CUSTOMER VALUE OF SERVICE, SHORTAGE COSTS, AND DEMAND-SIDE MANAGEMENT PROGRAM DESIGN

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In the last decade, Demand-Side Management (DSM) has offered utilities a nontraditional planning option focused on deliberately changing the load shape to improve electricity system efficiency. Traditionally, DSM programs such as conservation, load management, and time-of-use (TOU), have been designed based on marginal costs derived from utility resource plans. Customers volunteered for these programs based on individual determination of the worth of electric service during particular hours and seasons. However, the programs were designed to influence customer use of energy according to utility needs for load relief and not according to customer preferences. An emerging approach takes a somewhat different path. Through the use of a customer survey which allows customers to reveal their value-of-service (VOS) for a variety of service reliability options, DSM programs may be designed to fit particular needs and desires of individual customers. In 1983 Pacific Gas and Electric Company initiated its Value-of-Service study to gather outage cost estimates of the four major customer classes (residential, commercial, industrial, and agricultural) with the intent to use this information in value-based planning. Those outage cost estimates are shown and the study methodology is discussed.

One way to design a DSM program is to set the incentive equal to the customer's value of the interrupted electric service. VOS enables a utility to segment the market in order to design and target incentives specifically for those customers whose valuation of outage cost is lowest. Two approaches which incorporate VOS concepts are interruptible or curtailable incentives and self-supporting TOU rates. The first of these two pays customers incentives to reduce load on request. Customers participate if they perceive the incentive to be at least as great as the inconvenience and monetary losses resulting from the interruption. The second is a further refinement: self-supporting TOU rates allow customers to reveal their implicit VOS. These rates entail the customer bearing the costs of a special meter in exchange for the opportunity to realize bill savings by modifying energy usage. Both approaches match incentives and participant costs, thereby realizing the goal of stable DSM designs because they correspond to customer value.

Although these two approaches apply the concept of setting incentives equal to the customer's outage costs, accurate estimates of these costs can only be obtained through further VOS research. The ultimate goal of this research is to replace the traditional engineering standards used by utilities with estimates of actual customer outage costs. Utilities may then more explicitly link the design of DSM incentives to customer preferences and costs.

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INTRODUCTION

In the last decade, demand-side management (DSM) has offered utilities a nontraditional planning option focused on deliberately changing the load shape to improve effective utilization of power generation resources. DSM includes both conservation and load management, although this paper will focus solely on load management options. The dual goal of DSM is to change the utility's load, usually by shifting demand away from expensive on-peak generation, and to offer customers an opportunity to moderate energy bills. The incentive structures of these programs have been, in most cases, based on marginal costs of capacity and energy derived from utility resource plans. Hence, the programs were designed to influence customer usage of energy according to utility needs for load relief and not according to customer preferences. However, customers volunteered for these programs based on their individual determinations of the worth of electric service during particular hours and seasons. Thus, an emerging alternative approach in the design of DSM programs is to link utility and customer preferences more explicitly. Specifically, the use of a customer survey will allow customers to reveal their value-of-service (VOS) for a variety of service reliability options. VOS research is the study of individual customer preferences and perceptions of the worth or value of alternative service options. Estimates derived from VOS studies may be used to design DSM programs to fit the needs and desires of individual customers based on their cost of sustaining an electric service interruption.

OVERVIEW OF THE TRADITIONAL LOAD MANAGEMENT INCENTIVE DESIGN

Marginal cost is defined by economists as the change in a firm's total costs resulting from an incremental change in output. In the case of a utility, the marginal cost is the incremental cost of producing (or reducing) one additional kW or kWh of electricity or therm of gas. Marginal costs only include those costs which do or would hypothetically change because of production; they exclude the value of past expenditures, called embedded costs. Marginal costs also reflect the changes in the availability of resources. This change in turn, provides a price signal to the customer of the cost of consuming energy. Incentive design for DSM, specifically for LM programs, has been based on marginal costs to the utility or ratepayer because this price signal encourages customers to use energy efficiently and provides them with information with which to make better decisions regarding whether or not to invest in technologies to alter their pattern and/or magnitude of energy consumption.

Electric marginal cost is composed of three components: energy-, capacity-, and customer-related costs. In the design of DSM programs, the first two components are most important. Marginal energy costs reflect the change in total costs incurred due to an incremental change in energy production. These costs typically include fuel and variable operations and maintenance expenses. Marginal capacity costs reflect the change in total costs incurred to serve an incremental change in demand. One method of calculating marginal capacity costs is to use the cost of a "perfect" resource addition -- such as a gas turbine. The gas turbine proxy is used by PGandE because when PGandE's system is operating under peak conditions, the demand for one additional kW of power is likely to be served by gas turbines. Since the gas turbine has relatively high operating cost but low capital costs, these units are used almost exclusively to provide peaking capacity and reliability.

The shortcoming of this approach is in deriving the true cost of capacity. In essence, marginal capacity cost should represent the value of system reliability -- the value a customer places on having a particular amount of capacity available in the event of a service interruption. This interpretation of capacity is often called the "shortage cost" methodology. Under the shortage cost, the gas turbine proxy <u>at best</u> represents only an approximation of the customers' preference for <u>marginal</u> changes in reliability; "at best" because it is assumed that a customer would both want the additional kW of capacity and be willing to pay for it. Therefore, the cost of one kW of capacity provided by a gas turbine is used to <u>approximate</u> the maximum amount a customer would pay to increase generating capacity by one unit.

Moreover, the gas turbine proxy includes an implicit utility preference for a particular level of overall system reliability for which the customer must also pay. First, the need for a gas turbine is defined based on the engineering standard of a loss of load probability (LOLP) of once-in-10 years. Second, while the cost of a gas turbine is fairly stable over time, the contribution that it makes to system reliability may vary substantially. To represent this variation, PGandE uses a "reliability adjustment factor" (RAF) calculated for each year of the planning horizon. The RAF is less than one when PGandE's system is more reliable than the LOLP generation reliability criterion requires, and is greater than one when the system is less reliable than standards dictate. Thus, when DSM program incentives for capacity are based on a gas turbine proxy, the amount of DSM that is encouraged is consistent with a traditional engineering determination of optimal reliability. While this method of incentive design appears on the surface to be in the economic interest of the utility, ratepayers, and society, it may bear little or no relationship to society's preference for reliability in general or for DSM as a curative to unreliability.

VALUE-BASED PLANNING

Because the gas turbine is only a proxy for customer value, direct estimates of value perceived by customers would be useful for designing DSM program structures. Specifically, these estimates would be used to design the structure of DSM programs which could successfully meet the goals of utility load shaping and correspond to customer value: the type of programs offered, and the amount and method of incentive payment. In addition, the availability of direct estimates would also enable the design of specific DSM options targeted toward particular groups of customers based on their preferences. Such preferences are usually based on the customer's ability to mitigate their specific difficulties resulting from power outages. For example, in many types of manufacturing, the costs associated with an outage, such as materials spoilage, lost production time, and overtime wage differentials, are not extremely high. However, for many of the Silicon Valley electronic industries, any outage is often quite expensive due to the nature of the production technology; the Silicon Valley industries would not be able to maintain production in an environment of frequent outages or low reliability without investing in instantaneous backup generation. Thus, value-based planning requires detailed information on the cost of an outage and the value of reliable service for customers of different classes, consumption patterns, and preferences.

VALUE OF SERVICE STUDY

In 1983, PGandE initiated its Value of Service Study to gather information to be used in value-based planning. The two primary study questions were:

(1) What is the value of reliability to customers as determined through outage costs?

(2) What are customer preferences for various options in service levels?

To measure a respondent's perceptions and preferences, PGandE used the technique of hybrid-conjoint analysis. This technique allowed researchers to quantify how consumers trade off some of one attribute of reliability to obtain more of another. Additionally, it revealed how customers value various levels of a single attribute. Customers' preferences for alternative electric service options were determined by the aggregation of responses to successive trade-off choices.

The survey was designed to allow customers to choose among various combinations of electric service outage attributes for <u>both</u> full and partial outages. The attributes of an outage include frequency, duration, notice, timing, costs including inconvenience, among others. The sampling design was based on classes of service. Of the four major customer classes: residential, commercial, industrial, and agricultural; the latter three were also segmented by usage levels, business type, and appliance saturation groups during the analysis. All the sampling plans, including those for the residential class, used annual kilowatt-hour usage as the principal stratification variable. The survey instrument was based on situations of hypothetical electric outages. The technique of posing hypothetical questions allowed for variance in all of the attributes of reliability, such as duration. Thus, it was possible to determine how customers would respond to various changes and to assess the value of each change.

The survey instrument contained sections relating to full and partial outages for residential customers and an additional outage cost worksheet for commercial, industrial, and agricultural customers. All customers were mailed materials prior to the main telephone interview. Respondents from all four customer classes evaluated the cost of full outages (system reliability options) and indicated how their household or business would be affected by each of combinations of attributes represented in the hypothetical situation questions. Each respondent evaluated the base case consisting of: two outages per year, for an average of one hour each with no advance warning and occurring on a winter weekday morning at 10:00 a.m., and eight additional scenarios. While each individual respondent evaluated only nine options, there were 64 options in total which were tested by randomly varying the eight additional scenarios. Examples of the options evaluated and the base case attribute levels are illustrated in Table I.

Figure 1 summarizes customer responses to the outage characteristic options. The pie charts show relative importance, or trade-offs, of the different aspects of electric service outages by customer class. The top two charts show that residential customers consider the size of their bills and the reliability of their service of about equal importance, while commercial customers considered reliability almost four times as important as the size of their bills. Only agricultural customers are concerned with the time of year that service interruptions occur; not surprising, given the high electrical usage for irrigation pumping during the rainless California summers. Industrial and commercial customers are significantly more concerned about the time of day and the day of the week.

Respondents also evaluated nine option cards for partial outages. The value of partial outage costs were determined by assigning points -- a non-technical term for percentage of load reduction -- to each of the residential respondents' appliances proportional to their demand during an interruption period. These assignments were based on an inventory of the respondent's electric appliances collected during the interview and rated according to the point of values of low, moderate or high kW usage. The validity of these partial outage cost estimates has not yet been evaluated and so are not shown.

In addition to the trade-off exercise, the nonresidential customers were asked to estimate directly how much a power outage on a specific day-type and of a specific duration would cost them using a worksheet enclosed with the survey. With this, respondents estimated the value of their service or outage costs under the existing level of system reliability prior to receiving the interviewer's call. Compiling the firm's outage cost included the impact of lost sales or production, idled workers, materials spoilage, cost of repairs and replacements, and the cost of restarts.

Over 1,400 interviews were completed: 484 among residential customers, 532 among commercial, 305 among industrial, and 103 among agricultural customers. Table II displays the estimated outage cost by service class.

Several observations about these findings should be made. First, the large difference between the average estimates outage cost for residential and non-residential customers indicates that there is a market for future DSM programs within the residential class. However, the reduced costs of employing residential customers to obtain utility load relief, for example, would be constrained by the mechanics of designing a program which provided sufficient relief for the utility from an aggregation of very small customers. Second, and perhaps more practical, the wide range of outage costs within the non-residential classes indicates that there are subgroups of customers with low outage costs who could be targeted for specific DSM programs which would not require large incentives. Further, those customers with high outage costs might be candidates for a premium service program which would provide electric service which is more reliable than the current service level.

The wide diversity of outage costs displayed in Table II indicates that various customers have very different preferences for reliability. By recognizing customer preferences, the utility can design incentive structures which correspond to the needs of particular subgroups of customers and their willingness-to-pay for either increased or decreased reliability. This type of information is needed to tailor specific rate designs to individual classes of customers. For example, the survey findings also provide very specific information such as the time of day particular customers are likely to accept interruptions of certain lengths in exchange for bill discounts of a particular magnitude. In this way, DSM programs may be targeted to subclasses of customers and financial incentives may be designed to correspond very closely to what those customers are willing to receive in exchange for the interruption.

VALIDITY OF THE ESTIMATES

The outage cost estimates derived from the PGandE survey exceed previous utility estimates. This is primarily due to the following factors:

- PGandE's market research method;
- The derivation of dollar per kilowatt-hour figures from individual customer data;
- The derivation of previous industry estimates from the decades of the 1960s and 1970s when appliance mix, equipment types, energy intensive technologies, conservation attitudes and energy prices were different from today; and
- The fact that other estimates were made on the basis of dollar-per-kilowatt-hour of energy consumed rather than dollar-per-kilowatt-hour of energy unserved.

As a way of evaluating the validity of the outage cost estimates, the data for the residential class was used to re-estimate outage costs using the multinomial logit model as an alternative estimation technique. This analysis showed that the outage cost estimates are highly sensitive to the model specification. This result is due, in part, to the design of the survey instrument. Consequently, PGandE is undertaking another VOS survey of the residential class. The new survey uses a different survey instrument which focus groups and pretest results indicate is more easily understood and completed by the respondents. Preliminary results are anticipated late in the summer of 1986 and final results will be available in early 1987.

The direct estimates for the non-residential class are considered to be more reliable than the indirect estimates for the residential class because they are based on the survey worksheets. Since respondents were asked to itemize their costs due to an outage, there was less potential for confusion and thus, inaccurate response.

Overall, while PGandE questions the actual magnitude of the values obtained for some of the classes and/or the range of outage costs within each class, the results are a good start. They do provide specific information about the diversity of customer's valuation of reliability and offer, at the very least, information about the relative value of reliability within each customer class. Further research to estimate customer outage costs will continue to be built on this initial study.

METHODOLOGICAL ISSUES

The PGandE value of service study and others like it provide a promising beginning for a new methodology which may be used, among other purposes, to design DSM programs and incentives. Outage cost estimates provide an alternative to the current design based on marginal costs and 1-in-10 year LOLP engineering standards. To pursue value-based DSM design, further research in this field is necessary. Immediate application of the PGandE findings have been delayed by two factors which we are currently working to resolve. The first hindrance is that the results may not be accurate for all customers and classes. Reliable estimates are difficult to obtain for two reasons. First, the customer is unaccustomed to thinking of electricity as a product, especially the residential customer. Rather, the customer often associates the cost of electricity with its end uses. Thus, it may be quite difficult for them to estimate how much a hypothetical outage with specific characteristics would cost them. Second, there is the issue of "moral hazard": the possibility that the customer does not accurately represent the true outage cost to influence the utility's behavior in the respondent's favor. This is perhaps most likely to exist, if it does at all, within the nonresidential class where customers may have a better understanding of electricity pricing.

Further, there is the difficulty of resolving the fact that the VOS capacity cost estimates are considerably lower than those derived from the gas turbine proxy. This result occurs because, under existing system reliability, the chance of an outage is slight; since the cost of a gas turbine is allocated across the few hours it is needed, the outage cost derived is much more expensive than the estimates derived from the VOS. This result seriously calls into question the future suitability of the 1-in-10 LOLP criterion. Moreover, it suggests that DSM incentive designs should undergo radical changes to accommodate the customer's VOS -- once it is accurately estimated. Thus, once again we are in the breach: translating economic theory into policy and program designs which are practical to implement.

PGandE is currently developing the methodology to utilize the VOS survey results for two DSM programs: interruptible and curtailable rates and self-supporting TOU rates. Although specific details are not yet available, the following discussion describes the manner in which the outage cost estimate will be applied to program design and the establishment of incentive levels.

INTERRUPTIBLE OR CURTAILABLE INCENTIVE DESIGN

Load management employs both curtailable and interruptible options to obtain load relief during critical peak hours. This is accomplished by paying customers incentives to reduce load upon request. Customers participate in one of these projects if they perceive the incentive to be at least as great as the inconvenience and monetary losses resulting from the interruption or curtailment.

This current approach is not optimal because the incentive design is not directly based on both the customer's cost of an outage and the utility's capacity costs, but only the latter. Ideally, these incentives should be designed using the customer's VOS as a function of the number of expected interruptions. Although this method will result in incentives that vary from year to year, they will be more acceptable to customers since the variation will reflect the changes in the participant's outage costs. More importantly, by using VOS estimates it is possible to segment the market beyond traditional customer classes. Incentives may then be designed and targeted specifically for those customers whose valuation of outage costs are lowest.

SELF-SUPPORTING TIME-OF-USE (TOU) RATES

Yet another approach to DSM incentive design which incorporates customer value is self-supporting TOU rates. These rates are a further refinement of interruptible and curtailable DSM designs. Rather than recruit participants by designing incentives which are targeted to those customers with the lowest valuation of outage costs, self-supporting TOU rates allow participants to reveal their implicit value of service. Self-supporting TOU rates entail the customer bearing the cost of a special meter in exchange for the opportunity to realize bill savings. These rates are designed such that they closely track utility costs throughout the day and year. The customers who could benefit from such a program are those who already use little on-peak electricity and those who can change their consumption pattern. Although there are no utility-imposed penalties for use of electricity during the expensive on-peak hours, the cost of the special meter acts as an incentive for rational customer choice. That is, the incentive to shift is generated not only by the differential in the cost of electricity at particular hours but also by the need to recover the investment in the meter, and not at all by altruism. Thus, this method implies that the participant evaluates the difference between the cost of altering consumption patterns and the cost of using electricity during the expensive hours.

In theory, the cost of altering consumption patterns should be equivalent to the cost of an interruption of some or all of the customer's appliances plus the cost of the meter. This self-induced outage only occurs if the bill savings are greater than the monetary losses and inconvenience of shifting consumption away from expensive hours.

CONCLUSION

DSM programs provide an important service to the customer by offering options to reduce the cost of energy, and to the utility by changing the demand for on-peak energy. Recognizing that a customer's value-of-service may not equal the utility's cost of providing an additional kW of capacity, is paramount to the successful future of DSM programs. Past DSM programs have not been based on an evaluation of customer outage costs and, as such, it is likely that participants were either overpaid for load changes or offered insufficient incentives to join the programs. Further, it was not possible to design programs which were targeted to those customers with the lowest outage costs. Although the two approaches presented utilize the concept of setting incentives equal to the customer's outage cost, accurate estimates of these costs can only be obtained through further VOS research.

We must recall that the results of additional research will be applicable to far more than just DSM program and incentive design. VOS estimates can be useful in a wide range of utility planning areas beyond designing DSM programs and incentive levels; they can be used to design a cost-based interruption strategy in the event of system disturbance or to establish levels of system reliability and reserve margins. In fact, PGandE is currently using the 1983 VOS survey results to design and propose an alternative method of calculating reserve margins. These are all areas where quantitative standards and engineering estimates are currently utilized, much could be gained by developing methodologies which better incorporate the value customers place on the availability and reliability of electric system services and resources. The ultimate goal of this research is to replace the gas turbine proxy estimates of capacity costs with estimates of actual customer outage costs. The utility may thereby more explicitly link the design of DSM incentives to customer preferences and costs.

REFERENCES

Pacific Gas and Electric Company, 1987 Test Year Load Management Supplemental Exhibit (PG&E-13A), Application No. 85-12-050, San Francisco, CA.

Robinson Associates, Inc., The Value of Service Customer Survey: Final Report, prepared for Pacific Gas and Electric Company, Bryn Mawr, PA., March 1985.

TABLE I

EXAMPLES OF PGandE VALUE OF SERVICE SURVEY OPTIONS[1/]

Characteristics	Option 1[2/]	Option 2	Option 3	Option 4
Frequency	2 outages per year	12 outages per year	1 outage every 2 years	4 outages per year
Average Length	1 hour	4 hours	30 minutes	8 hours
Advance Notice	none	1 hour	10 minutes	4 hours
Season	winter	summer	winter	summer
Day of Week	weekday	weekday	weekend	weekday
Time of Day	10:00 a.m.	6:00 p.m.	3:00 p.m.	12 noon
Monthly Electric Bill	Current Bill	25% lower	40% higher	10% lower

1/ Each customer evaluated eight options in addition to the base case (option 1) but there were actually 64 options tested by the total population.

2/ Option 1 describes the current reliability characteristics of the PGandE system which was used as the base case for this analysis.

Robinson Associates, Inc., The Value of Service Customer Survey: Final Report, prepared for Pacific Gas and Electric Company, Bryn Mawr, PA., March 1985, page 38.

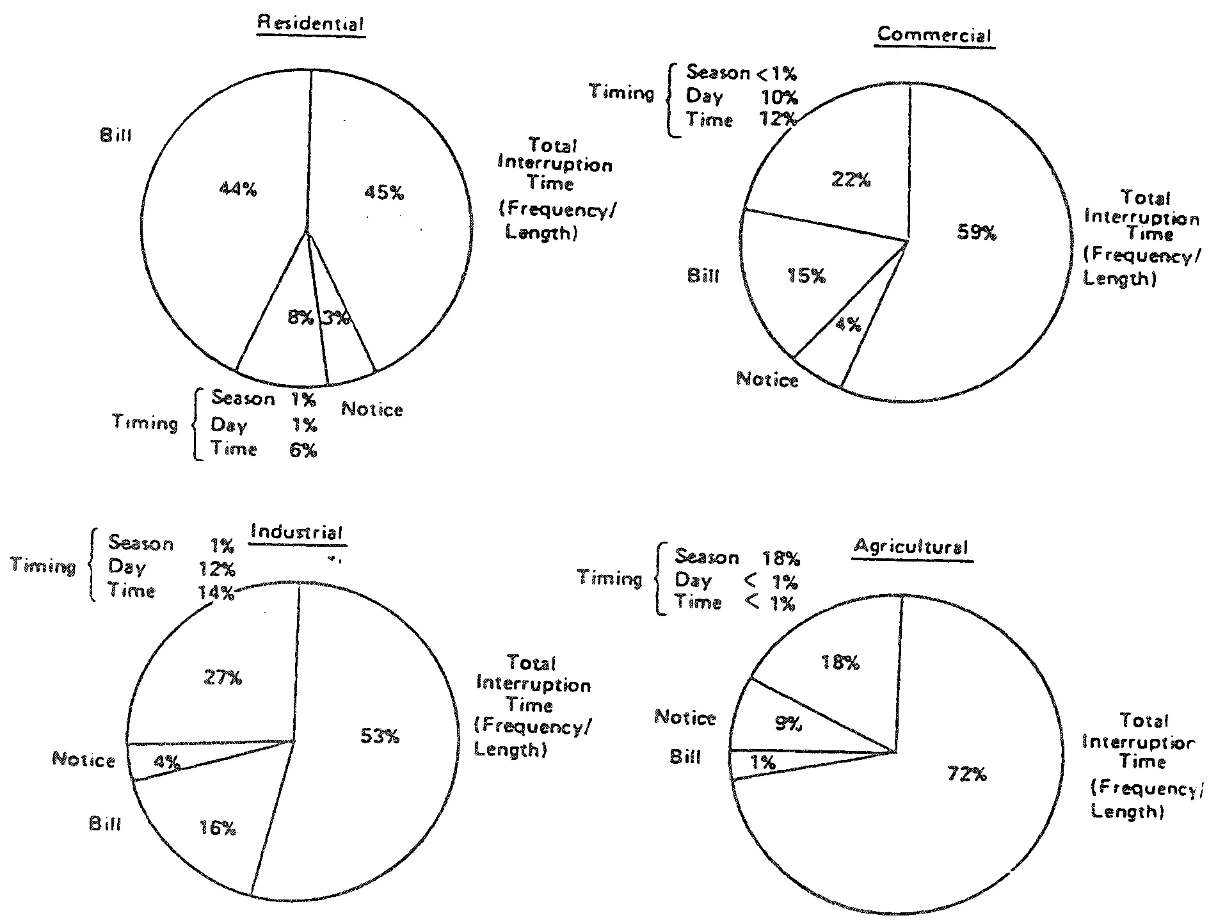
TABLE II
ESTIMATED FULL OUTAGE COSTS BY CLASS

($ per kWh interrupted)

	Average Cost	Median Cost	Range
Residential	10	-	-
Commercial	89	29	1 - 954
Industrial	78	81	2 - 2,360
Agricultural	75	3	0 - 723

Robinson Associates, Inc., The Value of Service Customer Survey: Final Report, prepared for Pacific Gas and Electric Company, Bryn Mawr, PA., March 1985, page 38.

FIGURE 1
RELATIVE IMPORTANCE OF SERVICE CHARACTERISTICS



Robinson Associates, Inc., The Value of Service Customer Survey: Final Report, prepared for Pacific Gas and Electric Company, Bryn Mawr, PA., March 1985, page 38.