Minimum Cost Model Energy Code Envelope Requirements

Craig C. Conner and Robert G. Lucas, Pacific Northwest Laboratory
Stephen J. Turchen, U.S. Department of Energy

This paper describes the analysis underlying development of the U.S. Department of Energy's proposed revisions of the Council of American Building Officials (CABO) 1993 Model Energy Code (MEC) building thermal envelope requirements for single-family and low-rise multifamily residences. This analysis resulted in revised MEC envelope conservation levels based on an objective methodology that determined the minimum-cost combination of energy efficiency measures (EEMs) for residences in different locations around the United States.

The proposed MEC revision resulted from a cost-benefit analysis from the consumer's perspective. In this analysis, the costs of the EEMs were balanced against the benefit of energy savings. Detailed construction, financial, economic, and fuel cost data were compiled, described in a technical support document, and incorporated in the analysis. A cost minimization analysis was used to compare the present value of the total long-run costs for several alternative EEMs and to select the EEMs that achieved the lowest cost for each location studied.

This cost minimization was performed for 881 cities in the United States, and the results were put into the format used by the MEC. This paper describes the methodology for determining minimum-cost energy efficiency measures for ceilings, walls, windows, and floors and presents the results in the form of proposed revisions to the MEC. The proposed MEC revisions would, on average, increase the stringency of the MEC by about 10%.

Introduction

In October 1992, the Energy Policy Act of 1992 (EPAct) was signed into law. Section 307 of EPAct directs the U.S. Department of Energy (DOE) to "support the upgrading of voluntary building energy codes for new residential and commercial buildings." In supporting the upgrading of building energy codes, EPAct directs DOE to "assist in determining the cost-effectiveness and the technical feasibility of the energy efficiency measures" and to periodically "seek adoption of all technologically feasibfe and economically justified energy efficiency measures."

The Council of American Building Officials (CABO) Model Energy Code (MEC) is a prominent energy conservation code currently adopted by many states. Various versions of the MEC have been adopted by about 10 states, and more states are currently considering adopting the MEC. EPAct makes numerous references to the MEC for residential buildings; e.g., EPAct requires each state to certify whether its code meets or exceeds the 1992 MEC. EPAct also directs the U.S. Department of Housing and Urban Development (HUD) and the U.S. Department of Agriculture to establish residential energy-efficiency standards that meet or exceed the 1992 MEC for federally assisted housing. Participating in the process of updating the MEC partially fulfills DOE's EPAct mandate to be a participant within the building code/standard process.

In response to the EPAct directives, DOE proposed MEC changes to CABO in 1993. Overall, the proposed changes increased the MEC stringency by about 11% for single-family homes and about 14% for multifamily buildings. However, in some cases, DOE proposed lessening the stringency of the MEC, most notably for ceilings without attics. The MEC code change committee disapproved the proposed changes in 1993. DOE has made improvements in its analysis primarily in response to comments raised by opponents and is resubmitting very similar code changes in the 1994 code change cycle. This paper discusses the methodology DOE used to generate and present the proposed MEC code changes.

DOE decided to concentrate initially on envelope efficiency measures in proposing updates to the MEC. Specifically, DOE proposed updates to the U_o-value requirements for ceilings, walls, and floors over unheated spaces. Envelope efficiency measures are perhaps the most significant aspect of the MEC amenable to being updated. For example, DOE did not attempt to propose new requirements for residential space heating, space cooling, and water heating minimum efficiency requirements because any such requirements adopted into a state code would be preempted by the National Appliance Energy Conservation Act of 1987. DOE had the analysis tools in place that allowed a detailed analysis of envelope efficiency measures by the code change submittal deadline of the end of 1992 for the 1993 code change cycle.

Minimization of the long-term energy-related costs of buying and living in a home was selected to be the cost-effectiveness criterion. The methodology accounted for all the present and future costs and benefits related to energy efficiency measures. The economic perspective was that of the home owner or, for multifamily units, both the renter and the building owner. 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 results of this cost/benefit analysis specified an overall level of energy conservation in terms of a building envelope U_o-value (thermal transmittance) that should give the lowest total of construction and operating costs to the owner and, in the case of apartments, the renter. This life-cycle cost optimization was performed for 881 cities in the U.S. The resulting conservation levels were the basis for DOE's proposal to upgrade the MEC.

EPAct directs DOE to consult with federal and nonfederal organizations involved with building codes and standards. Interaction with the stakeholders is an important element in defining and setting the proposed changes to the MEC. The revisions of the proposed U_o-value requirements were, in part, defined from our review and analysis of written and oral comments from opponents and supporters identified at a meeting convened by DOE, at the two CABO public hearings held in 1993, and from numerous other informal interactions. Many of the comments, as well as additional information obtained in meetings, phone conversations, and correspondence with the commenters, were relevant, persuasive, and substantiated. This information caused DOE to modify and improve many aspects of the analysis.

This paper summarizes the economic analysis and resulting proposed code changes. The analysis is described in much greater detail in a technical support document produced in support of the DOE proposed code changes (Conner and Lucas 1994).

Economic Methodology

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 becoming the preferred alternative. The LCC method sums the (discounted) costs and benefits of the investment, which, in turn, are calculated based on current 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.

$$\text{Life-cycle cost} = \text{Initial investment} + \text{Energy costs} + \text{Maintenance costs} - \text{Resale value} \quad (1)$$

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

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 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 a home-owner's 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 a lowest-cost set of EEMs for a home in a specific city using a specific heating system and energy type.

Financial and Economic Parameters

Values for several financial and economic parameters must be selected to develop the cost-effective proposed MEC requirements. These values are summarized in Table 1.

In choosing the parameters for the analysis, the intent was to identify and document the best source available for each parameter. Most of the parameter values are commonly

Table 1. Economic Parameters Used in the Analysis

Economic Parameter	Single-Family	Multifamily
Mortgage Parameters		
Interest Rate	8%	9%
Loan Term	30 years	30 years
Down Payment	10%	35%
Points and Loan Fees	1.6% of mortgage	3.5% of mortgage
Alternate Investment Rate	4.0% real, 8.1% nominal	4.9% real, 9.0% nominal
Federal & State Income Tax	24% average, varies by state	37%
Property Tax	1.36% average, varies by state	1.36% average
Period of Analysis	30 years	30 years
Building Life	50 years	40 years

reported statistics and are traceable to other published sources. Some parameters were developed at a national level, some at a state or regional level. If multiple sources for a single parameter were identified, an attempt was made to choose the best source, with a preference toward the most respected, most recent, and published sources.

Multifamily economics is considerably more complex than single-family economics, as both the building owner and the renter need to be considered. In addition, the economics of rental property includes depreciation, multiple mortgages, and (often) significant tax credits. It was assumed that the apartment builder or developer will pass the increased costs of energy conservation measures to the renter in the form of higher rents, thereby making those costs a "real" expense to the renter. The loan costs and associated taxes are paid by the owner/developer; therefore, the cost of an increase in energy efficiency was calculated from the owner's perspective. Savings on fuel bills were calculated using average residential fuel prices, as discussed later. Utility bills in new multifamily units are usually paid by the renter. The cost-minimization methodology simply looks for the lowest total costs in multifamily units: At what point are the construction and financing costs associated with energy efficiency minus the utility bill savings at their minimum?

The typical multifamily housing financing was developed based primarily on input from Mr. Michael Evans, National Director of Real Estate Advisory Services for the accounting firm of Ernst and Young, San Francisco, California. Mr. Evans has considerable experience with the economics of the apartment industry.

Multifamily housing is financed by a conventional loan or, less frequently, with a government-guaranteed (HUD) loan. A typical loan has a 9% interest rate (8% to 8.25% for HUD-guaranteed financing), 2 points (1 to 2 for HUD), 35% down payment (15% for HUD), and 0.5% to 0.75% in miscellaneous costs (e.g., filing fee, appraisal, title insurance). Conventional loans have a 10-year term amortized over 25 to 30 years. The difference in the term and the amortization implies a balloon payment at the 10-year point, but housing is typically sold or exchanged before then. (HUD loans have a 30- to 35-year term, amortized over the same 30 to 35 years.) A construction loan precedes the loan secured by the completed building and is converted to the secured loan after 18 to 24 months.

Some multifamily housing units receive a low-income tax credit (LITC), which is a credit on taxes owed, not a tax deduction on the income of the owners. LITCs amount to 70% of the value of the low-income units for conventional mortgages and 30% of the value for federally financed mortgages (HUD programs). Energy-efficient features, such as insulation and energy-efficient windows, qualify under the HUD and LITC programs like any other building components. According to Mr. Evans, over the long term, about two-thirds of all apartment units will have conventional loans and no LITC and about one-sixth will have conventional loans and the tax credit. The remaining one-sixth of the units will have HUD loans equally split between those that receive the tax credit and those that do not. We assumed these splits in determining the financing rates shown in Table 1.

Energy-Efficiency Measures

The EEM options selected for the analysis represent the conservation investment options from which the LCC analysis could choose to determine the consumer's optimal level of investment in energy conservation. For each type of EEM (e.g., wall insulation), lists of candidate levels, costs, and thermal characteristics were developed. Only commercially available EEMs that had been used to build a significant number of homes were included as candidate options: ceiling insulation options ranged from R-11 to R-49, wall insulation options ranged from R-11 to R-21 batt insulation with up to R-7 sheathing insulation, floor insulation options ranged from R-11 to R-30, and window options ranged from a U_o-value of 1.31 to 0.35.

Blown loose-fill insulation was assumed in ceilings with attics. A separate analysis was performed for ceilings without attics. It became evident that high levels of insulation were not cost-effective in ceilings without attics because of the costly construction changes (thicker framing) needed to make room for the insulation. Because of this, DOE proposed adding new requirements to the MEC strictly for ceilings without attics—the MEC currently does not differentiate between ceilings with and without attics.

The three primary cost data sources for EEMs were R. S. Means (1993), the National Construction Estimator (Craftsman 1992), and NAHB (1986). The three cost sources were not sufficiently detailed nor current to characterize window costs, so window cost data was obtained from two regional sources that were judged to be the best data available. The first was a survey of nine Pacific Northwest window manufacturers for the Washington State Energy Office (Byers 1990). The other source of window cost data was the work done for the California Energy Commission by Eley Associates (1991).

Initially, EEMs in homes that used eight specific heating equipment, distribution system, and fuel combinations were analyzed using the ARES software. The heating equipment types and fuel combinations were natural gas with a forced-air furnace, oil with a forced-air furnace, liquid petroleum gas (LPG) with a forced-air furnace, electric resistance with a forced-air furnace, electric heat pump with forced-air distribution, and electric baseboard. The natural gas and oil furnaces had either forced air or hydronic distribution systems. In most climates with significant cooling loads, central electric air conditioning was assumed. The National Appliance Energy Conservation Act of 1987 (NAECA) minimum standards for heating and cooling system efficiency were assumed.

Heat loss/gain from HVAC distribution systems was accounted for. Duct efficiencies accounting for the presence and location of ductwork were used to modify the heating and cooling equipment efficiencies. Data from four sources indicated that the efficiency of air-ducted systems in single-family homes averages only 75% (i.e., a 25% energy loss). Hydronic systems (piped water/steam) are common heating distribution systems in the Northeast. The hydronic efficiency was set at 96% for the single-family prototype. Little research has been done on distribution system losses in multifamily buildings. However, we believe the distribution losses are much lower in multifamily buildings because the ducts/pipes are more commonly located inside the conditioned space. We conservatively assumed a low air-duct efficiency loss of 5% and a hydronic pipe loss of 0% for multifamily buildings.

Fuel/Energy Prices

Residential energy prices from the *State Energy Price and Expenditure Report 1990* (SEPER) (EIA 1992), were used in the analysis, except for electrical heating prices, which were obtained from *Typical Electric Bills* (EIA 1988). The 1990 fuel prices for each state were updated for the recent fuel price escalation.

From -the consumer’s perspective, the energy cost savings from changes in energy conservation levels are driven by marginal fuel prices, which may not equal average fuel prices. Energy prices are often tied to the consumption rate per household; higher consumption rates can result in lower (or higher) average unit costs for energy. We obtained marginal electric heating prices from *Typical Electric Bills* (EIA 1988) and adjusted the average prices given in the SEPER (EIA 1992) for electric cooling and natural gas heating. No difference between average and marginal fuel prices was assumed for fuel oil and LPG.

The residential fuel price escalation rates used in the analysis were taken from the most recent data in *Annual Energy Outlook* (EIA 1993). Real fuel price escalation rates of 0.2% for electricity, 1.5% for natural gas, 0.5% for heating oil, and 0.3% for LPG were assumed.

Building Prototypes

For the analysis, it was necessary to model prototype single-family and multifamily buildings that represent typical construction. As costs and benefits vary linearly with envelope component areas, the prototype dimensions had little effect on the analysis, with the notable exception of window area. The MEC has gross wall U_o-value requirements that account for individual U-values of walls, windows and doors. Assuming a higher window area makes the gross wall U_o-value higher (less stringent) because windows have higher U-values than insulated opaque walls. For the single-family analysis, limited data indicated that a *typical* house had a window area equal to about 12% to 14% of the conditioned floor area. We assumed a slightly conservative high window area equal to 15% of the floor area and 56 ft^2 of doors. For the multifamily analysis, a conservatively high window area equal to 25% of the wall area was assumed, along with 40 ft^2 of doors.

Aggregation into MEC Format

A large number of individual LCC analyses were performed using the ARES tool. Two residence types—single-family and multifamily (three stories or less)—were optimized separately for each of the eight fuel/equipment types. All 881 cities available in ARES were used in the analysis, providing a density of locations such that any location in the United States was close to one of these 881 cities.

The 14,096 sets of component U_o-values (881 cities, eight HVAC/fuel types, two building types) were aggregated to U_o-value curves that can be used in the MEC. The minimum-cost EEM levels for each heating fuel/equipment type were first combined into U_o-values for all heating equipment/fuel types at each city based on the frequency with which each type of equipment was present in each region. Single-family and multifamily ceilings and floors were determined to be similar in construction and cost and were consolidated. Single-family and multifamily wall requirements were markedly different because of the larger fraction of multifamily walls that are generally displaced by windows; therefore, separate multifamily wall requirements were produced.

U-values for each envelope element were then grouped into 500 heating degree-day (HDD) bins (e.g., 2000 to 2500 HDD). The weighted average for each bin was then determined using 1992 housing start data (U.S. Department of Commerce 1993). Cities with a high number of housing starts were weighted proportionally high. For ceilings and floors, the weighted average U_o-value in each HDD bin was set to the U_o-value of the nearest EEM (i.e., nominal insulation level, such as R-30). The proposed wall requirements are a series of horizontal lines centered through the weighted averages of the bins except at low and high HDDs, where the wall U_o-values were essentially unchanged from those of the 1993 MEC. Again, gross wall U_o-value requirements combine opaque walls, windows, and doors.

Results

The proposed MEC maximum U_o-value requirements by component are shown in Figures 1 through 5 for ceilings with attics, ceilings without attics, walls in single-family and multifamily homes, and floors over unheated spaces, respectively. The axes of these figures (HDDs on the horizontal axis and U_o-value on the vertical axis) are the same as those used in the MEC. For comparison, Figures 1 through 5 also show the existing 1993 MEC requirements as dashed lines. Figure 6 shows a contour plot of HDDs throughout the United States to help determine the HDDs for any given region of the country.

On average, the proposed U_o-value requirements are significantly more stringent than those required by the 1993 MEC. Figure 1 shows that for cities below 5000 HDD, the proposed ceiling with attic U_o-value requirement is generally below the 1993 MEC requirement. The requirements shown in Figure 2 are significantly less stringent than the 1993 MEC requirement. DOE proposed this separate, less stringent, set of requirements for ceilings without attics as a result of the much higher cost of putting in high insulation levels in “vaulted” ceilings. Figure 3 shows that the proposed single-family wall U_o-values are less than the 1993 MEC requirement except in the very mild and the cold climates. In Figure 4, the proposed multifamily wall U_o-value is lower than the MEC requirement except in mild and very cold climates where the requirements are the same.

The proposed floor requirements (Figure 5) would require no floor insulation for locations with less than 500 HDD. A footnote associated with Figure 5 (not shown here) indicates that there are no insulation requirements for unheated basements for locations with 500 to 1500 HDD. Our analysis shows that floor insulation over basements is not cost-effective in the these mild climates because the ground provides some natural insulation and advantageous thermal mass effects. In the cooling season, floor insulation over basements is not necessarily helpful, as the insulation isolates the house from the cool basement. As crawlspaces do not have the thermal connection to the ground to the extent that basements do, R-13 insulation is cost-effective for crawlspaces in the 500 to 1500-HDD range.

Cost and Benefits of the Proposed MEC Requirements

Table 2 compares the estimated costs and benefits from the consumer’s perspective of the proposed revisions relative to the 1993 MEC requirements. Shown are the incremental changes in LCC, energy costs, nonenergy costs, first costs (assuming no mortgage), down payment costs, and a simple benefit-to-cost ratio for the single-family and multifamily prototypes. The proposed code changes will increase construction costs and decrease energy costs. The nonenergy costs from the consumer’s perspective include the down payment, mortgage costs, and taxes. Note that the energy cost savings less the first cost increase is lower than the LCC savings primarily because of the discounting of future costs and the tax benefits of the mortgage. The various cost impacts for the multifamily prototype are much lower than the

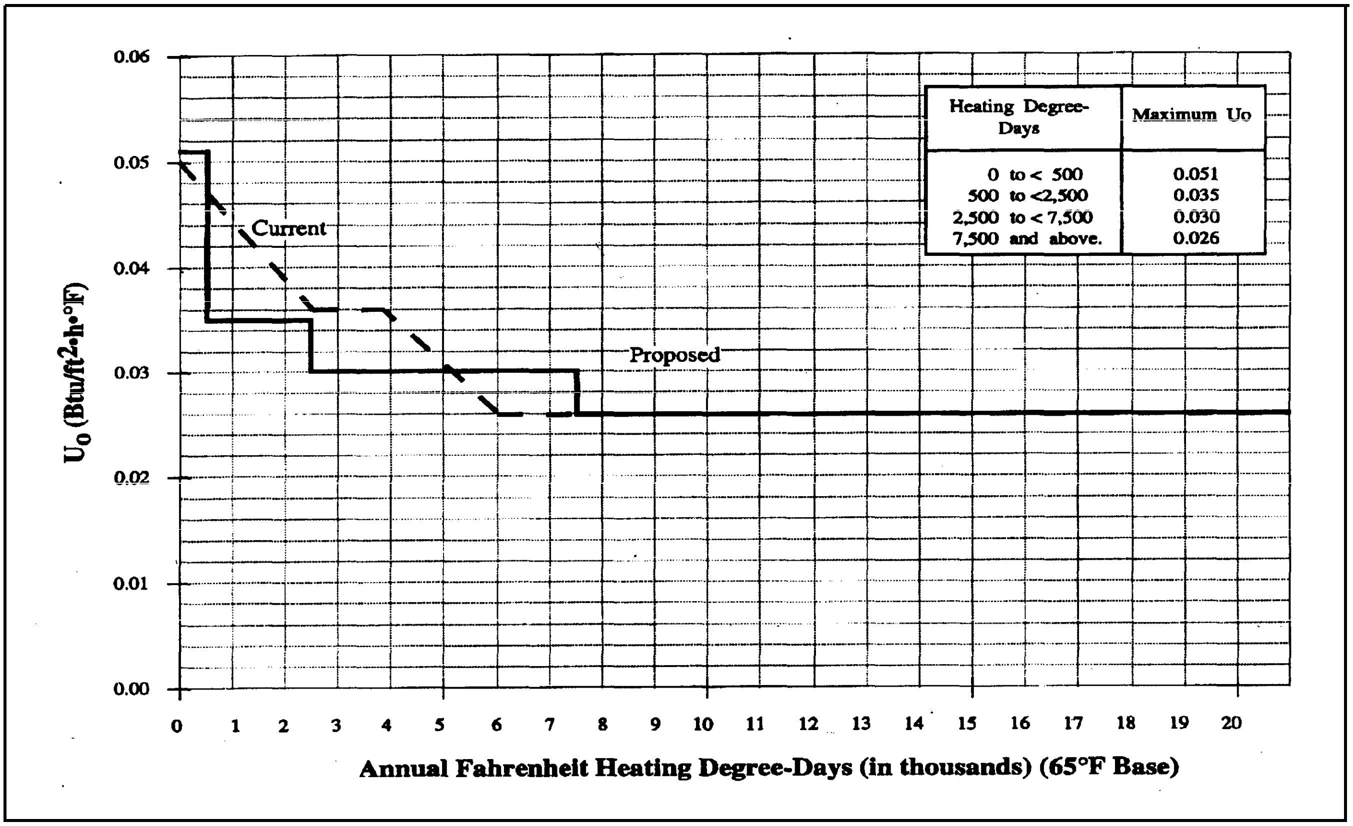

Figure 1. Proposed MEC U_0 Requirement for Roof/Ceilings with Attics

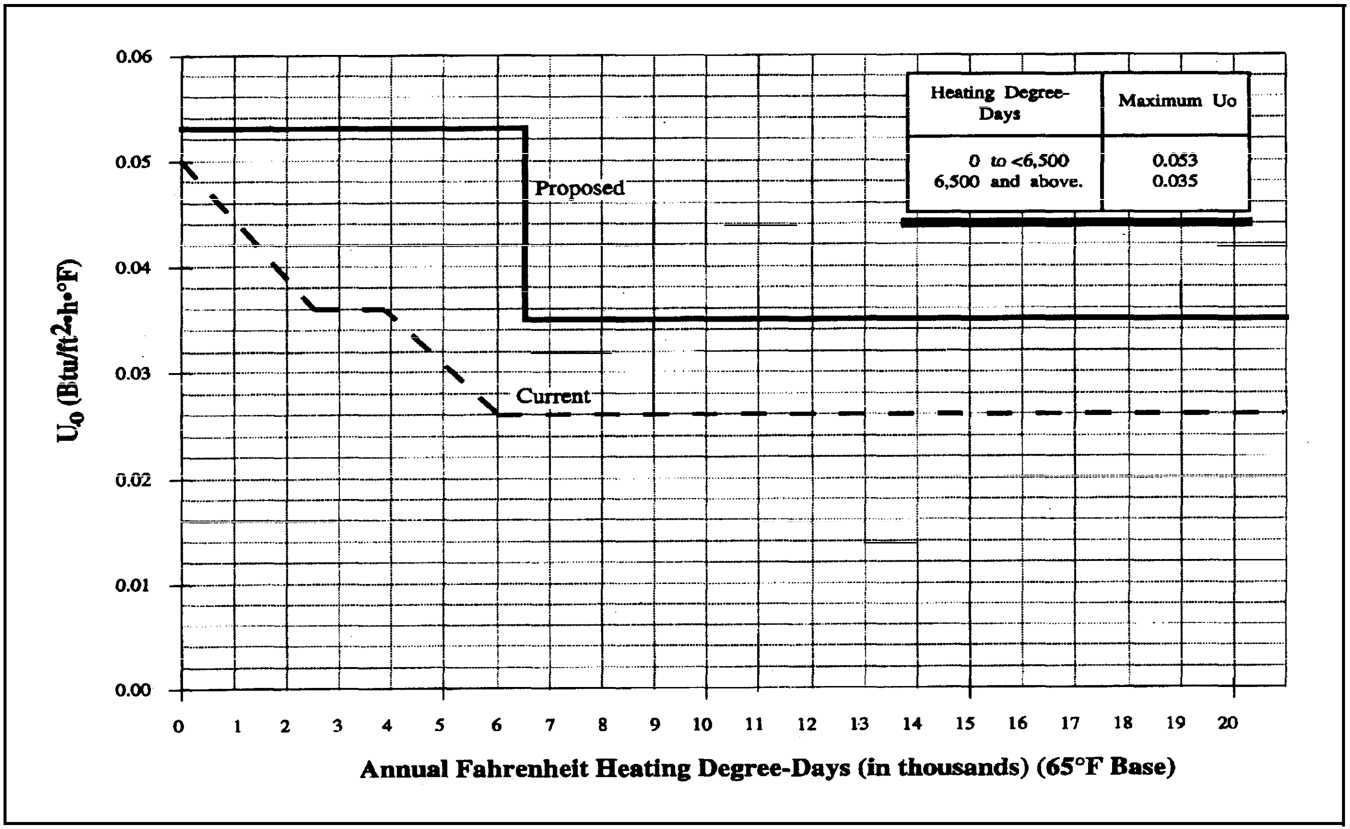

Figure 2. Proposed MEC U_0 Requirement for Roof/Ceilings Without Attics

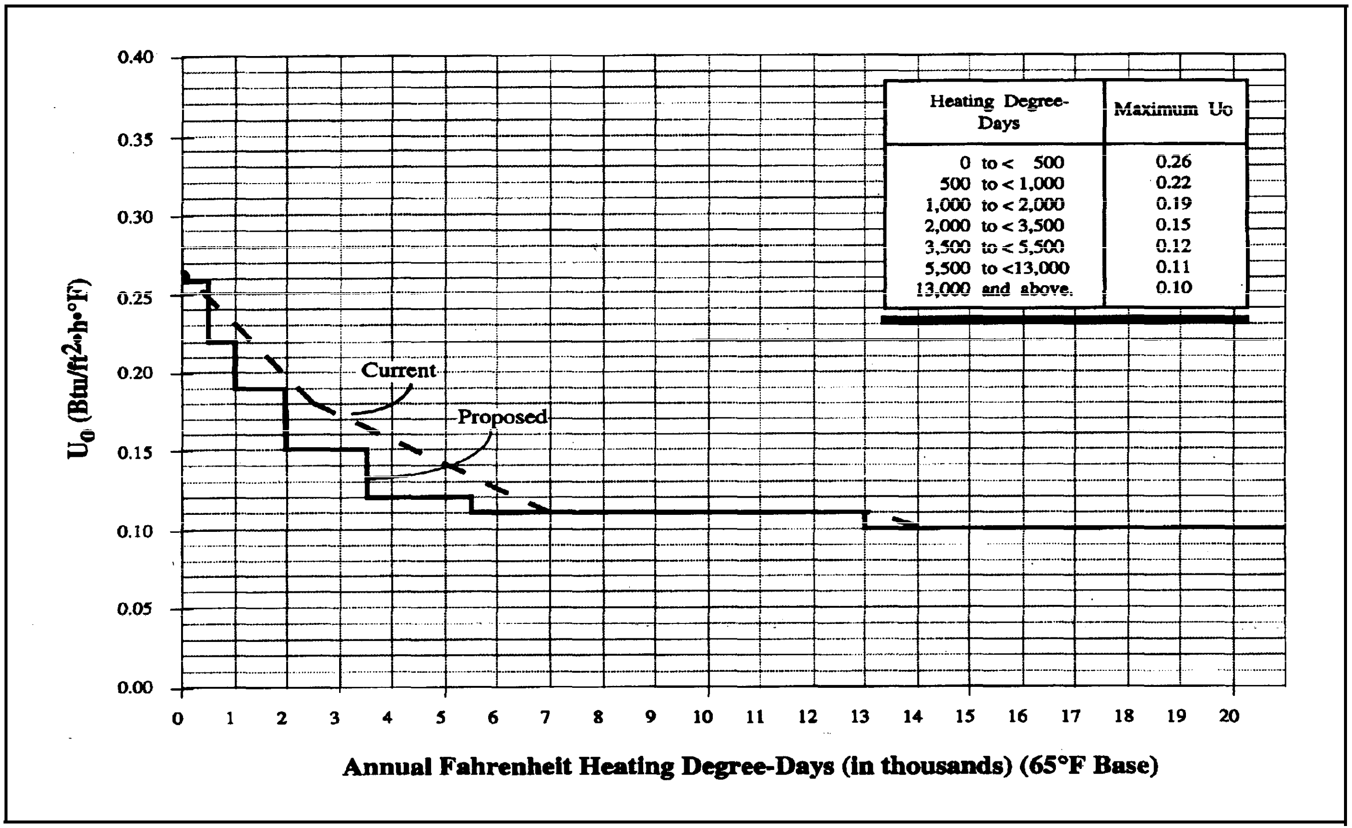

Figure 3. Proposed MEC U_o. Requirement for Single-Family Walls

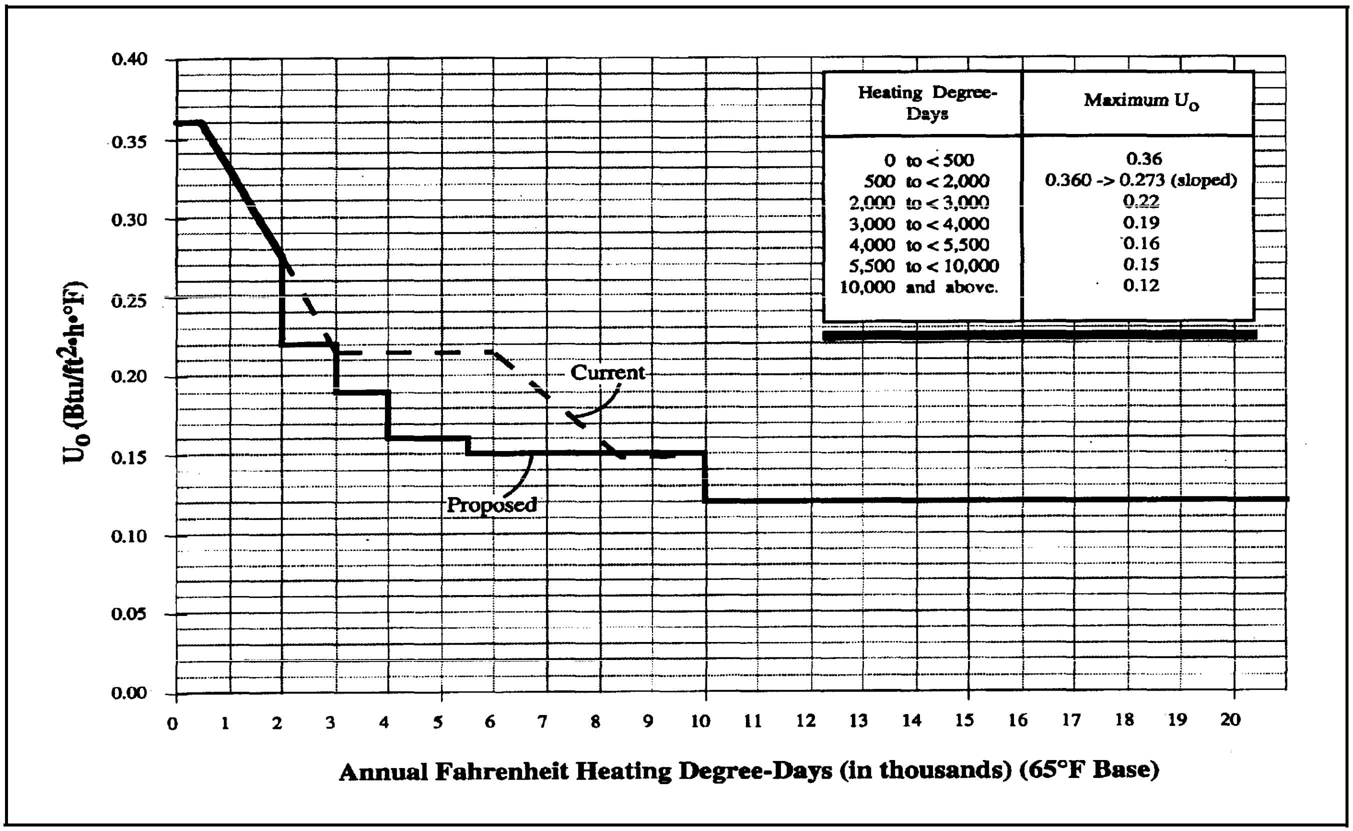

Figure 4. Proposed MEC U_oRequirement for Multifamily Walls

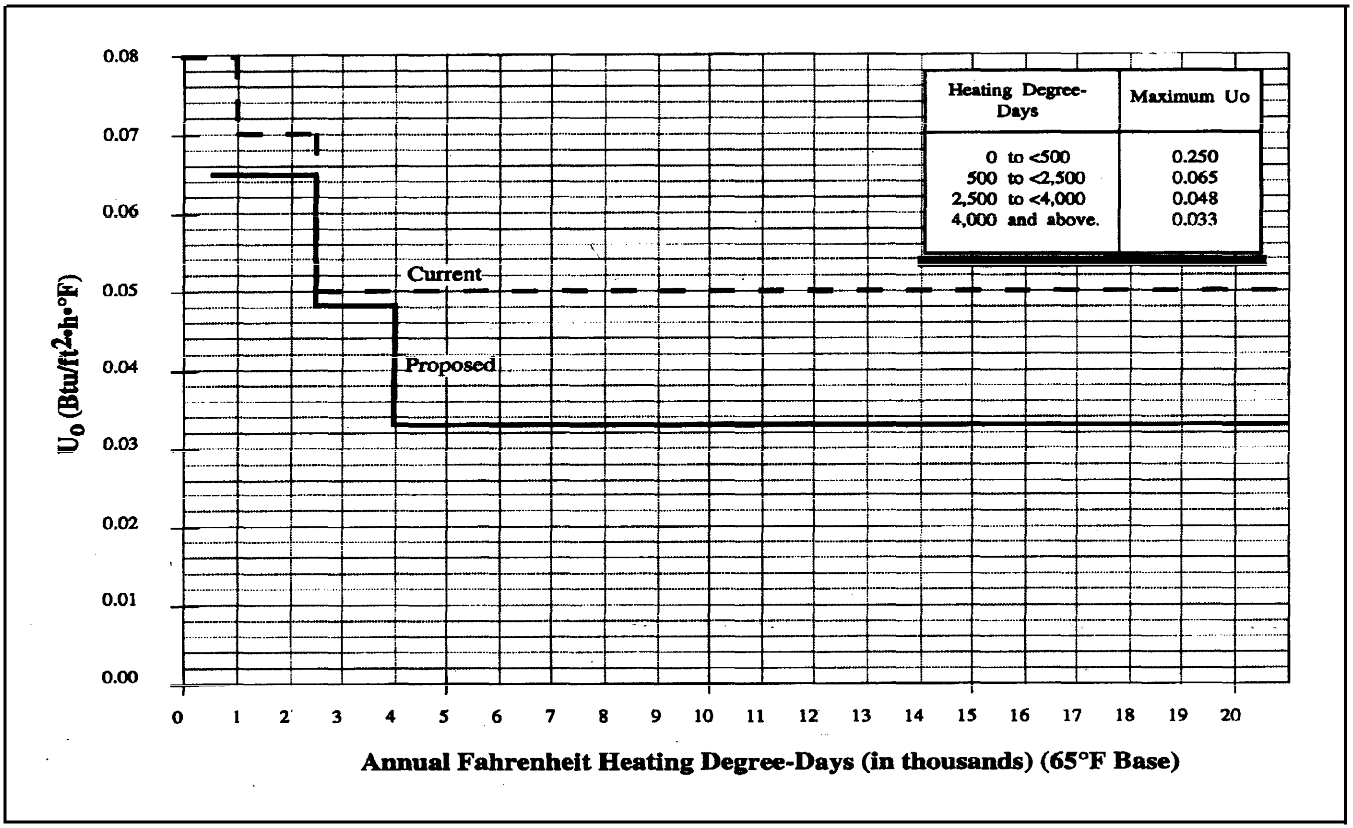

Figure 5. Proposed MEC U_o Requirement for Floors over Unheated Spaces

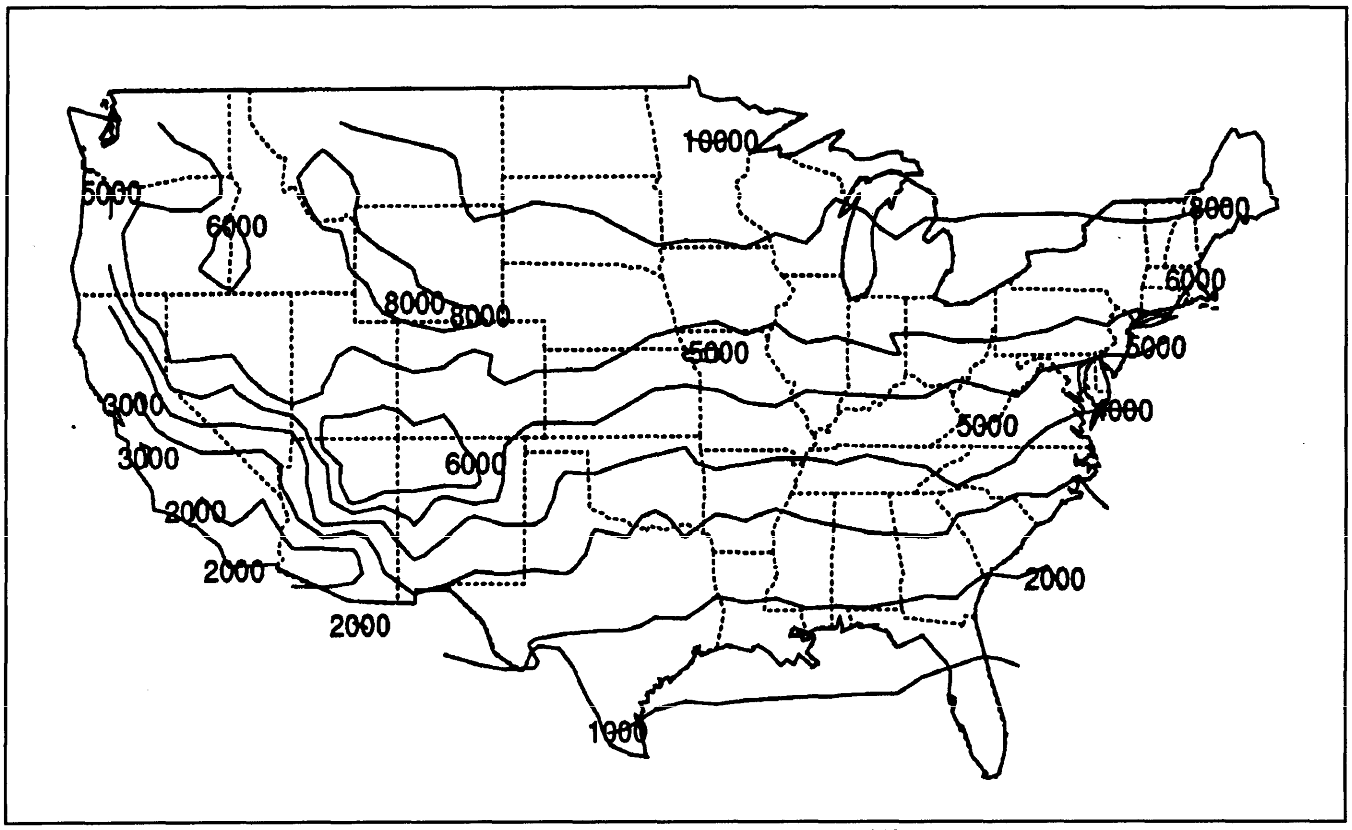

Figure 6. Heating Degree-Days (Base 65°F)

corresponding impacts for the single-family prototype, primarily because of the much smaller envelope area of the multifamily prototype. The starts-weighted average of the proposed changes for all 881 cities was used to produce Table 2. The costs and benefits of the proposed revisions relative to the 1993 MEC will vary with location and climate. As shown in Table 3, the cost impacts for single-family homes will also vary by heating fuel/equipment type. The cost savings are significantly higher for electric resistance because of the high price of electricity relative to the other fuels.

Table 2. National Average Estimated Cost Impacts of Proposed Revisions

Economic Parameter	Cost Change Per Housing Unit Single-Family	Multifamily
Life-cycle cost savings	$700	$300
Present value of energy cost savings	$1100	$510
Present value of nonenergy cost increase	$400	$210
First-cost increase	$420	$270
Down payment increase	$42	$95
Benefit-to-cost ratio	2.75	2.4

Many organizations and individuals (including the authors) are concerned about housing affordability. The nature of this concern varies, although there are two general perspectives on the affordability issue. The first emphasizes low first cost for residences by either keeping costs down so that buyers are able to qualify for loans to purchase homes or by adjusting existing lending practices so that decreased energy costs from energy-efficient homes are reflected in the purchasers' ability to qualify for a larger loan. The biggest concern is often with the first (new home) buyer and how the additional first cost for higher energy efficiency will eliminate some prospective buyers from qualifying for loans. There is also some concern that the first buyer will not receive a fair return on the energy-efficiency investment on resale.

The second perspective on the affordability issue emphasizes minimizing total costs, including purchase costs and operating costs. The objective of this perspective is to minimize the sum of the costs of owning the home, including both energy costs and mortgage costs for energy efficiency improvements. This perspective is associated with a longer-term focus that captures the benefits of energy efficiency over the home's lifetime. Nonmarket costs or impacts of energy consumption, such as environmental externalities, are sometimes included as costs.

It is our opinion that both sets of concerns can and should be addressed. The methodology used here minimizes total costs of owning and operating a home over most of its useful life. Some might suggest alternative values for the discount rates, feasible constructions, and other parameters, but the methodology remains the same. Some might also want to add market "externalities" by including social costs of fuel consumption not reflected in the market; for example, including the impact of increased fuel use on the environment, reflecting marginal costs of new power sources, and reflecting the higher-than-average capacity charge associated with HVAC loads.

A simple method of looking at the costs and benefits of higher energy efficiency over time is by studying the cash flow. Figure 7 shows the national average cumulative cash flow for a typical first owner of a single-family home built

Table 3. National Average Estimated Cost Impacts by Heating/Equipment Type for Single-Family Homes

Economic Parameter	Cost Change per Housing Unit Nat. Gas	Oil	Heat Pump	Elec. Res.
Life-cycle cost savings	$600	$670	$800	$1900
Present value of energy cost savings	$1000	$1100	$1200	$2400
Present value of nonenergy cost increase	$400	$430	$400	$500
First-cost increase	$420	$420	$420	$420
Down payment increase	$42	$42	$42	$42
Benefit-to-cost ratio	2.5	2.6	3.0	4.8

to the conservation levels proposed here, relative to a home built to the 1993 MEC. A 30-year mortgage and a 10% down payment are assumed. At the time of the purchase, there is a cost of about $48 to cover the increased down payment and other up-front cost increases. Because the energy cost savings easily exceed the mortgage payment increases, the net cash flow for each year is positive (excluding the first year, which has the up-front costs). The cumulative cash flow becomes positive after only 2 years and continues to grow in all future years. Note that if the first owner sells the house, any future owner will also obtain a positive cash flow after 2 years. The cash flow from increased conservation for future owners is even more favorable than the cash flow for the first owner because depreciation causes the purchase cost to decrease and future fuel cost escalation causes energy cost savings to increase. We believe that this cash flow analysis shows the proposed upgrade of the MEC to be clearly beneficial to the consumer.

Conclusions

DOE has responded to the direction provided by Congress in the EPAct legislation and has become an active participant in the building code/standard community. The proposed code changes are based on a detailed technical analysis that accounts for all the major costs and benefits of energy conservation to the home occupant. Increasing the stringency of the MEC to cost-effective levels will save not only energy but also homeowner money. The proposed code changes, if adopted, would make housing more affordable to the home owner or apartment renter. DOE intends to continue its involvement in the CABO MEC code updating process and to participate in the development and promulgation of other building energy conservation code and standards.

Acknowledgments

This paper was produced by the Pacific Northwest Laboratory (PNL) with support from the U.S. Department of Energy (DOE). PNL is operated by Battelle Memorial Institute for DOE under contract DE-AC06-76RLO 1830.

References

Byers, D. 1990. The *Cost of Energy Efficient Windows in Washington.* WAOENG #89-61, Washington State Energy Office, Olympia, Washington.

Comer, C. C., and R. G. Lucas. 1994. *Technical Support Document for Proposed 1994 Revision of the MEC Thermal Envelope Requirements.* PNL-9400, Pacific Northwest Laboratory, Richland, Washington.

Council of American Building Officials (CABO). 1993. *Model Energy Code; 1993 Edition.* Falls Church, Virginia.

Craftsman Book Company. 1992. *1992 National Construction Estimator.* Carlsbad, California.

Eley Associates. 1991. *Volume 1: Low-Rise Residential Confidence and Sensitivity Study, Life-Cycle Cost Analysis.* Eley Associates, San Francisco, California.

Energy Information Administration (EIA). 1988. *Typical Electric Bills.* DOE/EIA-O040(88), Washington, D.C.

Energy Information Administration (EIA). 1992. *State Energy Price and Expenditure Report 1990.* DOE/EIA-0376(92), U.S. Department of Energy, Washington, D.C.

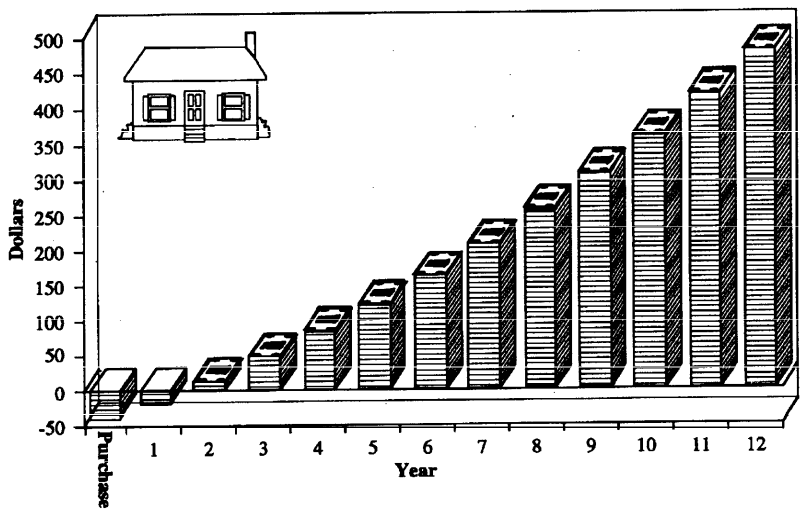

Figure 7. Typical Cash Flow for the First Owner of a Single-Family Home

Energy Information Administration (EIA). 1993. *Annual Energy Outlook.* DOE/EIA-0383(93), U.S. Department of Energy, Washington, D.C.

Lortz, V. B., and Z. T. Taylor. 1989. *Recommendations for Energy Conservation Standards for New Residential Buildings. Volume 2: Automuted Residential Energy Standard- User's Guide - Version 1.1.* PNL-6878 Vol. 2, Pacific Northwest Laboratory, Richland, Washington.

National Association of Home Builders (NAHB). 1986. *An Economic Data Base in Support of SPC 90.2: Costs of Residential Energy, Thermal Envelope and HVAC Equipment.* NAHB Research Center, Upper Marlboro, Maryland.

R. S. Means Company, Inc. 1993. *Means Residential Cost Data—1993.* Kingston, Massachusetts.

U.S. Department of Commerce. 1993. *Housing Units Authorized by Building Permits: December 1992.* C40/92-12, Washington, D.C.