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ECONOMICS AND UTILITY ENERGY-EFFICIENCY PROGRAMS: ENERGY-EFFICIENT MANUFACTURED HOUSING

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INTRODUCTION

As utilities investigate ways to implement conservation programs, the differences between customer and utility economic perspectives become more important. Because utilities bear the cost of new energy sources, energy-efficiency investments that are cost-effective to them may not be cost-effective to their customers who pay average energy prices and have different economic parameters.

The Bonneville Power Administration (BPA) and other parties in the Pacific Northwest have initiated an innovative manufactured (mobile) home energy conservation program. Because manufactured homes are regulated by the Department of Housing and Urban Development (HUD), are exempt from local regulations, and comprise up to 50% of new housing starts in some parts of the United States, utilities and energy planners need to find creative ways to make the economics of manufactured housing energy-efficiency investments more attractive.

Differences between the economic criteria and perspectives of consumers and utilities can be used to design energy-efficiency programs. This paper discusses life-cycle cost (LCC) analysis as a framework for highlighting these differences and examines other economic criteria. It then presents information from the Pacific Northwest manufactured housing program to illustrate the application of this framework to a real-world program. Findings from this program should be of interest to utility and government planners who are designing innovative energy-efficiency programs.

AN ECONOMIC FRAMEWORK FOR PROGRAM DESIGN

Life-cycle costing is a useful tool for analyzing energy-efficiency investments because it is a comprehensive approach for integrating the many economic factors inherent in investment decisions. Life-cycle cost analysis provides a tool for comparing long-run benefits and costs associated with specific investments, such as energy conservation measures (ECMs). Based on this criterion, the alternative with the lowest LCC is preferred. Future costs are discounted with an appropriate discount rate so that total costs can be summed in terms of their present discounted value. Because of discounting, costs far into the future usually tend to have a small effect on total discounted life-cycle costs.

The basic cost elements of the generic LCC method are shown in simplified form in (1):

$$LCC = C_P + C_O + C_M - S \quad (1)$$

where C is the present discounted value of specific cost components, C_P is procurement costs (including mortgage payments), C_O is operating costs (including energy costs), C_M is maintenance and replacement costs, and S is the discounted salvage value. (See DOE 1989 for a discussion of the method.) The discussion that follows focuses on ECM investments in manufactured homes. All costs are presented in terms of their present discounted value.

In our case, C_P represents the purchase cost plus financing costs of the ECMs. Adjustments for taxes and tax benefits are included. C_O is basically the cost of the energy required to keep the building comfortable. ECM effects on heating and cooling energy costs tend to offset changes in the procurement cost. S represents the resale or scrap value of the ECMs at the end of the analysis period.

An informative way to display LCCs is to plot the LCCs versus ECM procurement (investment) costs or, alternatively, energy savings. In Figure 1, hypothetical ECMs have been ranked according to their benefit-to-cost ratio, and the LCC has been calculated as each ECM was added. The curve exhibits a "U" shape: the first ECMs added to the base-case building decrease the LCC until it reaches the minimum, or optimum, value; additional ECMs continue to save energy, but the LCC starts increasing. Note that additional efficiency improvements usually can be added until the LCC is as large as the original, or base-case, value. Although such an investment would be no better than the base-case in LCC terms, the resulting building would consume substantially less energy than the base-case building.

Even though a relatively small number of cost terms comprise the LCC, several factors can have large effects on the values. The discount rate used to discount future costs is one such factor. The discount rate used in calculating the LCC varies depending on whose perspective is being represented. Private and public sector discount rates usually differ because of differences in relevant time horizons, alternative investment opportunities, perceptions of risk, and other influences. These influences tend to make private discount rates higher than public sector rates. Real discount rates of about 3% are typically used in analyses conducted from the societal perspective, whereas rates of 10% or more are often used to reflect consumer or business perspectives.

Figure 2 illustrates two major effects of discount rate on LCC. The four curves show how the LCC shifts as the discount rate varies from 1% per year to 10%.[2] First, as the discount rate <u>increases</u>, the total computed life-cycle cost <u>decreases</u> because future costs are more heavily discounted. Second, the optimum LCC shifts to the left as the discount rate increases: fewer energy-efficiency investments are cost-effective for higher discount rates.

Figure 1. Typical Life-Cycle Cost Curve

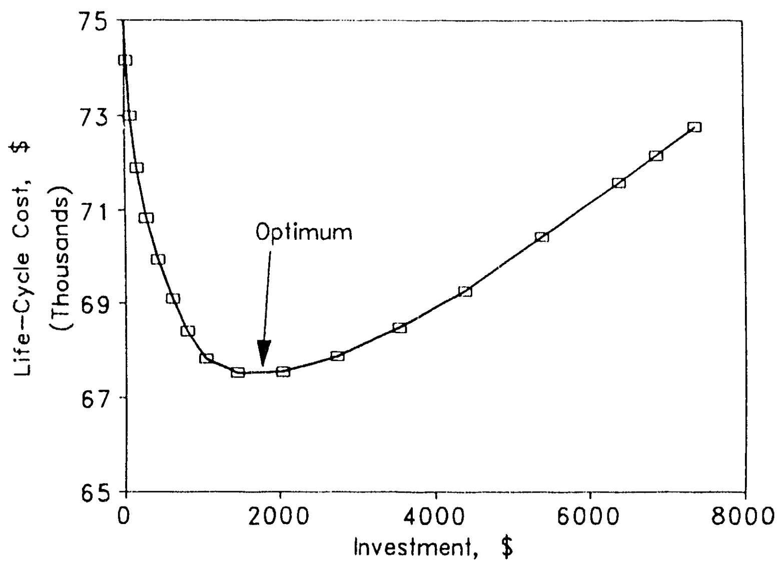
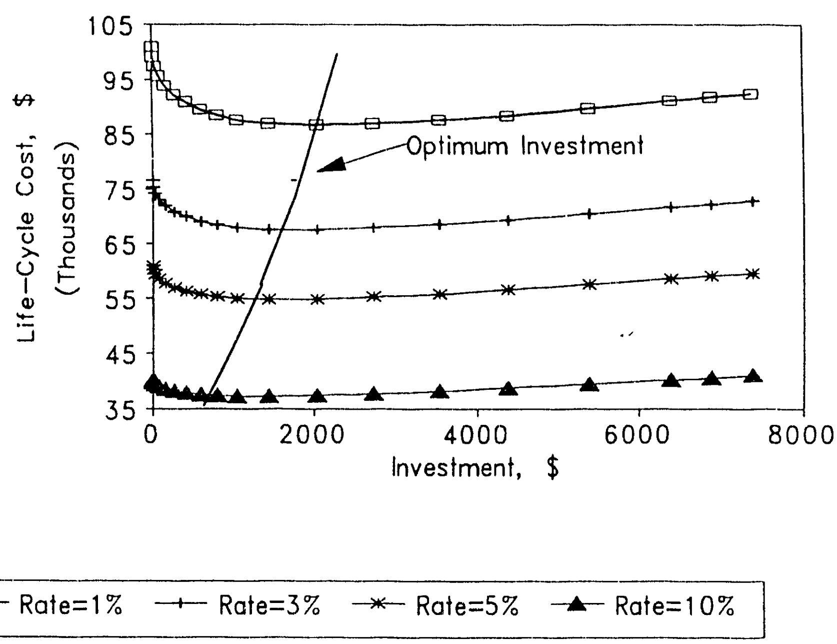


Figure 2. Discount Rate Effect on Life-Cycle Cost



Higher fuel prices increase LCC because they are the major determinant of operating cost, C_o. At higher fuel prices, the LCC curve shifts upward. As fuel price increases, the optimum investment level also increases: additional ECMs become cost-effective as energy prices rise.

Life-cycle cost is not only sensitive to the initial fuel price, but also the rate at which fuel prices are expected to increase. Higher fuel price real escalation rates increase LCC because future operating costs increase. Higher escalation rates also increase the optimal level of efficiency investment: more investments in efficiency are justified at higher fuel price escalation rates.

Table 1 summarizes the effect of discount rate, fuel price, and fuel price escalation on LCC. These relationships are important when designing conservation programs because customers, utilities, product producers, and implementing organizations may have very different economic perspectives that should be taken into account in the design.

Simple payback is a rule-of-thumb measure of the economic effects of an investment that most consumers can easily understand. The simple payback of one investment relative to another can be calculated by comparing the changes in purchase cost and annual energy cost between the two investment alternatives. We use the simplest form of payback measures defined by the American Society for Testing and Materials [(ASTM) 1986]. Our

Table 1. Effects of Factors on LCC

If this factor increases	then LCC...	and optimum efficiency investment...
Discount rate	Decreases	Decreases
Fuel price	Increases	Increases
Fuel price escalation rate	Increases	Increases

simple payback analysis neglects discounting of future costs, fuel price escalation, tax effects, financing costs, etc.[3] The simple payback in years is calculated using (2)

$$P = (C_1 - C_2) / (E_1 - E_2) \qquad (2)$$

where P is the simple payback, C is the capital cost, E is the energy bill in year one, and 1 and 2 refer to alternative investments being compared.

First-year cash flow provides a measure of an investment's net effect on expenditures during the first year. The effects of two alternative investments are compared by calculating the first-year net expenditures associated with one investment and subtracting the net expenditures associated with the second.

While first-year cash flow and simple payback periods are useful indicators of economic effects, they have serious deficiencies. The simple payback criterion conveys no information about the magnitude of costs or energy savings. Neither measure adequately takes into account costs and benefits that accrue in the future. Neither considers the effects of fuel price escalation rates and discounting of future costs. Both avoid dealing with future uncertainties by ignoring the future.

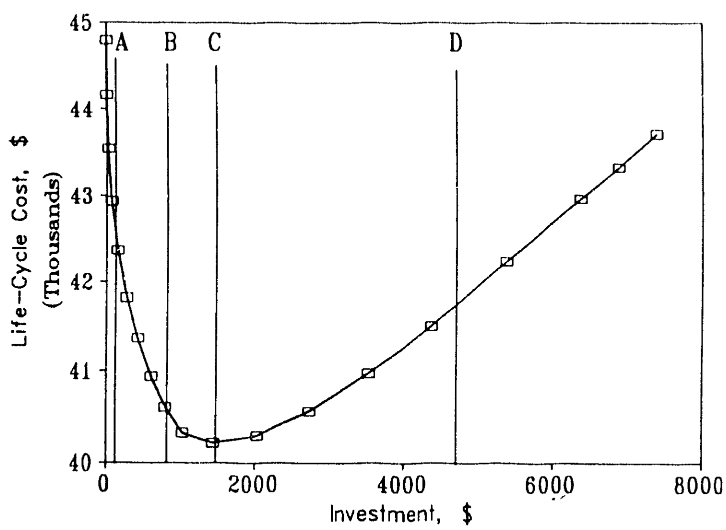
They do have the immediate benefit of being valuable as screening tools. In an era of rising fuel prices, a positive first-year cash flow generally indicates that all future cash flows will be positive. A very short payback suggests that an investment will be beneficial regardless of future uncertainties.

An important issue in using simple payback as a screening tool is selecting an appropriate payback period threshold. Consumers and businesses often require relatively short paybacks to justify conservation investments. Although it is easy to use the simple payback to evaluate conservation investments, consumers and businesses may fail to make some prudent investments if such a simplified tool is the single criterion used. Because of market imperfections, consumers may under-invest in conservation measures.

Differences between the economic perspectives of utilities (or planners) and utility customers (consumers) can provide the basis for the design of programs to produce cost-effective energy conservation investments.

Figure 3 defines four energy-efficiency investment levels for a hypothetical consumer product. The lowest investment level, A, represents the minimum efficiency offered in the market. This level can be established by existing

Figure 3. Alternative Consumer Investment Levels



building standards or codes, or can reflect producer marketing decisions and consumer purchase decisions.

Investment B represents the typical market response. Typical consumers recognize the benefits of some energy-efficiency investments and invest at the level they perceive to be economically attractive.

Investment C represents the LCC optimum consumer investment in energy efficiency. Information programs can reduce the risk and uncertainty that consumers perceive to be associated with efficiency investments, and can improve consumer knowledge about the benefits of such investments, thus helping to move consumers from level B to C.

The highest investment level shown, D, corresponds to the optimum investment from a conservation program designer's perspective. Level D differs from level C because a program designer may face different economic parameters than the consumer. Although level D saves the consumer energy, it is not cost-effective based on the consumer's economic parameters. As noted earlier, a government agency may use the societal, rather than the consumer, discount rate, thus justifying higher investments in energy efficiency.

These are the conceptual underpinnings of the LCC analysis approach and framework. An actual program is described below to illustrate how the approach can be applied in the real world.

ENERGY-EFFICIENT MANUFACTURED HOUSING PROGRAM EXAMPLE

This section discusses a regional conservation program targeted at one housing sector. It presents background information on the program and then discusses it in the context of LCC analysis and other economic criteria.

Program Background

The Bonneville Power Administration has been conducting projects in the Pacific Northwest to improve the energy efficiency of electrically heated manufactured homes. In the mid-1980s, BPA studies showed that manufactured homes used much more energy per square foot than site-built homes and were over one-third of all new electrically heated homes. A multiyear program was started to gain a better understanding of the industry and its products, to develop a working relationship with the industry, and to implement actions to improve energy efficiency. Table 2 summarizes the program.

Data collected from the early projects showed that energy-efficient manufactured homes could be constructed to use less than a third of the space heating energy of standard manufactured homes in the region. Other data showed that the average manufactured home purchased was already 20% more efficient than required by HUD standards. The large-scale demonstration showed that each efficient manufactured home would save from 3,500 to 6,500 kWh/yr over typical manufactured homes. Average levelized costs of the conservation measures ranged from approximately 2.7 cents/kWh in the mildest climate zone to 1.9 cents/kWh in the coldest zone. This was well below the utility avoided cost of nearly 6 cents/kWh to build a new thermal powerplant. Early results provided BPA and utilities with adequate information to justify including manufactured homes in the Super Good Cents marketing and incentive program. Through this program, about 30% of all new electrically heated manufactured homes were built to high efficiency levels.

The utilities and BPA recognized, however, that capturing the remaining energy savings potential from the other 70% of the homes produced in the region warranted a more innovative, comprehensive program. These findings set the stage for BPA and others in the Pacific Northwest to develop a large-

Table 2. Summary of Regional Multiyear Program

Period	Events	Findings
1984-86	Conduct initial studies	Manufactured homes represent significant share of new homes (Hendrickson et al. 1985); existing marketing programs could be used for manufactured homes (Mohler and Smith 1986); significant energy savings can be achieved (Lee et al. 1986)
1987-88	Identify cost-effective efficiency upgrades	A wide range of upgrade possibilities exists (Harkreader, Lee, and Sherman 1987); cost-effectiveness for upgrades is established (Lee et al. 1988)
1987-90	Conduct large-scale demonstration and include homes in regional marketing program	Demonstration produces baseline data (Lee, Riewer, and Volke 1990); energy-efficient manufactured homes produce cost-effective energy savings (Baylon et al. 1990)
1990-present	Design and implement regional acquisition program (MAP)	Innovative program to acquire energy savings is designed and initiated

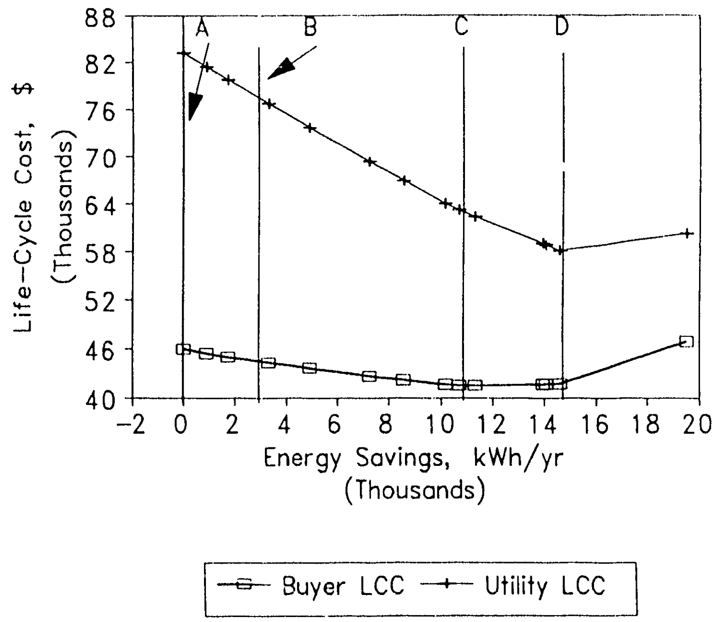
scale energy-efficiency program for manufactured homes called the Manufactured Housing Acquisition Program (MAP).

Manufactured Homes Economic Analysis

Figure 4 shows how adding ECMs affects the LCC and energy savings of manufactured homes in the Pacific Northwest from two perspectives: the home buyer and the utility. The LCC values are plotted relative to energy savings, rather than investment cost. The consumer calculations use a mortgage interest rate of 13% (nominal), a mortgage term of 20 years, and a down payment of 20%.[4] The real consumer discount rate used is 10% based on the assumption that buyers could choose to buy down their home loans to avoid a nominal interest rate of 13%. All ECM costs are retail prices. The calculations have been made relative to the minimum efficiency levels offered by regional manufactured home producers.

As before, level B indicates the efficiency level selected by the typical consumer and level C corresponds to the optimum level based on a life-cycle analysis from the consumer's perspective. Typical consumers already buy higher levels of efficiency than the minimum available, but do not invest up to their optimum LCC level. As noted before, information programs might be one

Figure 4. Consumer and Utility Life-Cycle Costs Comparison



way to move consumers from level B toward level C. Level D corresponds to an efficiency level that reflects an optimum investment from the perspective of the utility faced with providing electricity to these homes. Based on information generated by its regional research projects, BPA and the region's utilities were able to determine what efficiency level corresponded to level D.

Figure 4 also compares the home buyer's LCC curve with the utility's LCC if the utility were investing in the ECMs. The utility LCC curve differs substantially from the buyer's curve because of differences in key parameters. Two of the major differences are that 1) the utility curve reflects a real discount rate of 3%, rather than 10%, and 2) the utility's investment costs are based here on manufacturer wholesale costs, rather than retail costs.

The discount rate used in the utility analysis reflects a societal perspective as specified by the Northwest Power Planning Council (NWPPC 1991, p. 914). Figure 2 showed that lower discount rates increase the magnitude of LCC and make higher efficiency investments cost-effective.

The second major parameter difference is the use of manufacturer wholesale costs to calculate investment costs. Dealers mark up wholesale cost about 30% to arrive at the retail price (Harkreader, Lee, and Sherman 1987). When BPA and regional utilities developed the MAP, they negotiated to make payments directly to manufacturers, which avoided paying the retail markup. This was a major factor making the program economically viable.

Based on past research, BPA and the utilities determined that it was economical in the acquisition program to invest in manufactured home efficiency improvements in lieu of new generating plants. They determined that it was economical to pay manufacturers $2,500 for each home built to level D in Figure 4. Agreement was reached with regional manufacturers to build <u>every</u>

electrically heated manufactured home (over 90% of the manufactured homes built in the region) to this level, thus reducing space heating needs 60% compared with the homes that customers typically purchased. This program took the investment in efficiency from level B to level D at a cost of about 2.5 cents/kWh to the utilities.

Despite the inadequacies noted earlier in evaluating economic impacts with cash flows and paybacks, it is informative to use them to examine program consumer impacts. Figure 5 shows simple paybacks and Figure 6 shows first-year cash flows with and without the manufacturers' $2,500 incentive.[5]

Figure 5. Consumer Payback Period

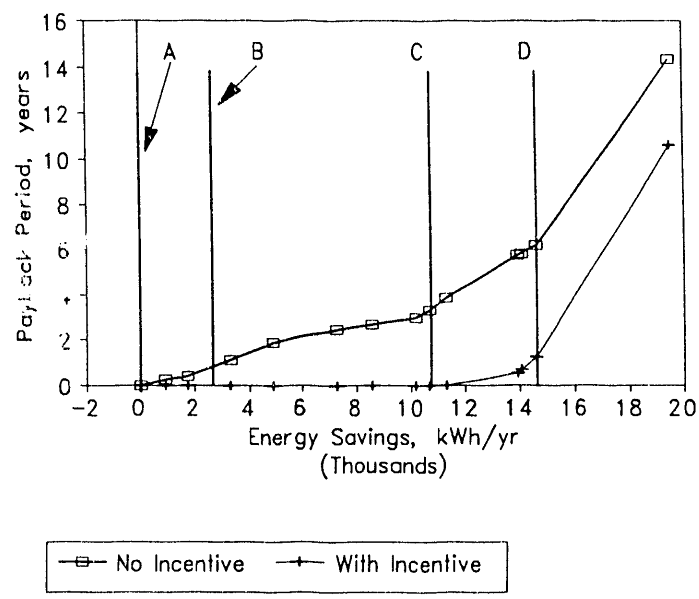
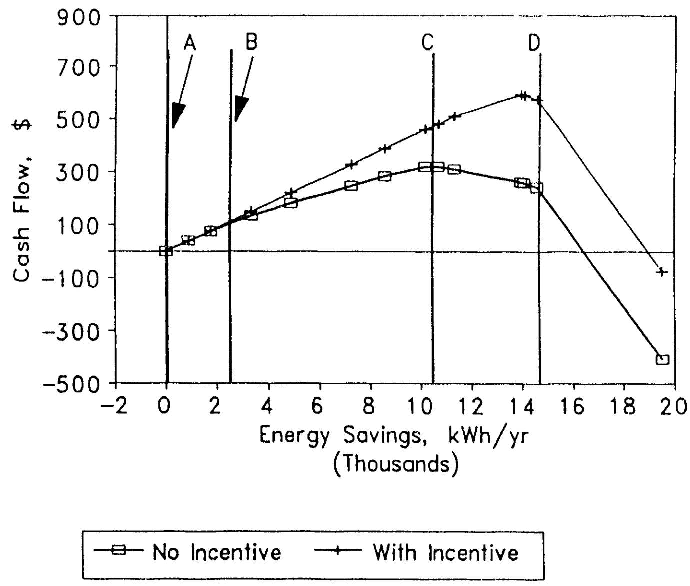


Figure 5 shows that without the incentive the simple payback is a relatively short 4 years or less for all efficiency measures up to level C, the consumer LCC optimum. Thereafter, the payback period increases rapidly, reaching about 7 years at level D, the utility LCC optimum. Even though this is a longer period, it is still fairly reasonable for consumer investments. With the incentive, the payback is immediate for ECMs up to the consumer's optimum LCC level, level C.[6] Even at the utility optimum investment level, level D, the consumer payback is a very minimal time, about one year. The incentive, therefore, substantially reduces the consumer's payback period.

Figure 6 shows that, even without the incentive, the consumer benefits from a positive first-year cash flow in all cases except at the highest energy savings shown.[7] Without the incentive, energy savings increase the consumer first-year cash flow up to the consumer LCC optimum level, C; consumer cash flow reaches $300 per year at this point. Beyond level C, the cash flow declines, but remains positive for several additional efficiency investments. With the incentive, the first-year cash flow increases faster up to about $600 per year near the utility optimum level, D. It then declines, going slightly

Figure 6. Consumer First-Year Cash Flow



negative for the highest savings level plotted.

These figures illustrate two important findings. First, typical consumers appear to under-invest in energy efficiency, even when the investments are analyzed using two economic criteria, payback and cash flow, which should be readily understood by most consumers. Second, incentives can make significant improvements in the payback period and cash flow associated with consumer investments in energy efficiency.

CONCLUSIONS

The LCC approach provides a comprehensive and consistent framework for analyzing alternative utility resource investments. In an LCC context, the cost-effectiveness of energy-efficiency investments depends on several key factors including the discount rate, fuel and energy prices, and fuel and energy price escalation rates. The LCC of alternative investments can be very different from the perspective of 1) the utility and 2) the utility's customers.

Analyzing the LCC impacts of energy-efficiency investments from the societal, utility, and customer perspectives can provide valuable information to utilities and planners for designing energy-efficiency programs. This study has shown, both conceptually and in terms of an actual energy-efficiency program, that the optimum customer investment in energy efficiency is likely to be less than that appropriate for the utility. A utility or program planner can use LCC analyses based on different perspectives to target actions and investments. LCC analysis can also show a utility or program planner how large the gap is between typical consumer choices and the utility optimum. This information can be used as the basis for designing programs to increase consumer awareness and to provide incentives that make efficiency investments economically attractive to consumers. The regional MAP highlights how this information has been used in a specific program to make substantial efficiency improvements in one housing type.

Significant questions are suggested by the results of this study of the economics of energy-efficient manufactured homes. First, what pricing strategies do manufacturers and dealers use when a large incentive is paid to the manufacturers? Data on the prices charged by manufacturers and dealers need to be analyzed to answer this question. Second, why are typical consumer investment choices so far from their LCC optimum level? Both the payback and cash flow analyses confirm that typical consumer behavior undervalues conservation investments in manufactured homes. Analysis of consumer preferences and knowledge will have to be conducted to explain why. An initial study is underway to begin answering this question. Third, how do consumers respond to price changes in manufactured homes? There is little information available about how changes in manufactured home prices, such as those resulting from energy-efficiency improvements, affect consumer demand. An initial study is also underway to address this question. An important issue for all program participants is what is likely to happen if the program is modified or the incentives are eliminated. The LCC framework provides a way to start addressing these issues.

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ENDNOTES

1. The Pacific Northwest Laboratory is operated by Battelle Memorial Institute for the U.S. Department of Energy under Contract DE-AC06-76RLO 1830.
2. All results displayed here are based on real rates, i.e., with no inflation effects included.
3. An alternative simple payback is calculated by tracking the stream of costs and savings until cumulative net savings equal additional costs. For a home, the additional costs would be the down payment, points, incremental mortgage payments, etc., adjusted by taxes and tax benefits, minus the utility bill savings. The only neglected factor is the effect of discounting future costs and savings. This approach provides a crossover point at which the home buyer has saved an amount equivalent to the initial dollars invested. It can be shown that this crossover can be shorter or longer than the simple paybacks calculated with (2), depending on the length of the simple payback.
4. Because this analysis is only intended to be illustrative, the values selected may not be the most common, but are simply reasonable values for the market.
5. In both cases, it is assumed that the manufacturer passes the incentive through to the retailer and wholesale cost is reduced by the amount of the incentive times the dealer markup. Research will be conducted to determine if this is an accurate assumption.
6. It is assumed that the incentive is the wholesale cost of the ECMs or $2,500, whichever is less.
7. To avoid the discontinuous impact the down payment would have on first-year cash flow and the need to calculate future opportunity costs of the down payment, we have assumed that 100% of the cost attributable to the ECMs was financed.

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