Bridging the Gap: Designing DSM Programs Based on the Difference Between Utility and Consumer Economic Perspectives

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As utilities plan demand-side management (DSM) programs, the differences between customer and utility economic perspectives can play an important role in assessing the economic benefits of the programs. Because utilities directly bear the cost of new energy sources, energy-efficiency investments that are cost-effective to a utility may not be cost-effective to its customers who usually pay average energy prices and have different economic parameters.

This paper discusses the relationship between life-cycle costs and the energy efficiency decisions of home buyers and utilities. It discusses the key factors in a life-cycle cost analysis and how they affect the optimum energy efficiency choice. In addition to discount rates, fuel prices, and fuel price escalation rates, risk adjustments influence the selection of an optimum efficiency level. This paper highlights differences between household and utility perspectives and the reasons why a gap often exists between the home owner's and utility's optimum efficiency choice.

A case study of an innovative Pacific Northwest manufactured (mobile) home DSM program illustrates the role of consumer and utility perspectives. Prior research showed that regional utilities' long-term perspective and economics justified higher energy-efficiency investments than most manufactured home buyers were making. This recent DSM program has addressed both market imperfections and basic economic differences between consumers and utilities by employing a "conservation acquisition" approach, which has led to a significant market transformation. This program has been very successful at closing the gap between the economic interests of the home buyer and utility.

Introduction

As utilities investigate ways to implement demand-side management (DSM) programs, the differences between customer and utility economic perspectives can play an important role in assessing the economic benefits of the programs. Because utilities directly bear the cost of new energy sources, energy-efficiency investments that are cost-effective to a utility may not be cost-effective to its customers who usually pay average energy prices and have different economic parameters.

The Bonneville Power Administration (Bonneville) and other parties in the Pacific Northwest have initiated an innovative energy conservation program, the Manufactured Housing Acquisition Program (MAP), that makes energy-efficiency investments in manufactured (mobile) homes. Because manufactured homes comprise up to 50% of new housing starts in some parts of the United States and are regulated by preemptive standards issued by the Department of Housing and Urban Development (HUD), which have less stringent energy-efficiency requirements than many local building codes, utilities and energy planners cannot ignore manufactured homes in their planning process and cannot rely on regulations to improve the energy-efficiency of manufactured homes. More innovative approaches and programs are needed,

Recognition of the differences between the economic criteria and perspectives of consumers and utilities can be helpful in designing energy-efficiency programs. This paper discusses life-cycle cost (LCC) analysis as a framework for highlighting these differences. 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. LCC analysis compares long-run costs associated with specific investments, such as energy conservation measures (ECMs) incorporated in DSM programs. Using LCC analysis to optimize a decision, the alternative with the lowest LCC is preferred. Future costs are discounted with the relevant 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.

Life-Cycle Cost Analysis

Life-cycle cost analysis can be as comprehensive as desired, taking into account direct and indirect costs and benefits. For the present purposes, we limit the discussion to direct costs. The basic cost elements of the simplified, generic LCC method are shown in Equation (l):

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

where C_p is procurement costs, C_O is operating costs (including energy costs), C_M is maintenance and replacement costs, and S is the salvage value. To simplify the presentation, the terms represent the discounted present value of the cost stream using the appropriate discount rate. (See DOE 1989 for a discussion of the method.) Because this paper uses the MAP to illustrate an application of the LCC method, the discussion that follows focuses on ECM investments in manufactured homes.

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 home comfortable; decreases in heating and cooling energy costs tend to offset increases in the procurement cost due to investments in ECMs. S represents the resale or scrap value of the ECMs at the end of the analysis period and, because it is a benefit, its value is subtracted from the other costs.

An informative way to display LCCs is to plot the LCCs versus ECM procurement costs or, alternatively, their corresponding energy savings as is done later in this paper. 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 decrease the LCC until it reaches the minimum, or optimum, value; additional ECMs continue to save energy, but the LCC starts increasing (as the benefit-to-cost ratio continues declining). Note that 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.

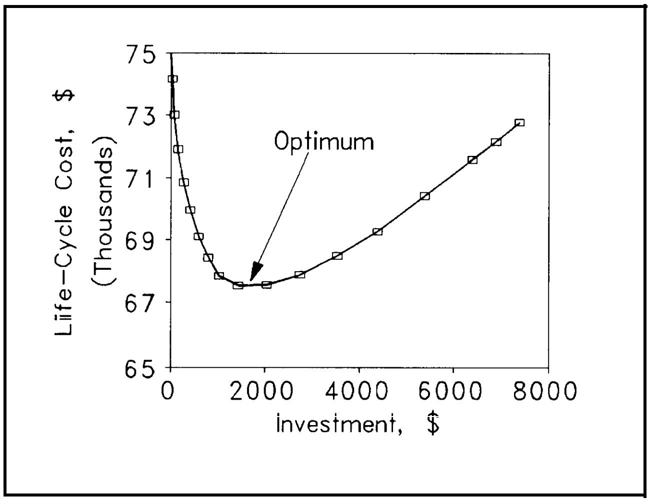

Figure 1. Typical Life-Cycle Cost Curve

Effects of Parameter Values on Life-Cycle cost

Even though a relatively small number of cost terms comprise the LCC, several factors can have large effects on the values.

Discount Rate Effects. 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. (Kavanaugh et al. 1994 derives a nominal discount rate estimate of 19% for manufactured home buyers.) Opportunity costs and perceptions of risk affect these rates. Risk effects are discussed later.

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 *increases,* the total computed life-cycle cost *decreases* because future costs are more heavily discounted. Second, the optimum investment shifts to the left (decreases) as the discount rate increases: fewer energy-efficiency investments are cost-effective for higher discount rates.

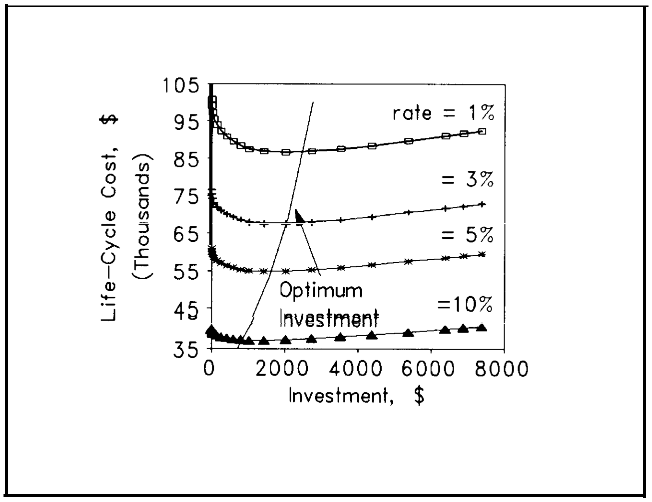

Figure 2. Discount Rate Effect on LCC

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

LCC is not only sensitive to the initial fuel price, but also the rate at which fuel prices are expected to increase. Higher fuel price 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.

Risk Adjustments. The risks associated with different investments should also be included in a LCC analysis because they may have a significant effect on the actual values of projected future costs and benefits. Financial risk can be defined as "the variability (i.e., standard deviation) of project returns or cash flows over time" (Awerbuch 1993, p. 25): investments with returns that are more variable than the returns of other investments are riskier. Uncertainties about energy resources affect their riskiness. For example, uncertainties about the cost of building future powerplants or operating DSM programs affect the likely revenue requirements of utilities. Hirst (1992) suggests that utilities can reduce the variability in their revenue requirements and, therefore, their risks, by investing in DSM programs.

Awerbuch (1993) examines financial risks for electric generation in more detail. He points out that in the past most electric generation was provided by fossil fuel technologies and the riskiness (particularly that resulting from fuel price variations) was considered relatively uniform across the technologies used. However, largely because they are not affected by fuel price variations the same way fossil-fuel generation is, new capital-intensive, renewable resource and DSM technologies necessitate addressing risk differences explicitly. This is usually done by adjusting the discount rate. (Note, however, that Lind (1982) points out difficulties in applying a simple adjustment of the discount rate to account for risk over multiple periods.)

Awerbuch (1993) identifies several points important in the assessment of energy and DSM investments. First, an investment's future benefits (inflows) and costs (outflows) should be evaluated with separate discount rates reflecting the appropriate risk level. Second, risky benefits should be discounted with a higher discount rate, whereas risky costs should be discounted with a lower discount rate. Logically, the discounted present value of highly variable costs should not be decreased by applying a higher discount rate to reflect their higher risks. Third, energy resource investments with future costs that are negatively correlated with the general economy are typically riskier because their returns (benefits minus costs, or net cash flow) are highly correlated with trends in the general economy and overall investment portfolio returns. The second and third points suggest that future fuel costs for a fossil-fueled powerplant should be discounted at a discount rate diminished by the risk adjustment and not an average portfolio discount rate such as the utility's weighted-average cost of capital. Fourth, the use of a utility's weighted-average cost of capital in the revenue-requirements method for evaluating alternative energy resources usually distorts the analysis in a way that favors expense-intensive (e.g., fossil-fueled powerplants) over capital-intensive (e.g., photovoltaic) technologies.

Figure 3 illustrates the effects of taking financial risk into account in the LCC calculation for the consumer. The curves show the effect of different discount rates applied to consumer electricity rates. Because the electricity rates affect future utility bills, more risk in energy prices causes a downward adjustment in the discount rate. Awerbuch (1993) derives an estimated composite discount rate differential of 7% between fossil-fueled and photovoltaic generation. The four curves show how the LCC curve shifts as the risk adjustment varies from 0% to -9%. First, as the risk increases (the discount rate adjustment becomes more negative), the total computed life-cycle cost increases because future costs are discounted less. Second, the optimum investment shifts to the right as the investment becomes riskier: more energy efficiency investments are cost-effective when the risk associated with energy prices is higher.

Figure 3 shows the effect of only one kind of risk. The effects of uncertainties in DSM program cost and energy savings are not displayed; if they were included, they might partially offset the effects of energy price risk. Nevertheless, the figure highlights the potentially significant role that energy price risk can play in the life-cycle cost analysis and presents a strong argument for factoring risk into DSM program analyses.

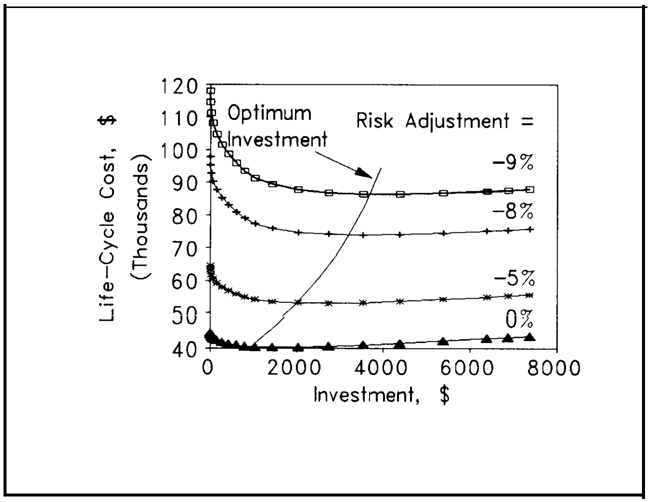

Figure 3. Fuel Price Risk Adjustment Effect on LCC

Summary of Effects on Life-Cycle Costs

Table 1 summarizes the effect of discount rate, fuel price, fuel price escalation, and fuel price risk on LCC. These relationships are important when designing conservation programs because these factors are instrumental in determining the economic viability of such programs. Furthermore, customers, utilities, and implementing organizations may have very different economic perspectives, reflected in the values for these economic factors, and they should be taken into account in program design.

Different Economic Perspectives

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 4 shows, from the consumer's perspective, a representative life-cycle cost curve as a function of the investment in energy efficiency. It defines four energy-efficiency investment levels. This figure is for a hypothetical product and is designed only to illustrate several points discussed below.

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
Fuel price risk	Increases	Increases

From the consumer's perspective, the lowest investment level, A, represents the minimum efficiency offered in the market. This level can be established by existing building standards or codes, or can reflect producer marketing decisions and consumer purchase decisions.

Investment level B represents the average market response, assuming that consumers do not typically invest at the minimum life-cycle cost level for a number of reasons associated with market imperfections. Because of market imperfections, typical consumers may underestimate the benefits of energy-efficiency investments and invest at a level that is not their actual economic optimum, Level B is determined by the interaction between the market supply and demand curves.

Investment level C represents the consumer's optimum investment in energy efficiency based on the consumer's

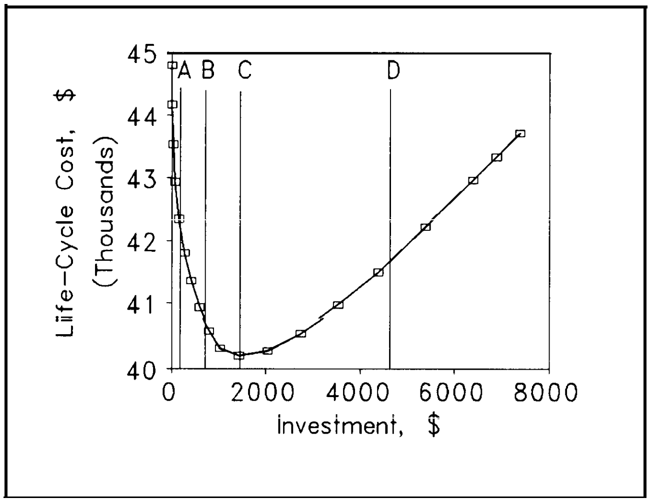

Figure 4. LCC and Alternative Efficiency Investment Levels

LCC. Utility information programs can help move consumers from level B to C by improving their knowledge about the benefits of such investments. Usually energy-efficiency codes and standards are set to achieve level C.

The highest investment level identified, D, represents the optimum investment from a conservation program designer's perspective, The program designer might represent a utility (and the utility's economic perspective) or a planning body such as the Northwest Power Planning Council (and a societal economic perspective). Level D can be determined from the LCC curve for the conservation program planner. (This curve is not shown in Figure 4, but the example shown in Figure 5 illustrates how this level is determined.) Level D reflects the investment level that corresponds to the program planner's minimum life-cycle cost. Level D differs from level C because a program designer may face different economic parameters than the consumer. For example, a government agency may use the societal, rather than the consumer, discount rate to calculate the optimum LCC, thus justifying higher investments in energy efficiency. Although level D saves the consumer energy, it is not cost-effective based on the consumer's economic parameters.

Over time, utility programs that promote and demonstrate the feasibility of higher efficiency levels can play a significant role in institutionalizing residential energy efficiency improvements. One common mechanism is the effect of utility programs in providing the impetus and information needed to establish energy-efficiency codes and standards .

These are the conceptual underpinnings of the LCC analysis framework discussed here. An actual program is described below to illustrate how the approach can be used to examine a program 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.

Program Background

For over 10 years, Bonneville has been conducting projects in the Pacific Northwest to improve the energy efficiency of electrically heated manufactured homes. In the mid- 1980s, Bonneville studies showed that manufactured homes used much more energy per square foot than site-built homes and that they comprised over one-third of all new, electrically heated, single-family housing starts each year. 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. Bonneville's energy-efficient manufactured home projects during the past 10 years have been well documented (Hendrickson et al. 1985, Mohler and Smith 1986, Lee et al. 1986, Harkreader, Lee, and Sherman 1987, Lee et al. 1988, Lee et al. 1990, Baylon et al. 1990, and Gilbertson et al. 1993).

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. A large-scale demonstration project, in which 150 energy-efficient manufactured homes were constructed and monitored, showed that each efficient manufactured home would save from 3,500 to 6,500 kWh/yr over typical manufactured homes. Average levelized costs (in constant 1990 dollars) 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 at the time of nearly 6 cents/kWh for a new thermal powerplant. Project results provided Bonneville and utilities with adequate information to justify developing a full-scale energy-efficiency program for manufactured homes.

The utilities and Bonneville worked with manufactured home producers to develop a large-scale energy-efficiency program for manufactured homes called the Manufactured Housing Acquisition Program (MAP). This program is one of the first "market transformation" DSM programs and is unique in that utilities pay manufacturers directly for the efficiency upgrades of their homes. The payment is based on manufacturers' wholesale costs rather than the retail costs charged buyers.

Manufactured Homes Economic Analysis

Figure 5 shows how adding ECMs affects the LCC and energy savings of manufactured homes in the Pacific Northwest from two perspectives: the home buyer's and the utility 's. The LCC is calculated for individual ECMs, such as different floor, wall, and ceiling insulation, using the relevant economic parameters. The LCC values are plotted relative to energy savings, rather than investment cost as shown in previous figures. The consumer curve assumes that home buyers pay the full cost of efficiency upgrades; the utility curve assumes that the utility pays the full cost. For consumers, ECM costs are based on retail prices; for utilities, the costs are based on wholesale prices. Reasonable consumer and utility values for the economic parameters have been used in calculating the LCC, but the curves should be considered illustrative only. Future research should be conducted to estimate these parameters more accurately. The calculations have been made relative to the minimum efficiency levels offered by regional manufactured home producers.

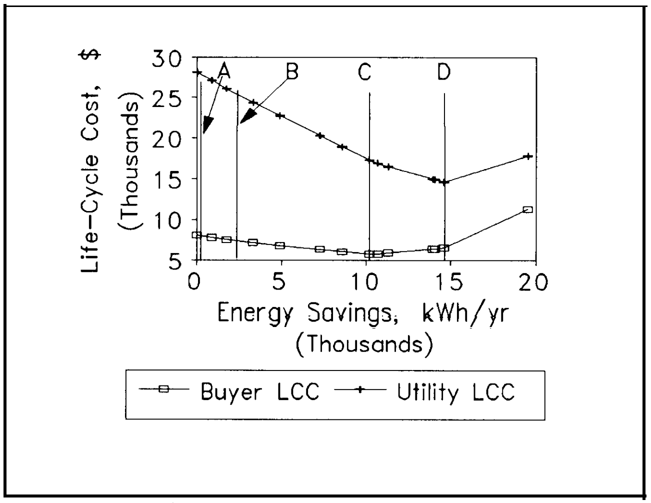

Figure 5. Manufactured Housing Utility and Buyer LCC

As before, level A is the minimum efficiency level offered in the market. Level B indicates the efficiency level selected by the typical consumer. Typical consumers already buy higher levels of efficiency than the minimum available, but do not invest up to their optimum LCC level. Level C corresponds to the optimum level based on a life-cycle analysis from the consumer's perspective. As noted before, information programs might be one 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, Bonneville and regional planners were able to gain an understanding of the approximate energy efficiency that corresponded to level D.

The utility's LCC curve shown in Figure 5 differs substantially from the buyer's curve because of differences in key parameters. Two of the major differences are that we have assumed that (1) the utility has a lower (that is, riskier) risk-adjusted discount rate than consumers have for discounting energy costs because the utility faces more variability y in energy prices (because consumers are insulated partially from energy cost changes by utility rate-making practices) and (2) the utility's investment costs are based on manufacturer wholesale costs, rather than retail costs that would face the consumer. The second assumption is consistent with the design of the MAP. Dealers mark up wholesale cost about 30% to arrive at the retail price (Harkreader, Lee, and Sherman 1987). When Bonneville and regional utilities developed the MAP, they negotiated to make payments directly to manufacturers, thus avoiding paying the retail markup. This was a major factor in making the program economically viable.

Based on Bonneville's past manufactured housing research, Bonneville 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 5. Agreement was reached with regional manufacturers to build every 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 (1990 $) to the utilities.

Of course, Figure 5 is an idealized representation of the economics and energy-efficiency aspects of the MAP. The program was not designed explicitly based on the life-cycle cost approach described here, although many of the key elements of the approach played a role in program design. Values of the economic parameters for both consumers and utilities were not all known or factored into the design of the program. Recent research by Kavanaugh et al. (1994) provides a much better understanding of the economic parameters for manufactured home buyers, but more study is needed to characterize the consumer's economics fully. Many complexities, such as rate-making practices and discount rate differences, that affect the economic impacts on utilities, have been neglected to simplify the presentation. Several questions also remain about how the program was actually implemented by the industry at the consumer level; for example, how much of the MAP payment reached the consumer and how much was captured by the manufacturer and dealer? Has the MAP had any fundamental effect on consumer perceptions of energy efficiency and the risk associated with conservation investments? It would also be very desirable to know how effective information programs or other financial incentives would be in moving consumers toward higher efficiency levels. Some of these questions are being addressed in an on-going evaluation of the MAP.

Although the MAP was not explicitly designed using the life-cycle cost framework presented here and we don't have answers to all the economic questions, the MAP illustrates the value of the described methodology well. If average consumers invest in less energy-efficiency than their minimum life-cycle cost level would dictate, then the utility can investigate what causes the underinvestment and identify ways to remedy associated market imperfections. If the utility would benefit from investments in even higher energy efficiency, then comparing the utility and consumer LCC curves would help identify what incremental investment the utility might have to make and what mechanisms might be effective to motivate buyers to purchase more efficient products.

Conclusions

The LCC approach provides a useful tool for analyzing alternative utility resource investments. In a LCC context, the cost-effectiveness of energy-efficiency investments depends on several key factors including the discount rate, fuel and energy prices and price escalation rates, and risk. The LCC of alternative investments can be very different from the perspective of (1) the utility, (2) the utility's customers, and (3) society.

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 the typical consumer's efficiency choices and the utility's investment in energy efficiency that minimizes its LCC. 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 illustrates the relevance of this type of information to a specific program that has made substantial efficiency improvements in one housing type.

For DSM program planning purposes, the first step in the approach outlined here would be to develop the information needed to analyze the life-cycle costs for society, the utility, and consumers. This information would include among other data the ECM costs, energy prices, energy price projections, and risk adjustments. It may be appropriate to apply a different discount rate to costs and benefits, and risk adjustments associated with future costs should be distinguished from those applicable to future benefits. Second, the LCC for different efficiency investments should be calculated for each perspective and the differences between the relationships should be investigated. Third, mechanisms should be identified that would be most appropriate for closing the gaps between current consumer behavior and the societal, utility, and consumer optimum efficiency levels. Information programs can be used to reduce the gap between the efficiency level usually selected by consumers and the consumer's life-cycle optimum level. Financial and economic mechanisms such as rebates, interest rate buy-downs, and reduced utility rates may be needed to move consumers to efficiency levels beyond their optimum. Of course, the cost of such programs must be factored into the utility's life-cycle cost calculation.

The life-cycle cost framework outlined here provides a useful tool for DSM program design. By focusing on the long-term economics and economic differences that exist between consumers and utilities, the LCC approach helps characterize consumer behavior and identify opportunities that can lead to a win-win situation in which both consumers and utilities are better off. This framework can be valuable to utilities and energy planners setting out to design new programs and to others attempting to modify existing programs, such as the MAP, which is being revised to accommodate a recent update in the national manufactured housing thermal standard.

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Endnotes

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2. Unless noted otherwise, all results displayed here are based on real rates, i.e., with no inflation effects included.

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