# How Much Load Relief? From Which Households? Engineering Residential Direct Load Control in Wisconsin

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Central air conditioning has become increasingly common in Wisconsin homes since 1989, creating needle demand peaks on some summer days. To avoid or defer building new capacity to serve those peaks, Wisconsin utilities and regulators are exploring the benefits and costs of direct load control (DLC) programs for air conditioners. Specifically, five utilities developed and implemented a variety of DLC programs in 1992 and 1993 to assess the load relief available and the most effective cycle/shed designs, as well as the attractiveness of different incentive and promotional strategies.

The Wisconsin Center for Demand-Side Research facilitated the coordination and evaluation of these DLC programs. This effort included development of a comprehensive sample for metering, and protocols for both metering and survey data collection. A total of 745 homes was monitored, using a mix of whole premise meters, single-channel end-use meters and multi-channel end-use meters that yielded data for more than 1300 points.

Although the benefit-cost ratio for each utility's DLC program depends upon its specific avoided costs and preferred strategy, the results indicate that such programs *can be* cost-effective in Wisconsin. Peak day relief ranged from 0.5 kW to 2.1 kW per participant, depending upon connected load, age of the air conditioner, square footage of the house and the cycle/shed strategy as well as external conditions. Moreover, post-control energy paybacks (for the purposes of this paper, "payback" refers to the increase in load, over and above the normal diversified load of an air conditioner, that can occur after direct control is ended) were negligible, free ridership appeared to be relatively low (under 10%), and equipment failure was in the expected range. Program designers should be cautious, however, in seeking maximum load relief through the use of shed strategies: post-control demand (kW) paybacks—secondary peaks as units are released from control—are considerably larger than those associated with less severe control strategies.

## Introduction

Do direct load control programs for air conditioners make sense in Wisconsin? The state's summer climate is generally considered to be temperate compared to other states, such as Florida. Certainly that is evidenced in a comparison of annual cooling hours (hours where the temperature exceeds 80°F, or 26.7°C) for south Florida (Miami = 2495) and Wisconsin (Madison = 293). Nearly an order of magnitude separates the cumulative cooling hours.

However, an examination of the design ambient conditions (the 1% design dry-bulb and wet-bulb temperatures, respectively) reveals a completely different situation. For Madison, the 1% design temperatures are 91°F/74°F (32.8°C/23.3°C) while Miami design temperatures are 91°F/77°F (32.8°C/25°C). Clearly, these data indicate that—while the duration of the cooling period is much shorter—under peak conditions Wisconsin residents experience temperature extremes and the associated discomforts that are comparable to those of more southerly climes.

A series of severe summers in the late 1980s, most notably 1987 and 1988, set many high temperature records across Wisconsin. Temperatures exceeding 100°F

(37.8°C) were common. This situation, coupled with a boom in residential new construction, led to a rapid increase in the saturation of residential central air conditioners. As seen in Figure 1, the saturation rate nearly doubled between 1983 and 1990, from roughly 16% to 30%. By 1993, the saturation rate was approaching 40%. This increase in central air conditioner saturations meant increases in electric utility loads as well. But even with such extreme temperatures, the annual cooling hours remained relatively low. As a result, although summer demand sharpened, utility planners and regulators had to be wary of building capacity to serve needle peaks. Other solutions needed to be assessed.

## Background

In light of the rapidly expanding use of residential central air conditioning, several Wisconsin utilities began independently planning, designing and evaluating direct load control program offerings for their service territories. By 1992, the state's five major electric utilities (Madison Gas and Electric Company, Northern States Power Company, Wisconsin Electric Power Company, Wisconsin Power and Light Company and Wisconsin Public Service Corporation) had established individual DLC marketing and implementation infrastructures. The programs were developed to fit each utility and its customers, and were marketed independently of one another. It was clear, however, that questions about the cost-effectiveness of different program designs and concerns about free ridership, post-control period paybacks and other issues were shared by all utilities and by the regulatory staff.

Recognizing their shared interest, the utilities and the state regulatory body (the Public Service Commission of Wisconsin—the PSCW) began discussing the merits of combining the utilities' individual evaluation efforts in early 1991.[1] The utilities and the PSCW agreed to coordinate these efforts and to ask the Wisconsin Center for Demand-Side Research (WCDSR) to help organize and manage the project. This decision not only allowed leveraging of evaluation efforts but also extension of the range of issues studied. In addition, it provided a continuing opportunity for utility and regulatory staff to review and discuss issues and concerns.

To help focus evaluation and planning efforts and facilitate project management, two distinct projects were defined. The first led to a comprehensive plan (developed in late 1991) to determine primary and secondary impacts from the utility and customer perspectives. The second centered around the development of a set of models to predict program participation, gross premise-level impacts and free ridership on the basis of various customer and program characteristics.

As with most WCDSR projects, steering committees were established to work with the Center's staff. The steering committees, which included both utility and regulatory staff members, helped to set the specific project objectives, select external contractors, resolve problems and review results and implications. These committees also served as effective vehicles for communicating and sharing information among utilities on matters of program design, advertising, customer sign-up rates, survey design and control day definition.

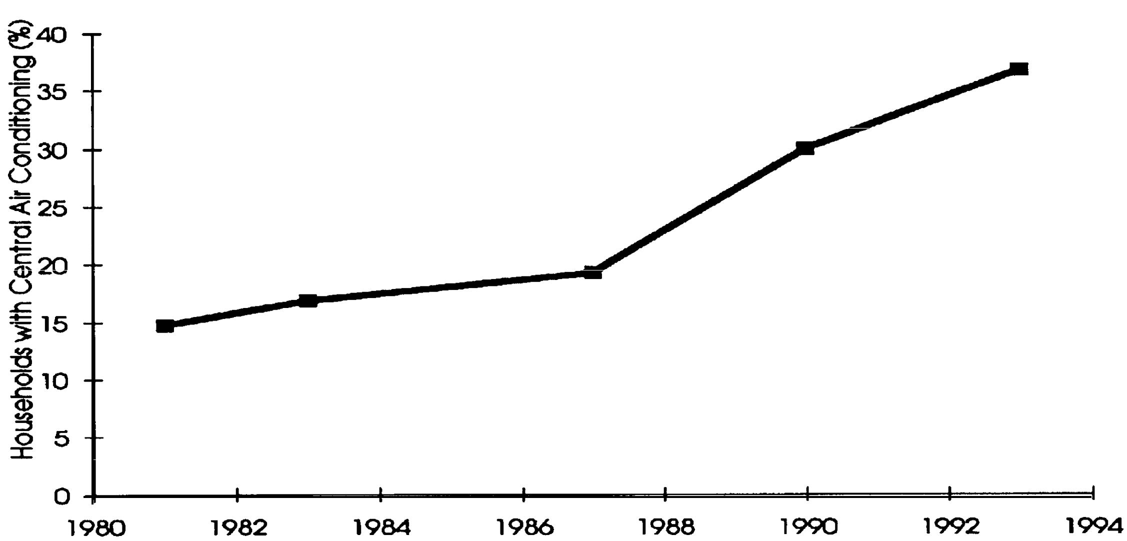


**Figure 1.** Penetration of Central Air Conditioning in Wisconsin

Both WCDSR evaluation projects initiated data collection during the summer of 1992. However, uncooperative weather patterns throughout the summer limited opportunities for control or, from the customer's point of view, "the need for control." As a result, collection and analysis of the impact data was restricted to evaluating the reliability of the data collection system. Figure 2 indicates the cumulative temperature humidity indices (CTHIs) for the years 1948 through 1992, demonstrating how unusually mild were the conditions experienced in 1992. Data collection activity was suspended in September of 1992 and resumed in May of 1993.

Although 1993 was not a peak year, the weather was closer to normal than in 1992; CTHIs reached 427, as opposed to 173 in 1992. Available control and non-control day information allowed completion of the impact evaluation and its inclusion in the participation modeling effort.

## Scope

The following subsections detail the utility DLC programs and the objectives and scope of the impact evaluation and participation modeling efforts, respectively.

*Utility DLC Programs.* Five utility programs were included in the impact analysis. As would be expected because of concern for customer comfort, utilities seek to use their DLC systems as infrequently as possible. However, the rationale and intended use of the systems varied from utility to utility. For example, one utility designed its program as part of its generation reserve and expected to use their single strategy (100% control—shed—of a small fraction of their participating customer pool for up **to six** hours) once every 10 years. Other utilities intended to use their strategy more frequently—up to six days per year—as a way to reduce system demand during peak periods and during periods of reduced generating capacity (e. g., scheduled or unscheduled outages).

The *control system* was identical for the utilities. All used one-way radio transmitter-receiver systems to control the outdoor section (condenser fan and compressor) of residential central air conditioners for customers in their programs.

The *time periods* that each utility could control according to the customer participation agreements varied. Some utilities were not subject to any limitation; others were limited to specific time windows (e.g., 10 a.m. until 10 p.m.). In general, the utilities control during normal weekdays and avoid, or are specifically prevented from, controlling on weekends or holidays.

The DLC *program designs* varied both across utilities and within utilities. One utility, due to their specific DLC objectives, chose to offer only one option; however, the other utilities offered a selection of customer options with varying incentive levels. A list of the options is presented in Table 1. In most but not all utility promotions, customers were given an opportunity to choose the control regime they preferred from the utility's menu of options and incentives.

Sign-up and ongoing incentives were available to varying degrees. Sign-up incentives were used by some utilities during their promotional campaigns and varied across

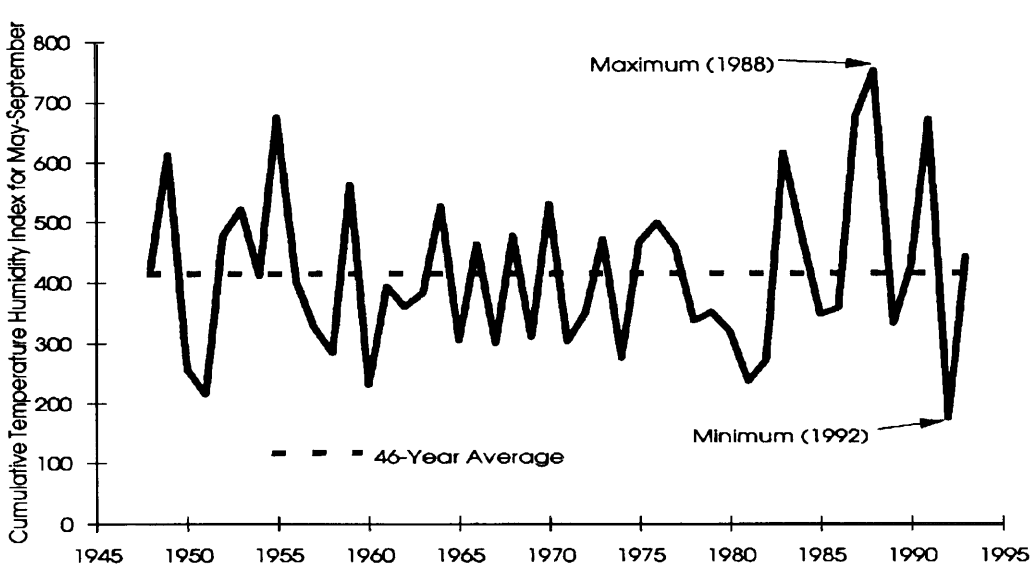


**Figure 2.** Cumulative Temperature Humidity Indices for Wisconsin (1948-92)

**Table 1**. Summary of DLC Program Control Strategy Options

| Control Option | Notes |
|---|---|
| 100% Shed | Set Time Limit; e.g., 4-hour |
| 100% Shed | Set Pattern |
| 100% Shed | No Time Limit |
| 75% Cycling | Off for 22.5 min. per half-hour |
| 67% Cycling | Off for 20 min. per half-hour |
| 50% Cycling | Off for 15 min. per half-hour |

utilities. Examples of these incentives included free programmable thermostats, air conditioner tune-ups or gift certificates for air conditioner cleanings and tune-ups. On-going incentives were typically in the form of bill credits during the summer (June through September) with the amount of credit varying by the individual utility and the control strategy accepted by the customer. An example of a credit for a 100% shed participant is on the order of $8 for each of the four summer months, or a total of $32 per year.

*Impact Evaluation.* The threshold issue for Wisconsin utilities and regulators is the cost-effectiveness of an air conditioner DLC program. Although assessing the costs and system benefits requires detailed analysis specific to each utility and service territory, the initial data requirement is a reliable estimate of the load relief available from participating households.[2] In addition, planners need to know the magnitude of the energy use and the secondary peak created by the release of control, as air conditioners work to dissipate heat built up during the control period. For this reason, the impact analysis was designed primarily to address the following key questions.

- What air conditioner load reductions can be achieved during a control period?
- How does load relief differ across cycle/shed strategies?
- What are the post-control period paybacks in terms of demand (kW) and energy (kWh)?

Clearly, however, a full assessment of program impacts requires attention to other issues affecting both the net benefits realized at the time of control and the effects of the program on customers. These issues were addressed in a series of secondary analyses designed to address the questions noted below.

- How reliable were the control system and equipment?
- What discount is appropriate to account for free riders?
- How is customer comfort affected by various control options?
- Do customers use secondary appliances (fans, etc.) to mitigate their discomfort?

*Participation Modeling.* The participation of five utilities offering a variety of DLC programs with different cycle/shed strategies, incentives and promotional approaches provided an unusual opportunity for comparative analysis and possible enhancement of the marketing mix. An understanding of the results achieved by the different utilities could then be used to increase market penetration and perhaps load impacts as well. For conceptual ease, the researchable questions can be divided into those associated with the participation decision and those associated with load impacts. However, it may also be hypothesized that the self-selection inherent in the customer's decision to participate in a DLC program results in a necessary linkage between the two.

First, key questions relating to participation are indicated.

- Are certain promotional techniques differentially successful in creating awareness or participation?
- What characteristics distinguish program participants from nonparticipants?
- What other factors appear to influence the decision to participate?
- What factors determine a participant's choice of cycle/shed strategy (and associated incentive)?

Next, the complementary questions relating to differential load impacts among households are provided.

- How do characteristics of the air conditioner and the housing unit affect impacts?
- How do behavioral factors and customer characteristics influence load impacts?
- What are the roles of cycle/shed strategies and incentives on the impact levels?

The answers to the questions detailed in the previous section can provide utilities and regulators with important information regarding the value of DLC programs in Wisconsin and the overall benefits of different cycle/shed strategies. If such programs can be cost-effective, the answers to the questions set forth in this section can guide their targeting and promotion to those customers who are *most likely to participate and provide the load relief required,* thus decreasing program costs and increasing impacts.

## Methods

The following sections detail the methods for the impact evaluation and participation modeling projects, respectively.

### Impact Evaluation

The variation in utility program offerings presented significant challenges to the design of the impact evaluation plan. Sample design, data collection protocols and analysis methods had to be carefully developed given the anticipated amount of data to be collected and analyzed. The assumptions and rationale for each aspect of the impact evaluation (sample design, data collection, and analysis) are detailed in the following sections.

*Sample Design.* Determining sample sizes required establishing goals for precision, selecting the level of monitoring detail and setting forth reasonable assumptions for parameters such as equipment failure rates and customer dropout rates.

To establish required sample sizes, the steering committee members agreed upon goals for the precision of estimates of both control period impacts and post-control period paybacks. Targets of 90% ± 10% and 90% ± 15% were established for the impacts and paybacks, respectively.

Utilities had the capability of collecting monitored data at several levels of detail. Specifically, they installed a mix of multi-channel end-use meters, single-channel end-use meters and premise (whole house) meters. Each level has its own set of advantages and disadvantages relative to precision, expense, customer inconvenience and data validation characteristics. In general, of course, the precision of data collection is inversely related to cost. That is, a multi-channel site, with proper attention, will provide more detailed and precise information than a site using a standard billing meter to measure whole house energy use. However, the installation and maintenance costs for the multi-channel site will also be substantially greater.

Given the need for detailed information (indoor temperature and relative humidity) that was required to address several of the secondary objectives, the committee established a sample breakdown whereby the utilities would split half of the total sample between multi-channel and single-channel metering, and employ premise level metering for the remaining half of the sample.

Information from previous DLC impact evaluations, coupled with preliminary information provided by the participating utilities established the remaining sample design assumptions. These assumptions included anticipated equipment failure rates (10%), customer dropout rates (between 5% and 20%, depending on the control strategy), required control days (between six and nine, depending on the number of utility control options) and non-control days (between nine and fifteen, depending on the number of utility control options).

Model-based sampling methods were applied using the information provided above to design a random stratified sample for each utility. Customer billing data for the summer (June through September), house size, and control strategies were the stratification variables. The final sample contained a total of 745 monitored sites with more that 1300 points being monitored on either a 5- or 15-minute basis.

*Data Collection and Validation Protocols.* Collecting and processing this vast amount of data required that a rigorous process be adhered to, lest the data quality suffer. Incoming data were processed using a series of checks to verify completeness and accuracy. The checks ranged from simple missing data checks to range checks (e.g., do indoor temperature data remain within a reasonable range, 60°F to 90°F [15.6°C to 32.2°C]?) and relational checks (e.g., does air conditioner usage exceed whole house usage?).

*Analysis methods.* A variety of measures and indices was created from the available data.

*Control Impacts.* The Duty Cycle Approach (DCA) was used to estimate control impacts using data from non-control days. Given the air conditioner size, in terms of connected load (in kW), a duty cycle for a specified time interval is determined by the ratio of the average observed air conditioner load to the connected load. Thus, the duty cycle approximates the percentage of time that the air conditioner operates during the time interval considered.

The DCA is particularly well-suited to this analysis because DLC programs achieve demand reductions by altering the air conditioner's natural duty cycle. The effects of DLC are both direct and indirect. Implementation of a cycling strategy *directly* affects an air conditioner's duty cycle by limiting and scheduling its operation during the control period. Operation of the DLC strategy *indirectly* affects duty cycles by inducing changes in the intensity of air conditioner use after the control period; i.e., payback. For example, an air conditioner may run continuously for several hours after being cycled or shed, to remove heat that may have built up during the control period.

Duty cycle distributions were calculated for each monitored site. Connected loads were established either from air conditioner survey data or from data periods where the air conditioner ran continuously for several time intervals. It should be noted that determining air conditioner usage from the premise-level data required a series of additional steps. In simple terms, the process involved disaggregating the premise-level data into the major end-uses (e.g., air conditioner, electric water heater and dryer) using commercial software.

The load impacts were then computed by multiplying the connected loads by the restricted duty cycle, that is, the duty cycle allowed for each cycling strategy.

*Paybacks.* To calculate post-control period impacts, another primary objective, it was necessary to use control day information. The calculation of payback also requires an estimation of the air conditioner load that would have occurred on a control day had control not been implemented.

This non-control profile was estimated by first regressing the control period load (of non-control days) on weather data and the air conditioner load for the last time interval prior to control. The resulting model was then used to estimate the control period loads that would have occurred. The payback was then estimated by the difference between the control and non-control profiles.

*Discomfort Indices.* Several of the secondary analysis objectives made use of discomfort indices calculated from indoor temperature, relative humidity and thermostat status data collected at the multi-channel end-use sites. The equation used to calculate discomfort (Engle et al. 1983) is given below.

$$D = 49 + [0.4\,x\,(T-50) + g(H)] + [(H-10)/6]$$

where

D = Discomfort index
T = Temperature in degrees Fahrenheit
H = Percent relative humidity
g = Positive function of H, bounded by 1 and 2

*Free riders* were defined as those customers who provide little or no load reduction during control periods. Free riders were identified by calculating the average duty cycle for each customer between the hours of 1:00 p.m. and 6:00 p.m. on the extreme non-control days. Those customers whose average duty cycle was less than 20% were deemed free riders.

*Control equipment failures* were determined by establishing upper limits for duty cycles calculated during control periods. The upper limit was established as (100% - Cycling Percentage + 5%). For example, a 75% cycling strategy would have an acceptable upper limit of (100 -75 + 5)%, or 30%. Therefore, if an air conditioner subject to 75% cycling had an hourly duty cycle greater than 30% during any control period, an error flag was set.

*Secondary cooling appliances.* To detect the usage of secondary cooling appliances during the control period, the average residual profile (premise profile minus the primary air conditioner profile) of the most extreme non-control day was subtracted from the residual profile of the most extreme control day to obtain a difference profile. The presence of a significant difference profile tends to support the hypothesis that secondary cooling appliances are in use during the control period.

## Participation Modeling

The participation modeling effort consisted of two components: an analysis of factors associated with the customer's decision to participate in a utility DLC program and an analysis of factors related to the premise-level load impact obtained from a participant. The first of these efforts required additional data about the demographics, life styles and attitudes of participating customers and about the characteristics of their homes—as well as the incentive received and the cycle/shed strategy accepted. Moreover, these efforts required comparable background information about a random sample of nonparticipating customers. The latter model required merging the appropriate data for participants with information about the load relief obtained from them and their free ridership status.

To meet the background information needs in a consistent manner, the steering committee worked with a contractor to develop a standard survey protocol.[3] This was included in each utility's individual process and market studies. Each utility participating in this portion of the program then collected the appropriate data from participant and nonparticipant samples, and provided the results for further analysis.[4] In total, data for 1666 participants and 1305 nonparticipants were available for the decision modeling. Because no impact data were required, these analyses were conducted on the 1992 program participants.

The background data set included information regarding the customer's home (square footage, ownership, duplex or single family home, air conditioner vintage), household demographics (income, number of people home during summer weekdays), life style (according to EPRI's needs-based segmentation), reported behavior (had air conditioner tuned or serviced in last year, added insulation, caulking, etc. to home in last two years), and perceptions and attitudes (overall comfort level of the home, how quickly the house would get hot without central air conditioning, would/did have to change the household routine to participate, have an obligation to save energy during peak periods, consider self an environmental activist). Other available information covered the customer's utility, awareness of DLC programs and, for participants, the incentive and cycle/shed strategy selected.

The load impact model analysis was restricted to participating customers who were end-use metered in 1993 and for whom matching background data were readily available. Data from a total of 348 customers were included in this effort.

## Results

The results of the projects are also described separately for the impact evaluation and the participation modeling efforts.

### Impact Evaluation

Overall, the results indicate that DLC programs can provide Wisconsin utilities with significant load relief at a cost-effective level. The specific benefits and costs, however, will depend upon the avoided costs and system characteristics of individual utilities, as well as the control strategies selected and program costs incurred. The following points are focused on the results that are evident at a statewide level.

- Load reductions varied by utility and by strategy. For comparative purposes, the optimal DLC impacts[5] (kW reduction per participant) on the peak days are shown in Table 2.

**Table 2**. Load Relief Impacts for Selected Control Strategies

| Control Strategy | Impact Range |
|---|---|
| 100% (Shed) | 1.8 to 2.1 kW |
| 75% | 1.6 kW |
| 67% | 1.0 to 1.1 kW |
| 50% | 0.5 to 1.0 kW |

The variation by utility may be related to underlying differences in usage, reflecting either microclimate differences or different customer characteristics. The data show that peak residential cooling loads typically occur in late afternoon (after 4:00 p.m.) and early evening (before 8:00 p.m.). However, certain utilities have a relatively flat load profile during peak times while others have a more pronounced peak use period.

- As expected, the post-control period demand (kW) paybacks were directly related to the severity of the control strategy. That is, shed strategies were associated with significantly larger demand paybacks than the cycling strategies.

- The post-control period energy (kWh) paybacks were negligible. Loads that had built up during control periods were removed shortly after control ended. Very little free-cooling (i.e., a situation where the home is warmer than the ambient temperature and therefore "loses" heat to the outside) was evident.

- Results of the customer comfort analyses were mixed. Some comparisons between control and non-control days were not statistically significant at a 90% confidence level and suggest the need for further investigation.

- Initial analysis suggests that humidity levels react more quickly than temperatures under the various control strategies. Further investigation and quantification of this phenomenon appears warranted.

- The residual differences used to detect the use of secondary appliances did not identify any statistically significant increase in use, on average, at the 90% confidence level.

- Free rider percentages varied across utilities from a low of 7% to a high of 32%. The 32% figure is somewhat misleading given that the individual utility offered a single control option, 50%, and their control days were relatively mild in comparison to the other utilities.

- Equipment/signal failure rates ranged from a low of 10% to a high of 14%. These rates include instances where the air conditioner was controlled with the wrong strategy (e. g., cycled when it should have been shed), the control signal was not received by the switch due to signal coverage and switch failures. Instances of switch failure were rare.

### Participation Modeling

As indicated earlier, the discussion of customer-level results may be simplified by addressing the decision to participate in a DLC program separately from the premise-level load impacts.

*The Decision to Participate.* The customer's participation in a particular utility DLC program can be conceptualized in the form of the tree shown in Figure 3. First the customer must be aware of the program offerings; next, must be willing to consider participation, and must opt for a specific program with the associated cycle/shed strategy and incentives.

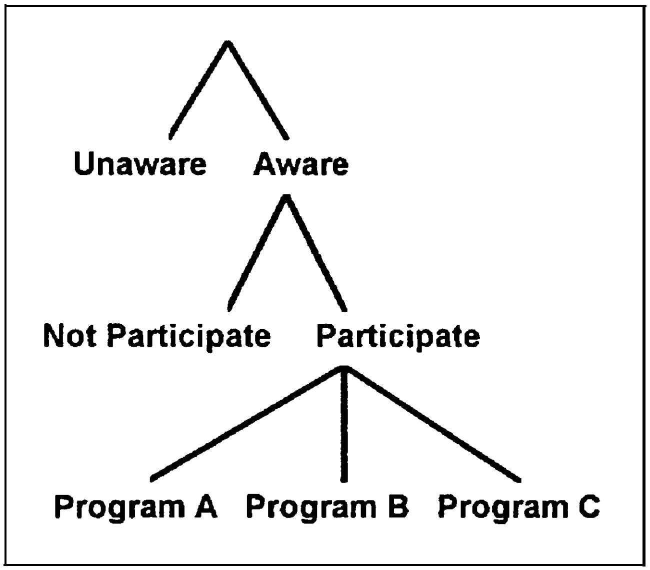


**Figure 3.** Hypothetical DLC Participation Decision Tree

This conceptualization led to the selection of a sequence of models. First, awareness of utility DLC program offerings was modeled logistically. Next, a nested logit model was developed to describe the participation decision and, given a positive decision, the selection of a specific program. [6]

*Awareness.* The awareness model was estimated across nonparticipants only; otherwise the unaware segment would have comprised only 15% of the sample. Indeed, among the nonparticipant sample, 64% reported program awareness, suggesting a relatively effective promotional campaign by the utilities.

The results for the demographics and life style variables studied indicate that awareness tends to be higher among unmarried customers and lower among those in households where no one is likely to be home during the day. The results also indicate that awareness is higher among customers who depend upon their air conditioners to keep cool. It appears that the participating utilities have been reaching customers who are likely to use their air conditioners at peak times. Although significantly enhanced promotional efforts might result in higher levels of population awareness, they might also stimulate increased free ridership.

*Participation.* The model discussed below omits customers who were unaware of the utility DLC programs: This restriction minimizes confusion between simple lack of awareness and a more or less informed decision not to participate in a program.

The availability of an incentive is a factor in customer decisions to participate, as is a feeling of personal responsibility for helping to save energy during peak periods, perceiving oneself as an environmental activist, home ownership, the number of people home on summer weekdays, *or* the unlikelihood of anyone being home. In addition, certain life style segments—Lifestyle Simplifiers, Appearance Conscious, and Resource Conservers (EPRI, 1989)–are more likely than others to sign up.

Those who are less likely to participate in DLC programs include customers who believe their homes will get uncomfortably hot or that participation will affect their household routines. Somewhat surprisingly, participation is also lower for those who report servicing or cleaning their air conditioners recently or having engaged in other shell conservation upgrades in the last two years. (Perhaps this reflects the customer's sense of having already done his or her share, or a desire to reap the rewards of a prior investment.)

These results provide guidance as to the groups from which the current set of participants are drawn. Additional analysis is required to determine whether promotional messages, program redesign or other incentives can be developed to increase the participation of segments that are underrepresented in the programs, or whether it is more cost-effective to target market even more narrowly those segments that do participate.

*Program selection.* Attempts were also made to model the choice by a participating customer among the specific cycle/shed options and incentives offered by his or her utility. Although the resulting models suggest several variables of interest for further study, the models were unsuccessful as predictors of program choice. Rather, they tend to assign every customer to the most popular option.

Several explanations of this result may be advanced: (1) the models offered fail to include the critical factors used by customers to decide among their options; (2) customers do not have any well-defined criteria for making their choice (3) utility-supplied program descriptions cover the features of the different programs without connecting these to understandable benefits customers can use to make their selection. Further exploration of these hypotheses would appear warranted.

*Premise-level Load Impacts.* Two additional models were developed from combining the matched impact data and background data. The first relates the maximum half-hour load relief to cycle/shed strategy, physical characteristics of the home and the air conditioner, demographics, life style, and the participation-decision model. To assist in netting out load impacts, the second model is designed to focus on the identification of free riders from demographic and household characteristics.

*Load relief* As would be expected, load relief is greater when the CTHI is higher. Moreover, it is positively related to more severe cycle/shed strategies, greater connected loads, and larger homes. Older air conditioners also provide greater load impacts than those that are newer.

However, *none* of the other demographic, life style, or attitudinal variables appears to be a significant factor in predicting premise-level load impacts. Moreover, the correction for self-selection into the participant sample is itself a nonsignificant contributor to the prediction of load relief. It appears that once a customer has agreed to participate in a DLC program, the resulting load impact is strictly a function of the physical characteristics of the home, the air conditioner and the program design—engineering estimates do not require significant behavioral corrections. In turn, this result, coupled with the conclusions in the previous section, suggests that targeting efforts should be directed at underrepresented segments, because any non-free rider participant with significant connected load will provide useful load impacts.

*Free riders.* The impact analyses, above, provide an estimate of free ridership rates that allows adjustment of the gross impacts. The model described here identifies factors associated with individual free ridership that may be useful in target marketing.

Demographically, free riders tend to be unmarried and to have lower incomes than other participants. They are more likely than others to have dehumidifiers in the home (and perhaps, then, to rely on those units rather than air conditioners for maintaining their comfort in hot weather). Finally, they appear to sign up for more stringent cycle/shed strategies than other participants (which, given their relatively lower reported incomes, suggests both a clear interest in the incentives as such and a prior awareness that they will not be personally inconvenienced).

## Discussions

In this section we focus on three broad issues relating to target marketing and implementation.

Among the more interesting aspects of the results is the lack of support for the role of demographic and life style factors in DLC impacts. We did *not* find, first of all, that attitudes toward conservation predicted load relief, at least among the groups studied and given the promotional messages considered. Moreover, we did not find that the self-selection that is involved in program participation decisions affects the impacts achieved.

We emphasize that these findings apply with confidence only to the programs studied. It is certainly possible that under less appealing incentive structures or cycling strategies, or with more environmentally-oriented promotional messages, demographic or life style difference would become more important. In the present case, however, they were not.

Evaluators may take comfort in being able to rely upon engineering estimates for customers who do voluntarily participate in programs under conditions like those studied. The range of uncertainties that must be assessed appear to be considerably less daunting than might be imagined.

We might raise the question as to *why* demographic and life style differences appear not to have much effect in this study. The answers must be rather speculative, however, given the lack of data against which we can test them.

The results do suggest that Wisconsin utilities target customers according to engineering parameters. In particular, they should target customers with larger homes and older air conditioning units—those that are most likely to have large connected loads. The utilities should be careful about enrolling single householders in rental units in such programs, however.

Our results also suggest that the most immediate practical problem to achieving greater load relief are the higher than expected equipment/signal failure rates. Wisconsin utilities are attempting to minimize these rates by:

- Conducting switch audits to identify both equipment failures and signal coverage problems
- Improving signal coverage by adding new transmitting facilities and using new technologies, such as paging systems

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solely the responsibility of the authors, however, and do not necessarily reflect the views or policies of any affiliated committee member or company.

## Endnotes

1. Cooperation in areas of mutual interest did not preclude individual utilities from conducting their own evaluations on topics of specific concern.

2. We conducted a meta analysis of residential DLC program evaluation reports (WCDSR, 1994). Although extremely valuable, this report indicates the need for region specific assessments of DLC impacts.

3. We thank HBRS for their assistance in this portion of the project.

4. For various design and cost reasons one utility did not participate in this portion of the project. Moreover, program design differences limited the use of one utility's data in several of the analyses described below.

5. Optimal DLC impacts refer to the load relief potential without equipment/signal failures included.

6. Because each utility offered a different set of options, the modeling at this level was utility-specific.

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