-19. The DEER provided incremental costs from regular-density (R-11 and R-19) to high-density batt insulation (R-13 and R-21). R.S. Means did not have this data. For this analysis, the DEER material costs were marked up by 20% to account for installation overhead and profit. Table 2 shows the resulting wall R-value costs.

Table 2. Wall EEM Options

R-Value	Cost $/ft^2	U-Value
11	0.00	0.093
13	0.07	0.083
19	0.51	0.061
21	0.86	0.055

The approach used to estimate floor EEM costs was similar to that for the other component measures. Cost is based on an assumed cost of $0.012 per R-1 of fiberglass insulation, with a manufacturer markup of 1.85 and a dealer markup of 1.34. Table 3 lists the EEM options, costs, and U-values for floor insulation.

Table 3. Floor EEM Option Characteristics

R-Value	Cost $/ft^2	U-Value
11	0.00	0.089
22	0.33	0.041
33	0.66	0.030

Assigning costs to windows means associating a cost and a U-factor. Obtaining a cost-versus-energy-efficiency relationship is difficult for windows because window costs are greatly affected by non-energy characteristics such as appearance. The rapid changes in window technology also make obtaining window efficiency costs more difficult. Recent expansion in the

[5] Personal communication with Mike Lubliner, report co-author.

use of vinyl framing and low-emissivity (low-E) coatings is driving a continuing trend towards lower price increments for more energy-efficient windows.

The most cost-effective windows can be represented using incremental prices for a few energy-related features. The base window is a single-pane, aluminum-framed window. Costs for each thermal improvement were assumed constant regardless of other characteristics, for example, the costs of adding a low-E coating are the same for aluminum- and vinyl-frame windows.

The window cost data were taken primarily from the California *Database for Energy Efficient Resources* (Xenergy 2001), which included costs for many window types from multiple manufacturers/suppliers. The data included new energy-efficient technologies, such as vinyl framing, low-E surfaces, and argon gas. The cost increments for vinyl windows compared to aluminum windows from the DEER database was so low ($0.17/ft^2) that older cost data was factored in by including a cost premium of $1.61/ft^2, as reported in the Manufactured Homes Acquisition Program in the Pacific Northwest (Ecotope 1995). The two vinyl price increments were averaged for this analysis. Low-E coatings were also a special case, because the price increment for low-E is falling fast. The cost for low-E coatings was estimated as $1/ft^2, which was supported in informal discussions with professionals associated with the glazing industry.

U-values and solar heat gain coefficients (SHGC) for the types of windows are shown below for the window types used in the analysis. The U-values and SHGC are based on median values of windows from the National Fenestration Rating Council *Certified Products Directory* (1999).[6] Actual U-values and SHGC for available windows vary considerably.

Table 4. Window Types

Window / Frame Type	Cost $/ft^2	U-Value	SHGC
Single / aluminum	0.00	1.20	0.79
Single / aluminum / tint	1.86	1.20	0.40
Single / aluminum / storm	2.40	0.80	0.65
Double / aluminum	3.04	0.75	0.65
Double / aluminum / low-E	4.04	0.59	0.40
Double / vinyl	3.93	0.49	0.52
Double / vinyl / low-E	4.93	0.35	0.40

SHGC impacts on HVAC first cost. Low SHGC windows reduce air conditioning loads, allowing smaller (less capacity) air conditioners because of the decreased peak cooling loads. Air conditioning sizing costs were obtained from the California DEER cost database report, as $612 for a ton reduction in air conditioner capacity.[7] The cost savings from air conditioner size was accounted for in the analysis based on this relationship between peak loads and SHGC.[8]

[6] The median U-value for low-E was adjusted from 0.36 to 0.35, because this is expected to become a common due to building codes.

[7] The EnergyGuage software was used to calculate the impact on cooling capacities from SHGC windows in a double-wide in Houston. Based on the Manual J load calculation methodology as incorporated into EnergyGuage, the peak load savings of 1.1 kBtu/hr (9% of a ton) for each 0.1 reductions in SHGC.

[8] Based on the Manual J load calculation methodology, a peak load savings of 1/4 of a ton was assumed for low SHGC windows.

Door energy-efficiency measures. Two doors with a total area of 36 ft^2 and a U-value of 0.35 were assumed in the analysis. Doors have a relatively small effect on the U_o of a home.

HVAC equipment energy-efficiency measures. The National Appliance Energy Conservation Act of 1987 (NAECA) (Public Law 100-12) sets minimum efficiency standards that will apply to manufactured homes. For heat pumps and air conditioners, the minimum NAECA requirements expected to take effect in 2006 (SEER 12 and 7.4 HSPF) were assumed. The current Federal minimum efficiency is 75% AFUE for fossil-fueled furnaces designed for installation in manufactured homes. Ducts were assumed to be 75% efficient in all cases.

Prototype home. This analysis used prototypical single- and double-wide homes. Initial results showed single- and double-wide homes produced very similar U-values. Since the average home size is increasing and double-wide homes dominate sales, the double-wide prototype was used for the analysis. The prototype was a double-wide manufactured home, 56 feet wide, 28 feet wide, 7.5 feet in ceiling height, 1568 ft^2 in floor area, with a window area that is equal to 12% of the floor area, and 36 ft^2 of door.

Energy Efficiency Measure Lifetime

The life-cycle cost analysis included the cost of replacing EEMs in the year that they are projected to fail. Insulation and windows were presumed to last at least as long as the 30 year period of analysis, so there was no replacement cost. Equipment lifetimes were not needed because the equipment efficiencies in the life-cycle cost analysis were fixed.

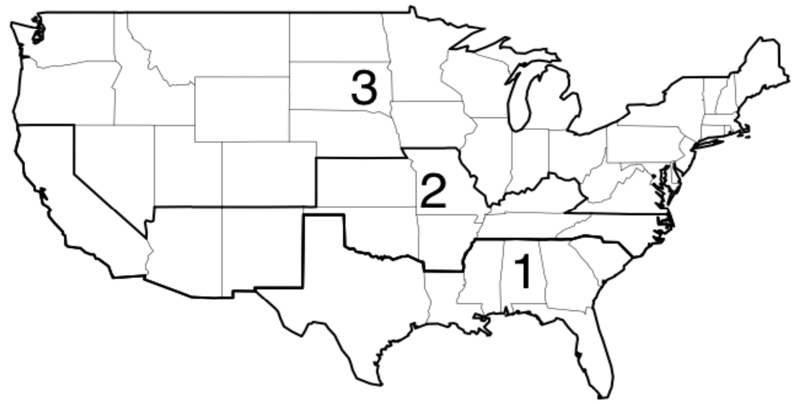
Least-Cost U_o and U_o Zones

HUD MHCSS heat loss/gain requirements are U_o maximums for the building envelope. The U_o computation includes the contribution of each building component -- ceilings, walls, floors, windows, doors, and crossover ducts (for multi-section homes) -- with the U-value (U) of each component weighted by area (A), UA, as shown below.

$$U_o = \frac{\text{UA ceiling} + \text{UA wall} + \text{UA floor} + \text{UA window} + \text{UA door} + \text{UA crossover duct}}{\text{Total exterior surface area}}$$

The individual U_o values for each city and fuel/equipment type were aggregated into the HUD zones. The zones are shown in Figure 1.

Figure 1. Zones for the U_o Requirements in the Current MHCSS



Individual Local Values

For each city, five combinations of HVAC equipment and fuel were calculated (all cases assumed electric air conditioning):

1. natural gas with a forced air furnace
2. LPG with a forced air furnace
3. oil with a forced air furnace
4. electric resistance with a forced air furnace
5. electric heat pump with forced air distribution.

The 881 cities in ARES were used in the analysis (Conner et al. 1992, Appendix C). Selection of all 881 cities provides a density of locations such that any point in the U.S. is not substantially separated from a location for which a least-cost U_o was produced. The selection of 881 cities and 5 equipment/fuel types resulted in the output of 4405 cases with specific U_o.

The results for separate HVAC equipment and fuel type were aggregated based on the prevalence of equipment types and fuels in each region. The fuel and equipment types by region obtained from the American Housing Survey (U.S. Census Bureau 2001) are shown in Table 5. The aggregation to zonal average was weighted by manufactured home shipment data (home sales) by state. This analysis did not examine new zone boundaries because the manufactured home industry has adapted to the current zones and prefers a small number of zones.

Table 5. Fuel and Equipment Types by Census Region (%)

Region	Electric Furnace	Natural Gas	Heat Pump	Oil	LPG
Northeast	12	19	0	37	28
Midwest	19	42	2	2	2
South	53	8	25	0	11
West	38	40	10	0	9

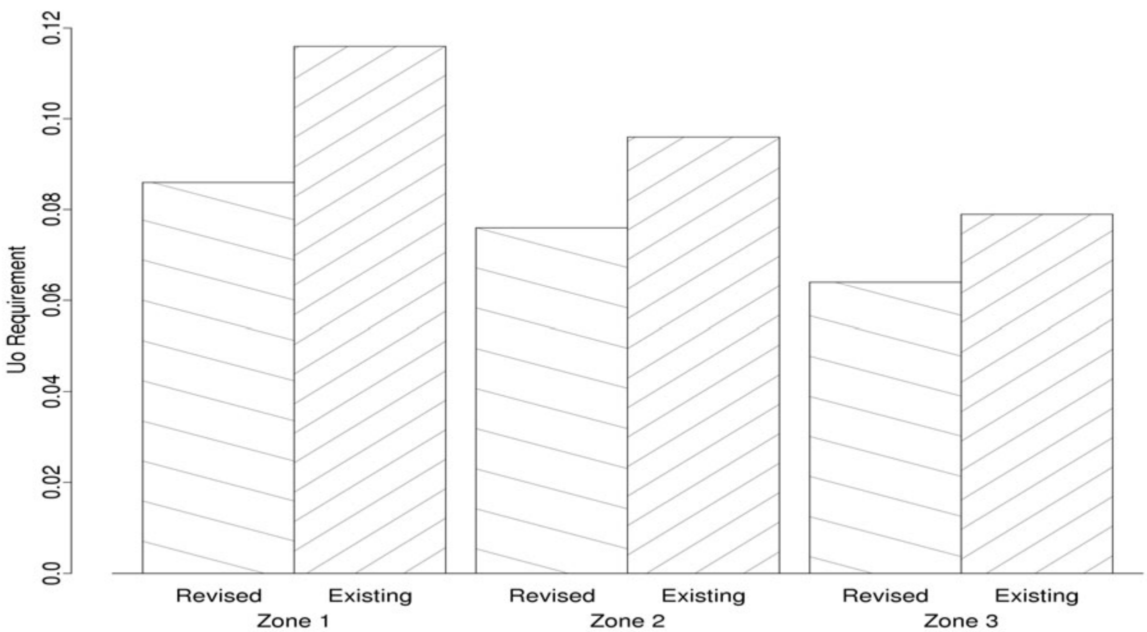
U_o by Zone

The existing and proposed U_o requirements for the MHCSS by zone are shown in Table 6 and Figure 2 below.

Table 6. U_o by Zone

Zone	Existing U_o	Revised U_o
1	0.116	0.086
2	0.096	0.076
3	0.079	0.064

Figure 2. Existing and Revised U_o



Based on sales-weighted national average, the existing national standard averages 0.097, the proposed standard averaged 0.075.

Life-Cycle Savings, Mortgage Costs, and Energy Savings

The costs and benefits from the consumers' perspective for the current HUD MHCSS and the proposed standards were compared. The proposed standard always increases costs to buy the new EEMs and decreases costs for energy. The net present value from the consumer's perspective is the difference between the increased EEM costs and the decreased energy costs.

The additional cost per current standard home to meet the proposed standard would typically be in the range of \$500 to \$700. Average energy savings is \$150 to \$180 a year. Note that the monthly savings in energy costs exceeds the increase in monthly mortgage payment yielding an immediate positive cash flow for the consumer. The net life-cycle savings to the consumers ranges from \$700 to \$1100 per home. Simple paybacks are about 4.2 years, 4.0 years, and 3.3 years in zones 1, 2, and 3 respectively.

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