

**AN ANALYSIS OF THE FINANCIAL INCENTIVES IMPACT ON
THE UTILITY DEMAND-SIDE MANAGEMENT PROGRAMS**

by

Andhika Prastawa

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APPROVED:

on July 10th, 1998 by

Prof. Saifur Rahman, Chairman

Dr. Yilu Liu, Member

Dr. Lamine M. Mili, Member

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Andhika Prastawa

Saifur Rahman, Chairman

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(ABSTRACT)

Many utilities implement the financial incentive plans in promoting their Demand-Side Management (DSM) programs. The plans are intended to reduce the customer investment cost for a high efficiency equipment option, so that to make the investment more attractive. Despite its potential to increase customer participation, the financial incentives could cause a considerable increase in program cost to the utility.

An analysis of financial incentive impact on the utility DSM program is conducted in this thesis. The analysis uses the combination of the customer participation modeling and the cost-benefit analysis of a DSM program. A modeling of customer participation by a discrete choice model is presented. The model uses the logistic probability functions. The benefit and cost of DSM programs are explored to develop the analysis methodology. Two typical energy conservation options of DSM programs are taken for case studies to demonstrate the analysis. The analysis is also conducted to see the effect of financial incentives on the performance of DSM programs in a fluctuating marginal energy cost. The result of this research shows that the financial incentive could induce the customer participation, thus provide an increase of benefit and costs. However, this research also reveals that, in certain circumstances, the financial incentive may result in a decrease of net benefit due to significant increase of cost. These imply that utilities must carefully evaluate the financial incentive plan in their DSM programs, before the programs are implemented.

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Chapter 1

Introduction

An increasing number of utilities all over the world devote a significant portion of their resources to demand-side management (DSM) programs designed to reduce their customers' electricity consumption. DSM activity is a program used by a utility, which directly or indirectly encourages its customers to change their energy consumption pattern so a utility-desired pattern is achieved. The activity is intended to benefit both the utilities as well as the customer. Successful DSM programs provide equal or better energy services and do so at a lower cost.

The effectiveness of utility DSM programs ultimately depends on the customer participation. The concept of DSM implies a utility-customer relationship that produces mutually beneficial results. Yet, customers and utilities can act independently to alter the pattern of demand. Therefore, to achieve those mutual benefits, a utility must carefully consider such factors as the manner in which the activity will affect the utility's load shape, the methods available for obtaining customer participation, and the likely magnitudes of costs and benefits to both utility and customer.

Customer participation in utility DSM programs is voluntary, implying that participant must expect a positive net benefit. To promote the DSM programs, it is important to identify and evaluate the customer characteristics. These include the customers' demographics, knowledge, awareness, attitude, and motivation toward energy conservation. In addition to these characteristics, there are several factors that could influence customers' decision to participate, such as economic condition, energy prices, technology, technology cost, regulation and tax. By recognizing the most prominent characteristics, the utility can determine an appropriate method to promote the programs.

One approach to promoting a DSM program is analyzing the decision to participate based on the aspect of the overall economic benefit to the customer. Even though economics may not be the most important driving force in customer participation, it is always a determining factor. In particular, the investment of energy-efficient technology and the resulting monetary saving to the customer are prominent aspects in the economics factor.

Utility financial incentives in DSM program promotion are intended to overcome the economic aspect barriers on customer participation. Ideally, these incentives would limit the high investment cost and long payback period of investment. Utilities generally offer financial incentives in the form of direct rebate or free installation service for an energy-efficient technology. Direct rebates reduce the initial investment for equipment purchase, or reduce the payback period to make the investment more attractive. Lower initial investment requirements or shorter payback periods may induce more customers to participate the program. However, as the number of participants increase, the utility expenses in the program also increase considerably.

To determine whether the financial incentive gives the expected benefit to the utility in a cost-effective way, it is necessary to analyze the effect of financial incentives on the utility's DSM program cost and benefit.

This study presents an analysis of the financial incentive impact on a utility's DSM programs. This analysis is based on the cost-benefit analysis of DSM programs combined with the customer participation probability model. The customer participation probability model represents the relationship between the decision to participate in the program and the payback period of investment. Since the payback period can also be expressed implicitly in terms of incentives, this model will be used to estimate the participation level for a certain range of incentive values. The incentive impact can then be analyzed based on a cost-benefit analysis using the participation level obtained. The results will not only show the impact of the incentives, but also whether or not the DSM program is cost-effective.

The outline of this thesis is as follows. Since it is necessary to have a background of DSM program process, an overview of the DSM program process is presented in chapter 2. This chapter explains that customer participation plays an important role in the effectiveness of DSM programs. A model of customer participation probability in utility DSM programs is developed in chapter 3. This model is intended to help in obtaining the mathematical approximation of customer participation probability. This chapter also presents the principle of the mathematical background for developing the model. After the customer participation model has been developed, the determination of DSM program cost and benefit for the purpose of the incentive impact analysis is presented in chapter 4. In this chapter, two case studies are used to

demonstrate the incentive impact analysis. This demonstration uses the cost-benefit analysis and the customer participation model. Chapter 5, the final chapter of this thesis, gives some conclusions of this research, as well as recommendations for further study.

Chapter 2

Utility Demand-Side Management

Program Process Overview

2.1. Introduction.

The utility Demand-Side Management (DSM) Program is referred to as a utility planning and implementation activity designed to influence its customer's use of electricity by deliberate interventions that will change the pattern and magnitude of the utility's load, thus producing desired changes in utility load shapes. The DSM program activity encompasses the entire range of management functions in directing the demand-side activity, including program planning, implementation, monitoring and evaluation. Utility programs that fall into the demand-side management category include load management, strategic conservation, electrification, customer generation, and adjustments in market share. The opportunity of demand-side management implementation can be found in all customer sectors, including residential, commercial, industry and wholesale. By this definition, the utility DSM program can promote load growth in a strategic and economic fashion for a utility with an abundance of generation capacity. On the other hand, a utility with capacity constraints may find it valuable to promote more demand-side conservation, high energy efficiency equipment and other activities aimed at managing existing and future loads.

Based on the above definition, there are two important aspects that should be noticed. First, that utility demand-side management includes only those activities that involve a deliberate intervention by the utility in the marketplace so as to alter its load shape. Therefore, under this definition, customer purchases of energy efficient equipment as a reaction to the perceived need of conservation would not be classified as demand-side management. However, a utility program that promotes a customer to install an energy efficient appliance, through its promotion activity, meets the definition of demand-side management. The second important aspect is that demand-side management includes programs that are designed for building load in both peak and off-peak periods, which is an extension scope beyond conservation and load-management.

In the past several years, more and more utilities have turned to energy-efficiency and load management programs which have incorporated DSM programs as low-cost energy and capacity resources. DSM programs can offer utilities a broad range of alternative for reducing or adding load during a particular time of the day, a certain season or annually. DSM programs provide the utility's management various alternatives in maintaining or improving the service to the customer and good relationship with customer, while also improving the company's financial condition. The high uncertainty in cost, performance and availability of supply-side resources, and increasing pressure on environmental regulation, lead many utilities to incorporate demand-side resources on their resource planning. The new planning scheme under the name of Integrated Resources Planning (IRP) modifies the traditional resource planning process by including the demand-side resources. These include further enhancements to help deal with uncertainty in the cost, performance, and availability of demand- and supply-side resources, and environmental externalities.

Under the IRP method, both supply- and demand- side planning approaches are used to achieve the lowest cost plan that meets both the utility and customer needs. The main objective is to minimize the cost of electricity to all customer groups. Under this consideration the cost effectiveness of a DSM alternative has to be carefully evaluated.

A typical DSM program plan contains the programs that will be offered to the different customer segments. This plan is then part of the Integrated Resources Planning. The process that is followed to develop the DSM plan is referred to as the DSM process. DSM process includes the DSM Program planning, DSM program implementation, and evaluation activities.

2.2. DSM Program Planning

The DSM planning objective is to determine the appropriate DSM program concept for a specific customer segment. DSM planning includes DSM objective determination, impact and cost estimation, and the development of an effective DSM program design. The ultimate aim of DSM planning, then, is to identify a DSM program concept that is cost effective, and translate it into program that works in the real world. Effective program design should be based on a good understanding of both customers and markets. A well-designed DSM program will enable the utility to attain the desired load impact, ensure the program's cost-effectiveness and strengthen customer relations.

2.2.1. DSM Objectives

Establishing the DSM program objectives is the first step in the DSM process. These objectives are essential since they will guide the DSM assessment process that eventually determine what type of DSM programs are implemented and establish references against which program achievements can be measured. There are three levels in utility planning hierarchy related to DSM programs [1]:

- Strategic Objective Level,
- Operational Objective Level,
- Load Shape Objective Level.

2.2.1.1. Strategic Objective Level.

In this level, a utility formal planning establishes the overall organizational objectives, which are reflected as strategic objectives. The range of the objectives are usually broad and typically include the improvement of cash flow, earning increase and improvement of customer and employee relationship. Broehl, et.al [1] explain that the achievement of these objectives is often limited by certain institutional constraints. These constraints represent the obvious regulatory environment that a utility faces, i.e. regulation, environmental considerations, and the obligation to provide a reasonable quality of services to a customer in a designated service area.

2.2.1.2. Operational Level.

The operational level objectives are intended to provide guidance for the utility management for specific actions in which their objectives are operationalized. The evaluation of

DSM alternatives should be carried out in this operational or tactical level. For example, in meeting the load growth, an examination of capital investment requirement for new plant unit may show periods of high investment needs. Through DSM programs, the need for new unit may be postponed, and therefore may reduce investment needs and stabilize the financial future of the utility. Operational objectives that can be addressed by DSM alternatives include:

- Reducing the need for critical fuels
- Reducing or postponing capital investment in construction programs
- Increased revenues or sales
- Offering customers with options that provide a measure of control over their monthly electric bills
- Reducing the risk of investing in diverse alternatives
- Increasing operating flexibility and system reliability
- Decreasing unit cost through more efficient loading of existing and planned generating facilities.
- Satisfying regulation constraint or rules
- Minimizing potential environmental impact
- Improving the image of the utility.

However, given those operational objectives, specific operational objectives have to be established on the basis of the condition of the existing utility, i.e. its system configuration, operating environment, customer characteristics, cash reserves, and competition.

2.2.1.3. Load Shape Objective Level.

In this level, the utility determines the changes in customer use of electricity that it believes would help to achieve specific operational objectives. There are six generic load shape changing possibilities that may represent the range of combination possibilities:

1. **Peak Clipping** refers to the reduction of the utility system peak loads during peak demand periods. This is a form of the classical load management process. Peak clipping is generally associated with the reduction of peak load by direct load control. This is most commonly practiced by direct utility control of customer's appliances. Some utilities consider peak clipping as a means to defer the need for additional generation capacity or capacity purchase. However, direct load control also can be used to reduce operating cost and dependence on critical fuels by economic dispatch. The net effect is reduction in both peak demand and total energy consumption.
2. **Valley Filling**, in contrast to peak clipping, is the second form of classical load management entails building off-peak loads. This may be particularly preferable where the long-run incremental cost is less than the average electricity price. This is often the case when there is underutilized capacity that can operate on low cost fuels. Under those circumstances, adding properly priced off-peak load decreases the average price. Valley filling can be accomplished in several ways. The most popular way is to displace fossil-fueled appliances by electric appliances (water heating or space heating). The net effect of valley filling is an increase in energy consumption without any increase in peak demand.
3. **Load Shifting** is another classical load management tool. It involves shifting load's from on-peak to off-peak periods. This is a kind of combination between peak clipping and valley filling. Popular applications include use of storage water heating, storage space heating, cool

storage for room AC, and customer load shift. The load shift from storage devices should displace the load that would have been used by conventional electrical appliances. The net effect is a decrease in peak demand but no change in total energy consumption.

4. **Strategic Conservation** refers to the energy consumption reduction that results from utility-stimulated programs directed at end-use consumption. This is not normally considered to be load management, since the change reflects a modification of load shape involving a reduction in sales and the pattern of use. In employing energy conservation, the planner must consider what conservation actions would occur naturally and then evaluate the cost-effectiveness of possible programs that can accelerate or stimulate those actions. Appliance efficiency improvement, energy efficient buildings, and weatherization are some of the examples for this load shape objective.
5. **Strategic Load Growth** consists of an increase in overall sales beyond the valley filling described previously. The net effect is an increase in both peak demand and total energy consumption. Load growth may involve an increased market share of loads that are served by other fuel. Load growth also could be produced by electrification so as to increase the electric energy intensity in residential and industrial sector. This rise in intensity may be motivated by a reduction in the use of fossil fuels and raw materials.
6. **Flexible Load Shape** refers to variations in the reliability or quality of services. Load shape can be flexible if customers are presented with quality of service options that they are willing to allow in exchange for various incentives. Therefore instead of influencing load shape on a permanent basis, the utility has the option to interrupt loads when necessary. The programs can be variations of interruptible or curtailable load, integrated energy management systems, or individual customer load control devices offering service constraints.

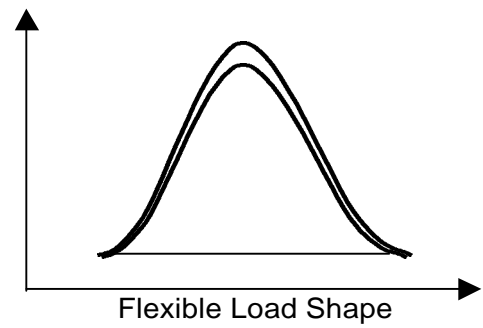
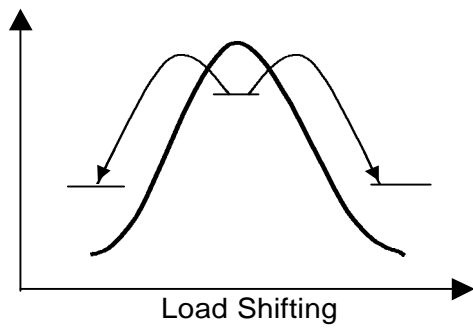
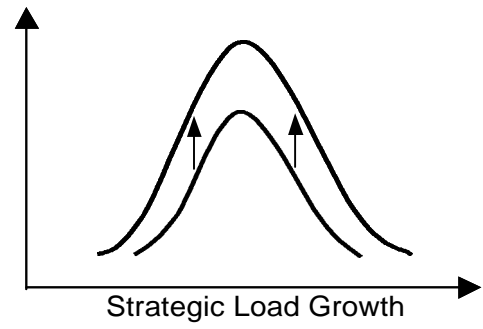
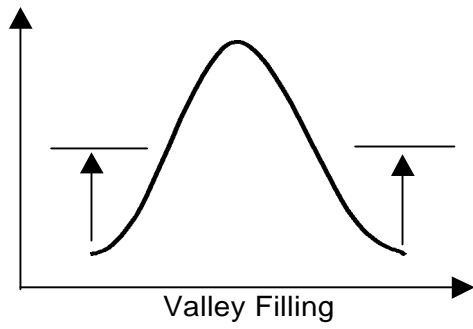
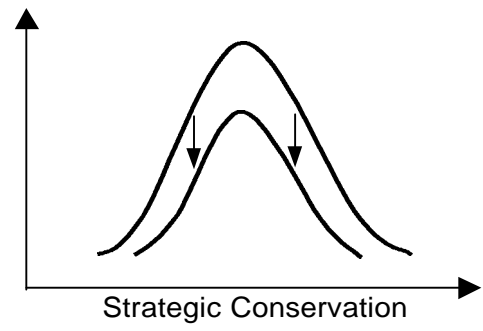
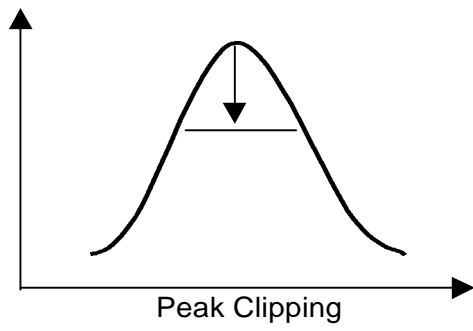


Figure 2.1. DSM Program load shape objectives

There may be a net reduction in peak demand and little if any change in total energy consumption.

2.2.2. DSM Impact Estimation

As outlined previously, DSM programs focus on deliberately changing the load shape so that it can be served more efficiently. This may give a false impression that the only load shape changes that occur are those induced by the DSM Program. This is because system load shape change may occur naturally due to fluctuation in customer mix, the naturally occurring load growth, reactions to energy prices, new regulations, or appliance and equipment turnover. Therefore, to estimate the impact of DSM programs, it is important to differentiate between naturally occurring changes and those changes resulting from DSM programs.

There are usually two steps that are used to estimate the impact of DSM Programs [2]. First is to develop a DSM baseline forecast as a reference with which the impact of DSM measure can be assessed. This is a forecast of electric energy consumption and peak demand in the absence of DSM programs. Most frequently the forecast is represented by a single value for each year of the analysis for a specific set of variables. These variables include annual energy consumption, summer peak demand and winter peak demand. The second step is to identify the DSM measures and estimate the unit DSM impact. Once the unit impact of DSM programs is determined, the aggregate DSM impact can be estimated. The aggregate DSM impacts correspond to the achievable potential impact of DSM programs, taking into account the customer participation rates. The aggregate impact obtained then can be used to assess the DSM impact by contrasting it to the DSM baseline reference.

2.2.2.1. DSM Baseline Forecast

The DSM baseline forecast is derived from the utility's official load forecast. Usually, the official load forecast does not contain the level of detail necessary to assess the impact on the forecasted energy consumption and peak demand of specific DSM measures. Therefore, it is usually necessary to create a separate computational framework that generates a detailed DSM baseline forecast. Different levels of detail that can be included in the baseline forecast is a function of data availability. The baseline forecast could become progressively more detailed at the system, sector, segment, end-use, technology, and equipment levels.

Ideally, to assess the impact of all applicable DSM measures thoroughly, the DSM baseline forecast should be established at the most detailed level, i.e. at the equipment level. However the data needed to accomplish this goal is typically not available. Therefore, in most cases it is only possible to establish the DSM baseline forecast at the technology or end-use level, and not at the equipment level.

There are three typical approaches for establishing baseline forecasts [2]. Each approach is determined by the data available and resources. The first approach is called the *bottom-up approach*. The approach required extensive detailed data starting from equipment to system level. The bottom-up approach begins with a detailed equipment inventory and the corresponding average annual energy consumption per device (unit energy consumption – UEC) and diversified load at the time of the system peak (unit coincident demand – UCD) for each type of equipment and for each year of analysis. This data is used to calculate the annual energy consumption and peak demand in each market segment level (e.g. existing single-family

housing, office building, etc.). The process is repeated for the other types and vintage of equipment and market segments, and the results are aggregated across all equipment types, end-uses, and segments to arrive at the subtotal of annual energy consumption or peak demand in the sector level.

The second approach is the *top-down approach*. This approach is intended as an alternative approach when the required data for bottom-up approach is not adequately available. In this approach, the baselines forecast is developed from the information at the customer or segment level. The starting point of this approach is the utility official forecast, which is allocated down to the different hierarchical levels. If the available official forecast is in the sector level, then the annual energy consumption and peak demand for the sector are first allocated to the various segments by their percentage of sharing. Next, the segments-specific energy consumption and peak demand are allocated to different end-use on the basis of end-use consumption data. Finally, the end-uses forecast can be allocated to the different technologies or equipment types.

Another approach that can be employed to establish baseline condition, particularly in residential and commercial sectors is the *prototype approach*, a variation of the bottom-up approach. The prototype approach integrates engineering simulation models into DSM analysis. Using these models, the energy consumption of prototypical buildings can be evaluated. Typically, prototypes are selected to analyze the most important customer segment in the utility's territory. Once prototypes are defined, their baseline characteristics (e.g. heating, cooling and ventilation system, loads and their usage pattern, etc.) must be determined. The next steps is to

run an energy simulation model to obtain the hourly load demand, which is then processed into average monthly and peak day profiles. From the results of each prototype, base line energy consumption and peak demand forecast at the end-use, segment and sector can be obtained.

2.2.2.2. Unit and Aggregate DSM Impact Estimation

DSM impact estimation covers two tasks of estimation. The first task deals with the issue of determining the unit DSM impact. The second task deals with the estimation of aggregate DSM impact.

To estimate the unit impact of DSM measure, the engineering or statistical method can be used. Engineering estimate of DSM program impacts is developed using engineering principles with assumptions about equipment and system performance characteristics and operation profile of measures installed through the program. This technique has been used in widespread application within electric utilities in program planning and screening, as well as in program monitoring and evaluation for their DSM programs. Engineering methods provide a relatively easy and quick method of developing estimates. The methods also can be relatively inexpensive and may serve as a primary method when the value of information does not justify more expensive statistical approach. In engineering methods, unit impact of a DSM measure is defined as the energy and or demand impacts resulting from the installation of a specific technology. The engineering estimation of savings typically involves equations, which express energy use or demand in term of a usage level divided by energy efficiency for some period. Unit impact may be derived from engineering simulations or from engineering algorithms.

Despite the advantages of engineering methods, there are some weaknesses that inherent to this method. The primary weaknesses of engineering methods is that they are not well-suited to account for customer choice, attitude, and behavior, while those customer attributes can have significant impacts on the effect of DSM programs. The accuracy of the engineering method is only as good as the assumption used in the calculation, and common assumption may not necessarily be appropriate for a specific program. Therefore, care must be taken the assumption used in developing engineering models.

Statistical methods are intended to estimate the impacts over extensive customer information, such as energy used data and demographic information [2]. These methods are helpful in accounting for behavioral patterns, which are not accounted in engineering methods. The econometric models developed by statistical methods may also be derived from customer response on climate, equipment saturation and rate structure. In general, the most common method in developing an econometric model in statistics is the multivariate regression techniques. The technique is concerned with causal relations between variables to develop average estimate of savings.

While statistical methods provide DSM program impact estimate over broader variables, there are several disadvantages that should be taken into account. Statistical method is a data intensive method, therefore a reliable model produced by statistical method requires a large number of data. In DSM program planning level such required data usually is not available yet, so as the statistical methods can not be used properly in estimating the impacts. The statistical methods also require a lot of computation, which may require specific computer-aided software.

With those facts, the statistical method can be higher cost and more time consuming method than the engineering analysis.

The second task of DSM impact estimation is to estimate the aggregate DSM impact. The unit impact obtained from previous task, combining with customer participation rate, determine the aggregate impacts. These impacts correspond to the achievable potential; they establish a realistic target for DSM saving that utility can expect to achieve through DSM program. In this task, it is necessary to estimate the participation rate. This can be obtained using data from similar utilities those implement similar program, or by developing a customer participation model.

2.2.3. DSM Program Cost-Effectiveness Analysis

Cost-effectiveness (C-E) analysis plays a major role in the subsequent process of DSM program planning. In large part, this is because DSM tends to effect different segment of society differently. As a result, C-E analysis provides both an indications whether a particular program is *good* and an indicator of for whom the program is *good*.

There are five typical analyses that widely used in practice [2,3]. The effectiveness of the program are generally indicated by the amount of load reduction, the avoided utility cost, the total customer and societal resources saving and the rate of participation. For each of the test, a cost-effective program is indicated by a ratio of benefit to cost greater than one. The following discusses the purpose and component of each analysis type in the C-E analysis:

1. Participant Test

The participant test provides a measure of the quantifiable benefit and cost of DSM program to a typical participating customer; it does not consider impacts on the utility. This test traditionally contains the easily defined components of customer's decision to participate the program. Thus, the test is an indication of the attractiveness of a program to the customer. The benefit components considered in the test are the bill reduction, avoided appliance cost, customer incentives and tax credit; while, the costs considered are bill increase, program cost paid by the participant and participation charges.

2. Total Resources Cost Test

The total resources cost (TRC) test provides a measure of the net resource expenditures of a DSM program from the point of utility and its ratepayers as a whole. The test is a measure of the change in the average cost of energy services across all customers. The net present value of the TRC test is a measure of the change in total cost of energy services for utility's customers. The benefit components accounted in this test are avoided energy and capacity cost, avoided appliance cost and tax credits, while the costs are the energy and capacity cost and the cost paid by the utility and the participants.

3. Ratepayer Impact Measure Test.

The ratepayer impact measure (RIM) test examines the difference between the change in total revenues paid to a utility and the change in total costs to a utility resulting from the DSM program. The changes in revenues and operation cost of a utility will in turn affect the utility electricity charge. If the cost increment is larger than the revenue increment the rate

will increase, whereas if the revenue increment is larger than the costs increment, then the utility can decrease the rate.

The revenue increment or the benefit component in the RIM test includes utility 's avoided cost, revenue increment resulting from additional sales and participation charges. Cost increment include: energy and capacity cost, revenue losses due to sales shrinkage, customer incentive expenses and program administration cost paid by the utility.

4. Total Utility Cost Test

The total utility cost (TUC) test looks into the impact of DSM program on the utility cost. A DSM program is one type of utility business program, therefore a utility must compares the cost and benefit of each of its business programs. The program benefits considered in the TUC test includes the energy and capacity avoided cost, and the participation charges, while the costs includes energy and capacity cost, customer incentive expenses and program administration cost paid by the utility.

5. Societal Test

The societal test is a measure of DSM program net benefit from society point of view as a whole. The test attempts to capture all benefits and costs of a DSM program, including environmental externalities. Therefore, the benefit accounted in this test includes avoided energy and capacity cost, avoided appliance costs and externality benefit, while the costs include the energy and capacity costs, program costs paid by the utility and participant, and externality costs.

2.2.4. DSM Program Design

DSM program design is intended to translate the cost-effective program concepts into an operational program. Effective DSM program design is based on a solid understanding of both customer and markets. By addressing customer needs and overcoming the market barriers, a well designed DSM program can attain desired load shape impacts, ensure program cost effectiveness and strengthen customer relation.

To achieve an effective DSM program design, Faruqui et,al [2] suggests the following steps as a guidance to design an effective program:

1. Identification of target markets and customer needs

As the customer of a utility consist of a very large class, it is important to identify the customer classes by conducting market segmentation; the division of the large class of customers into smaller groups with similar characteristics. By the market segmentation, the target equipment types, incentives and delivery mechanisms to a specific customer class can be determined effectively.

The market segmentation and customer types can be identify using three principle ways to segment the market. Segmentation can be developed based on the quantitative building or facility characteristics. The data of building characteristics, such as energy use, building size, building age and construction, and other variables can be obtained from load research and structured survey. The next principle is the segmentation based on the demographics and firmographic characteristics. Demographic data on residential

customers are often drawn from census reports on age, family size, income, and ownership status. The firmographic data is for nonresidential customer, and sometimes is used to capture the functional usage and ownership characteristics. The last principle is by attitudinal and organizational customer characteristics. These variables can be as broad as the customer's attitude toward the utility and as specific as the financial criteria the customer uses to make investment decision.

Further step in identifying the markets and customer needs is to identify the customer end uses that contain the greatest potential for achieving desired load impact and the DSM technologies that can best produce in each end use category. Having identified the end use priority, the targeted technologies that will be encouraged by DSM program should be matched to the market segment. This will help to ensure the maximum achievable impact of DSM programs.

2. Design program features to meet customer and utility needs

This step is intended to develop a specific program objective that meet with the customer and utility needs. Base on the obtained technology selection, market segment and customer need, the specific program objectives can be elaborated.

The program features that have to meet customer may encompass the technology selection, customer eligibility, utility financial incentive, and the selected delivery mechanism. Selecting a small number of high efficiency technologies can serve the load

impact desired, but limiting the customer choice. Therefore decision of the number of technology choice has to consider the customer preference of technology choices.

The financial incentives play an important role in affecting the customer participation, but the range of the incentives must low enough to stay within the utility economics constraint. The maximum of the acceptable incentive range typically based on the utility's avoided energy and capacity cost, while the minimum range is the level that meets customer's financial criteria, such as payback period or a minimal rate of return.

DSM program design must include careful choices about how to deliver the program to customer. The components that are typically related to the delivery aspect include the availability of equipment at manufactures and local vendor, role of trade allies, and support service delivery. The equipment availability refer to the ability to provide sufficient supply of eligible products. The shortages of product not only limit the participation but also create frustrated customer who are less likely to respond to future promotions.

3. Develop marketing strategy and method

In context of designing and implementing DSM programs, marketing is more tactical than strategic. Unlike selling which focuses on product and numbers, marketing focuses on customer needs and satisfaction.

Marketing encompasses the promotion, recruitment and sales aspect of the program. In designing the promotion of the program, several customer behavior stages in reaching the decision should be recognized. The stages of customer's decision making are the awareness of the DSM program, the understanding of the application, the evaluation of benefit the motivation to participate, and the adoption of the promoted programs. A proper marketing approach in each stage will help to provide an effective program promotion.

2.3. DSM Programs Implementation

DSM program implementation refers to carrying out DSM programs after their cost-effectiveness and design have been determined during the DSM planning phase. Program implementation involves the many detail operational decisions that must be made to realize the goal of DSM programs. Implementing the DSM programs takes several stages to proceed. This may include forming the project team, completing a pilot project and demonstration, and expanding to a system wide implementation. Those stages are necessary to help the utility in effectively marketing and administering the DSM programs that produce the desired DSM impact at reasonable cost.

The key factors in the success of a DSM program implementation are the customer acceptance and response to the programs. The customer acceptance refers to customer willingness to participate in an implementation of DSM programs, customer decision to adopt the desired appliance choice and efficiency, and behavior changes as encouraged by the utility.

Customer response is the actual load shape change that results from customer action combined with the characteristics of the device and systems being used. Therefore the load shape objective defined in the DSM program planning can be achieved only if the customer acceptance can be obtained as desired. The objective of the DSM program implementation is then to influence the marketplace to change the customer behavior.

2.3.1. Customer Participation

The success of DSM programs hinges on customer participation to accept the adoption of technologies that exhibit operating characteristics and energy-use value of benefit to electric utility systems and their customer. Therefore utilities have to be able to persuade their customers to actively participate the programs.

Typically, there are six categories of marketing implementation method used in current practice, which can be selected individually or in mixed method [1]. These marketing method are customer education, direct customer contact, trade ally, advertising and promotion, alternative pricing and direct incentives. The customer education and the direct customer contact objectives are to increase customer awareness of utility programs, and increase perceived value of service. The trade ally cooperation is intended to use the cooperation with vendors or contractors in influencing the customer acceptance. The alternative pricing and direct incentive objectives are to encourage customer acceptance by offering a financial benefit upon participate the programs.

The customer acceptance is influenced by the demographic characteristics of the customer, income, knowledge, awareness of the technologies and program available, and

decision criteria such as cash flow and perceived benefit and costs, as well as attitude and motivations. The customer acceptance is also influenced by external factors such as economic condition, energy prices, technology characteristics, regulation, and tax credit [3]. To augment or mitigate the external influences, taking into account the customer characteristics, for increasing the customer acceptance, utilities have to select appropriate mix of market implementation method.

2.3.2. Incentives in DSM Program

The most common barriers in DSM marketing implementation are the high initial equipment cost and relatively low rate of return on investment [1]. Customer participation in DSM programs is voluntary, implying that participants must expect positive net benefit. The implication of this criteria is that customer will have a low value of investment criteria and high rate of investment return. According to Hausman [4] research shows that the customer criteria on rate of return are generally higher than the standard rate of return on investment of equipment. These factors are often constrain the customer acceptance

Direct incentives are being used in a large number of DSM programs to encourage the participation. The objective of direct incentive is to increase short-term market penetration by reducing net cash outlay of equipment purchase or by increasing the rate of investment return. There is various type of direct incentives applicable to many customer options in each of major option category, they can be used in combination to produced customer acceptance.

Rebate and cash grants have been used widely due their administrative simplicity. They can give an advantage to customer by significantly lowering the first cost of new major appliances or other options purchases.

Low-interest loans are another type of direct incentives, which can allow the customer to purchase higher priced option by making several installments payment. Billing credit method is similar to low-interest loan, except that the credit is applied to the customer monthly bill in return for installing particular option.

Research by Train and Atherton [5] shows that customer acceptance is related by the incentive level. The research reveals that the participation level will increase as the incentive level increases. This gives another fact that direct incentive is effective to increase the customer acceptance. However, as the increase of incentive level will be followed by the increase of participant number, the DSM program cost for incentive expenses will be significantly increase as well. Therefore, the level of incentive should be carefully determined taking into account the utility operating characteristics, the technical characteristics and cost of end-use technologies promoted in DSM programs, and the customer behavior characteristics.

2.4. DSM Programs Evaluation

Just there is need to evaluate the performance of supply-side alternative, there is a need to evaluate demand-side alternative. The ultimate objective of the DSM programs evaluation is to

provide an assessment of the effectiveness of the programs in achieving their objective. The program evaluation can also serve as a primary source of information on customer behavior and utility system impact, and help the utility to revise existing and planned DSM programs as appropriate.

2.4.1. Engineering Methods

Engineering methods estimation for DSM programs evaluation can be developed using engineering principles with assumptions about equipment and system performance characteristics. These techniques have seen widespread application with electric utilities in DSM program impact evaluation. Although engineering methods have certain limitation, they are already widely used in one or another form throughout the DSM program impact evaluation process.

Engineering methods provide independent, stand-alone estimates of program impacts. This method is relatively quick and easy method in developing before- and after-implementation estimate. The strengths of engineering methods include the relatively inexpensive and less time-consuming process. This is because the methods rely on well-established methods that are generally easy to apply. Engineering methods are also important as a method for estimating the time-differentiation impacts, as statistical methods are limited by the periods of available data

However the accuracy of the method depends on many assumptions about behavior. Hence, the methods have a weakness that they are not well suited to accounting for the customer choice, attitude, and behavior patterns, whereas changes over those customer characteristics can have significant impacts on the effects of DSM program. Therefore, care must be taken in the

assumptions used in developing the model, and appropriate calibrations and benchmarking of the model to actual behavior characteristics of typical customer must be done. Other aspects that important to be considering in employing the engineering methods include using an appropriately simulation model or algorithm and assigning personnel with an adequate understanding of end-uses affected of the programs.

2.4.2. Statistic Methods

The statistics methods developed using extensive data on customer characteristics including demographics and energy use data. The methods can be used to determine the type of programs that would be most successful in a given region. While the statistical methods are suited to accounting for behavioral characteristics, such as customer choice, attitude and behavior patterns, they lack the technical detail provided by engineering simulation.

They are a variety of statistical methods, each with the potential to provide information on program impacts. None of them is the most appropriate method since each methods has different purpose and each different purpose has its own objectives justification in developing the model. However, in general the literature of energy conservation program evaluation has used two basic statistics approaches for estimating the energy saving attributable to DSM program, namely, the comparison approach and the multivariate regression approach.

The comparison approaches use in-house data of participant's energy consumption and compared to the energy consumption of non-participants. These comparison approaches can produce useful information about the effect of DSM program, while requiring minimal additional data collection. However there is a problem that the models give a limited information, in terms

of household demographics and appliance stocks, on the comparability of the participant and non-participant groups. The only data that confirm the similarity of the two groups are billing data and the limited in-house information.

In the other hand, the multivariate regression approach uses a larger data set that typically includes survey data on individual customers. This approach is more flexible in its ability to control for non-program factors that may influence energy use and bias the estimate of program energy saving. Multivariate regression models can control for many of the potential confounding factors that alter changes in energy use, increasing the ability of the model to isolate impacts attributable to the DSM programs. The issues among the multivariate modeling methods are conditional demand modeling, interaction variables, multicollinearity problems and regression diagnostics, which are beyond the scope of this research.

2.5. DSM Program Impact in Wider Aspects

Taking into consideration the nature of the electric system structure and characteristics, the DSM programs implementation can have a wide impact to the system. The main objective of the DSM programs is designed to reduce generation costs. The capital-intensive natures of generations provide a significant basis of saving due to unit deferral or cancellation. Nonetheless, the achievement of this objective can lead to wider impacts in large context of the electric system.

There are currently two important issues concerning the impact of DSM programs in wider context. The impact of DSM program on the transmission and distribution (T&D) system is one of the issues. The next issue is concerning with the environmental and economic aspect.

2.5.1. Transmission and Distribution

The expenditure of T&D system is expected to be substantially greater than their expenditures for generation capacity, while by properly targeted to a specific area, DSM programs can reduce significantly the expenditures of T&D system. It is becoming increasingly obvious that methods that combine DSM programs and T&D planing can help utility to select an appropriate form of DSM programs and targeted them towards areas where they can be most effective in reducing costs.

DSM programs provide a reliable alternative to T&D by reducing the peak load of the system. By lowering the peak load, the requirement of the upgrading or constructing new T&D lines due to the increase of load demand may be deferred or postponed. However, as a study revealed, the ability of DSM to provide alternative to T&D by reducing the peak load is dependent on a very close matching of the load reduction due to DSM and the timing of local area peak demand. Therefore, utilities that want to take advantage of local benefits of DSM have to evaluate the difference of the timing of the utility system peak and the local area peak. This is important to evaluate the local load and the costs estimates incurred by the DSM Programs.

2.5.2. DSM and Environmental and Economical Externalities

The social effects of DSM programs are primary environmental and economic. Effects on those factors are usually referred to as externalities. Externalities are effects of action taken by individual or firm that provide costs or benefit to third parties who are not involved in the transaction.

The social factor considered most frequently in DSM evaluation is environmental externalities. Due to increasing concern over environmental damage caused by the combustion of fossil fuels, such as acidic deposit and global warming, utilities recognize that electricity generation imposes certain external costs on society beyond the monetary costs that are tracked by existing financial systems. In such cases, DSM programs can be an important tool in mitigating the adverse environmental impacts of energy production.

Most commonly, utilities must credit to DSM activities the value of externalities to be avoided if DSM is adopted instead of generation resources. As an example, adoption of high efficiency room air conditioner is thought to avoid the social costs of producing electricity from coal which in turn will avoid the social costs associated with the emission of SO_x , NO_x , CO_2 , and particulate from the coal facility.

However, it is generally agreed that externality costs are difficult to identify and to quantify. An approach to value the externalities is to characterize and describe qualitatively the environmental effect of different resource options. Another more complicated approach is to rank and weigh the individual air, water, and terrestrial impacts of individual options. Some

utility approach the externality costs by quantify and monetize the emission associated with resource options. This approach requires quantification of emission, such as tons of SO₂ emitted per Mbtu of coal, and monetization of these emission. These monetary values, typically expressed in c/kWh, reflect the damages imposed on society by emissions from particular resources.

Some utilities are considering the inclusion of economic externalities in evaluation of DSM programs. These generally consist of regional economic and employment impacts of DSM programs. Some analysts have argued that DSM programs produce more local employment over their lifetime than a power plant of equivalent size. In addition, DSM expenditures tend to remain within the region, while fuel expenditures often move out from the region. These continuing economics benefit to the region may be credited to DSM in making resources comparison.

2.6. Summary

Demand-Side Management programs provide opportunities to utilities to serve their load more efficiently. DSM programs induce the customer to use electricity in concert with the load shape desired by the utility. By implementing the DSM program, a utility may modify its customer's energy consumption and pattern.

The effectiveness of DSM programs hinges on customer participation. Significant load

shape changes can only be achieved if enough customers participate in the program. However, the decision of a customer to participate in the program is affected by various factors. To implement the DSM programs effectively, a utility must be able to identify those factors.

High initial customer investment for a DSM option and low rate of investment are the most common barriers to customer participation in the program. DSM programs, especially those for energy conservation purposes, promote the use of high efficiency equipment to their customer. Yet high efficiency equipment often has higher initial cost than conventional equipment. Therefore, an incentive to reduce the initial investment is required to encourage the participation.

It becomes important then for a utility to assess how the incentive can affect customer participation in the DSM program. Different levels of incentives will provide participation levels differently, and therefore will produce a different DSM program impact. To analyze the impact of incentive in the utility DSM programs, it is required to develop a model of customer acceptance of utility DSM programs and then to conduct the DSM net-benefit analysis. Theses will be carried out in the next two chapters.

Chapter 3

Modeling the Customer Participation Probability

In Utility DSM Programs

3.1. Introduction.

Modeling the customer acceptance or participation probability in a utility-sponsored DSM program is important for DSM program impact estimation and design. To estimate the impact of a DSM program, a calculation of net saving is required. This involves, among other things, a prediction of the number of customers that would participate in the program. Using rebate programs, as an example, a utility must predict how many participants would be involved if the rebates had not been offered and how it could change the customer participation rate. Once the customer response to the level of rebates has been identified, an appropriate design of DSM program and its impact can be determined and estimated.

Many factors can influence the customer to accept and participate in a DSM program or in energy conservation action in general. Demographic factors such as income, education and age of head of households may have a significant effect on customer participation. As reported by a number of studies [6,7,15], there is a positive relationship between income and energy conservation action. Education, even though it covaries with income, also shows a positive relationship with the conservation effort as well [6,15]. Likewise, there are several other

demographic factors that impact on customer participation, even though the relationships vary in strength. The most important feature of demographic variables is that they can be used as segmentation criteria for designing and implementing energy conservation programs or specific DSM programs. Customer's opinion on energy conservation, investment criteria, expected benefit from participation and customer exposure to and understanding of the program are among the other aspects. Participation in DSM programs is voluntary, so participants must expect positive benefits from the program. Therefore, the expected financial benefit from participation is a significant variable in affecting the customer's DSM program acceptance. This variable can be incorporated in the customer's investment criteria.

The objective of this chapter is to develop a mathematical model for customers DSM program participation, using income class as the segmentation criterion and investment criterion as the driving variable. The result of this modeling will be used for determining the participation level in estimating the DSM program impact and cost.

The discrete choice model will be used to form the mathematical model. A discrete choice model is a regression model, which uses a logistic probability distribution function called as the logit function. In this regression model, the independent and dependent variable may not be a continuous, but a discrete choice of a given classification. In the case of DSM program participation, the independent variable may consist of a single or several demographic and economic variables of various aspects, while the dependent variable is the participation in the program, and has the value "yes" or "no". Therefore, the discrete choice is appropriate to model the customer participation in DSM programs.

The available real data of energy consumption and conservation related surveys would be used as much as possible in developing the model,. The EIA's energy related survey data would be as the main source of information [8].

The organization of this chapter is as follows. First, the logit model is introduced, and the form of logistic function and its characteristic are explained. The next section is the mathematical background of *maximum likelihood estimation* (MLE) for probability function parameters. In this section the iterative procedure to estimate the parameter of any probability function is explained. Next, this section presents the derivation of the MLE for the logistic function. The last section is the application of the logit model and its parameter estimation procedure for developing the participation probability of utility DSM programs. The Intention of this chapter is to demonstrate the viability of participation probability as a function of the individual payback period criteria.

3.2. The Logit Model

In this research, the logit model is proposed as an approach for modeling the customer acceptance participation of DSM programs. This choice is based on several reasons. First is that the customer choice is dichotomous; whether to participate or not. Further, it is necessary to find the statistical relationship between the decision to participation and the customer characteristics, including demographic and non-demographic aspects.

The logit function gives a model of probability limited from 0 to 1 dependent variable, which monotonically varies with the independent variables. A *sigmoid curve* that flattens out at either end so as to respect the requirement must be used (Figure 3.1).

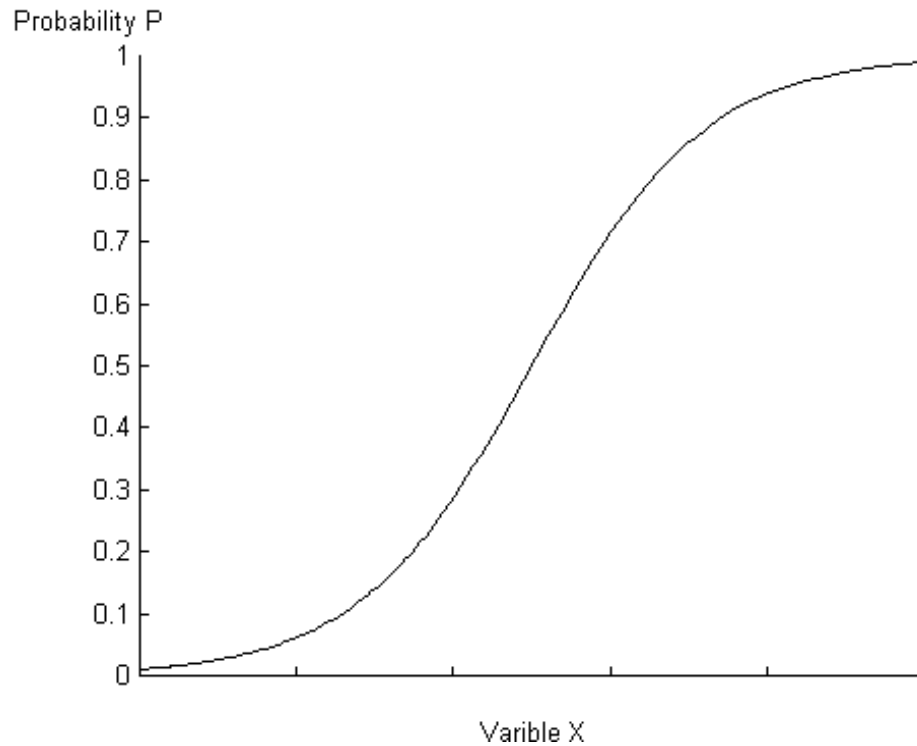


Figure 3.1. A logit function

A *logistic function*, that is

$$P(X) = \frac{\exp(\mathbf{a} + \mathbf{b} X)}{1 + \exp(\mathbf{a} + \mathbf{b} X)} \quad 3.1$$

meets the requirement. The complement of this function is simply,

$$Q(X) = 1 - P(X) \quad 3.2$$

$P(X)$ denotes the probability of a dependent variable being in a certain state, where X denotes the independent variables.

For a random sample with several independent variables, the logit function can accommodate such multi independent variables, as in

$$P(X) = \frac{\exp(\mathbf{X}^T \boldsymbol{\beta})}{1 + \exp(\mathbf{X}^T \boldsymbol{\beta})} \quad 3.3$$

where \mathbf{X} and $\boldsymbol{\beta}$ are the vectors of the independent variables and the coefficients, so that $\mathbf{X}^T \boldsymbol{\beta}$ stands for

$$\mathbf{X}^T \boldsymbol{\beta} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots \quad 3.4$$

with β_0 is equivalent with α in 3.1.

3.3. Estimation of the Coefficients

Several studies suggest using the *maximum (log)likelihood estimation* (MLE) to estimate the independent variable coefficients [6,9] for a logit function formed from a non-linear function. The MLE is concerned with determining those parameter estimates that imply the highest probability or likelihood of getting the observed values of dependent variables. This method also permits the estimation of the parameters of almost any analytical specification of probability

function, and yields a consistent estimate, together with ready estimates of their covariance matrix [9,12].

The estimation of coefficient may result from a set of individual data or grouped data. The reason to estimate the coefficient from a grouped data is that the large individual data is often grouped into a limited number in a certain category type for simplification and practical representation. The following is the description of the general concept of coefficient estimation using the MLE, followed by a specific coefficient estimation for the logit model, both using the individual and grouped data.

3.3.1. Estimation of the Coefficient by MLE

If a survey obtains a data sample of $i = 1, 2, \dots, n$ observations on an occurrence of a variable Y_i in a certain event or state, such as 0 or 1, and a set of independent variables X_{i1}, X_{i2}, \dots , arranged in the corresponding vector \mathbf{x}_i , then the probability that in observation i , $Y_i = 1$ can be expressed as

$$P_i = P(\mathbf{x}_i, \boldsymbol{\theta}) \tag{3.5}$$

with any given specification of function $P(\cdot)$, where $\boldsymbol{\theta}$ is an unknown fixed parameter vector. Since the observations are statistically independent, the probability density of a sample set of any given ordering of observed outcomes is the product of each outcomes probability,

$$f(y, X, \boldsymbol{\theta}) = \prod_{i \in Y_i = 1} P(\mathbf{x}_i, \boldsymbol{\theta}) \times \prod_{i \in Y_i = 0} Q(\mathbf{x}_i, \boldsymbol{\theta}) \tag{3.6}$$

This function is also the *likelihood function* $L(\mathbf{q})$ of the sample [9]. Since the likelihood function $L(\boldsymbol{\theta})$ is a product, a more convenient summation function can be obtained by taking the log of the function:

$$\log L(\boldsymbol{\theta}) = \sum \{ Y_i \log P(\mathbf{x}_i, \boldsymbol{\theta}) + (1 - Y_i) \log Q(\mathbf{x}_i, \boldsymbol{\theta}) \} \quad 3.7$$

Maximizing the log-likelihood, by equating the derivative of $\log L(\boldsymbol{\theta})$ to zero will provide the maximum likelihood estimation of parameter $\boldsymbol{\theta}$, that is $\bar{\boldsymbol{\theta}}$. The derivative of $\log L(\boldsymbol{\theta})$ is

$$\left(\frac{\partial \log L}{\partial \log \boldsymbol{\theta}} \right)^T = \mathbf{q} \quad 3.8$$

and $\bar{\boldsymbol{\theta}}$ is obtained by solving

$$\mathbf{q}(\bar{\boldsymbol{\theta}}) = 0 \quad 3.9$$

Since the equation has no analytic solution, therefore it is suggested to solve the equation by a successive approximation. One of the suggestion is to use the *Newton-Raphson method* [9], such that

$$\boldsymbol{\theta}_{t+1} = \boldsymbol{\theta}_t - \mathbf{Q}(\boldsymbol{\theta}_t)^{-1} \mathbf{q}(\boldsymbol{\theta}_t) \quad 3.10$$

where $\mathbf{Q}(\theta_t)$ is the second derivative of $\log L$. This iterative method must be completed by *starting value* \mathbf{q}_0 and convergence criteria. Once the convergence criteria is achieved, the θ_t becomes the maximum likelihood estimated $\bar{\theta}$.

Creamer [9] suggested using the *Gauss-Fisher* method by using the *information matrix* \mathbf{H} , the expected value with reverse sign of \mathbf{Q} :

$$\mathbf{H} = -E\mathbf{Q} \tag{3.11}$$

so that 3.10 becomes

$$\theta_{t+1} = \theta_t + \mathbf{H}(\theta_t)^{-1} \mathbf{q}(\theta_t) \tag{3.12}$$

3.3.2. Estimation from Individual Data

The general form of the logistic probability function (1) can be rewritten as

$$\begin{aligned} P(X) &= \frac{\exp(\mathbf{a} + \mathbf{b} X)}{1 + \exp(\mathbf{a} + \mathbf{b} X)} \\ &= \text{Pl}(X) = \frac{\exp(\mathbf{a} + \mathbf{b} X)}{1 + \exp(\mathbf{a} + \mathbf{b} X)} \\ &= \text{Pl}(\mathbf{X}^T \boldsymbol{\beta}) = \frac{\exp(\mathbf{X}^T \boldsymbol{\beta})}{1 + \exp(\mathbf{X}^T \boldsymbol{\beta})} \end{aligned} \tag{3.13}$$

Cramer [9] derived for the \mathbf{q} of 3.8 and \mathbf{H} of 3.11 for the logistic function as follows:

$$\mathbf{q} = \sum_i (Y_i - P_i(\boldsymbol{\theta})) \cdot \mathbf{x}_i \quad 3.14$$

$$\mathbf{H} = \sum_i P_i(\boldsymbol{\theta}) Q_i(\boldsymbol{\theta}) \mathbf{x}_i \mathbf{x}_i^T \quad 3.15$$

where $\boldsymbol{\theta}$ is the independent variable coefficient $\boldsymbol{\beta}$ in 3.13.

Substituting 3.14 and 3.15 to 3.12 yield the full iterative scheme for the logistic probability parameter estimation:

$$\begin{aligned} \boldsymbol{\theta}_{t+1} &= \boldsymbol{\theta}_t + \mathbf{H}(\boldsymbol{\theta}_t)^{-1} \mathbf{q}(\boldsymbol{\theta}_t) \\ \boldsymbol{\theta}_{t+1} &= \boldsymbol{\theta}_t + \left(\sum_i P_i(\boldsymbol{\theta}) Q_i(\boldsymbol{\theta}) \mathbf{x}_i \mathbf{x}_i^T \right)^{-1} \cdot \left(\sum_i (Y_i - P_i(\boldsymbol{\theta})) \mathbf{x}_i \right) \end{aligned} \quad 3.16$$

3.3.3. Estimation from Grouped Data

Variables in survey data are often in the form of a limited value set. Many independent variables with a capability for continuous variation are often limited to a few broad classes by the researcher or by the method and mechanism of the sample measurement and recording. In such cases, the estimation of logit parameters is taken based on *grouped data*.

To derive the parameter estimation from grouped data, consider data that are grouped into J classification, which denoted by $j = 1, 2, 3, \dots, J$ for the cells containing the grouped data. Each

cell consists of n_j number of observations wherein m_j observations have the dependent variable attribute. The relative frequency of the attribute in cell j then is expressed by,

$$f_j = \frac{m_j}{n_j} \quad 3.17$$

The maximum likelihood method can then be applied by treating the grouped data as a repeated individual observation. Following the method of estimation from individual data, for a grouped data, equation 3.14 and 3.15 become,

$$\mathbf{q} = \sum_j n_j (f_j - P_{1j}(\boldsymbol{\theta})) \bullet \mathbf{x}_j$$

$$\mathbf{q} = \sum_j (m_j - n_j P_{1j}(\boldsymbol{\theta})) \bullet \mathbf{x}_j \quad 3.18$$

and

$$\mathbf{H} = \sum_j (n_j P_{1j}(\boldsymbol{\theta}) \quad Q_{1j}(\boldsymbol{\theta})) \bullet \mathbf{x}_j \mathbf{x}_j^T \quad 3.19$$

Therefore the iteration equation (16) becomes,

$$\boldsymbol{\theta}_{t+1} = \boldsymbol{\theta}_t + \mathbf{H}(\boldsymbol{\theta}_t)^{-1} \mathbf{q}(\boldsymbol{\theta}_t)$$

$$= \boldsymbol{\theta}_t + \left(\sum_j (n_j P_{1j}(\boldsymbol{\theta}) \quad Q_{1j}(\boldsymbol{\theta})) \bullet \mathbf{x}_j \mathbf{x}_j^T \right)^{-1} \bullet \sum_j n_j (f_j - P_{1j}(\boldsymbol{\theta}) \quad Q_{1j}(\boldsymbol{\theta})) \bullet \mathbf{x}_j \quad 3.20$$

3.3.4. Estimating Significance

The estimation result from the participation probability model will include the estimated coefficients, their standard error and the resulting t-statistics. The interpretation and use of the t-statistic is identical to the ordinary linear regression case [12].

To calculate the standard error and the t-statistic of the coefficient estimates, let's call the information matrix H as in 3.10 :

$$\mathbf{H} = - E \mathbf{Q}$$

E is the expectation operator, which takes the mathematical expectation of each element of \mathbf{Q} .

The covariance matrix is of the MLE is then the inverse of H matrix of [9],

$$\mathbf{V} = \mathbf{H}^{-1} \tag{3.21}$$

Then standard errors of the coefficient estimates follow immediately by taking the square root of the diagonal element of the covariance matrix.

The t-statistic or t-value is a measure of the significance of each coefficient in the regression model. In the logit model, the t-value is the ratio of the coefficient estimates to their standard error, in absolute value [9]. The interpretation of the t-value is straightforward; value far from 0 contradict the hypothesis that the true value of coefficient estimate is zero and the hypothesis must be rejected. The standard procedure is to compare this computed t-value to a specific critical value of *Student's* distribution with N-K degrees of freedom, where N is the

number of data points and K is the number of coefficient [16]. Typically, a t -value of 10 would indicate a value of 99.9% confidence that the coefficient estimated is indeed not equal to zero. Normally, a t -value of 2 can be used as a cutoff point on which to judge whether the regression coefficient is a significant variable [17].

To test whether all the coefficients except the intercept are zero in the logit models, the likelihood ratio (LR) is also usually used. The LR test produces a statistics that approximately follows a chi-square distribution when the null hypothesis is true [16]. The likelihood ratio statistic is computed by:

$$LR = 2 \left(\log L(\beta) - \log L^0 \right) \quad 3.22$$

where $\log L(\beta)$ is the loglikelihood of the full model with all coefficient estimates, and $\log L^0$ is the *base line likelihood* [6], determined by:

$$\log L^0 = m \log f + (n - m) \log(1 - f) \quad 3.33$$

The m , n and f used in equation 3.33 are the number of observations, the number of observations with the dependent variable attribute and the relative frequency of the attribute respectively, as defined in equation 3.17. The formal test, then, is performed by comparing the calculated RL to a critical value taken from a table of the *chi-square* distribution with $K-1$ degrees of freedom and a certain significant level.

3.4. Customer Participation of Utility DSM Programs Modeling

In this section, the model to predict the customer response to utility DSM programs will be developed based on the logit model. The main purpose of the model is to demonstrate a general relationship between the payback period of a conservation technology measure investment and the level of customer response to the technology. The payback period of investment depends on the amount of investment and the amount of savings. The technical payback period required by the technology specification will, of course, not always be the same with the customer's payback period criteria. The customer's payback period criteria depend on their economic perception. A study [4] revealed that the individual discount rate of conservation technology investment of the customer, which may be implicitly expressed as payback period, varies with the customer income level. The study shows that income plays an important role in determining the individual discount rate.

The participation of an energy conservation program is affected by various demographic and non-demographic factors, as explained in the beginning of this chapter. Income is one of the most commonly used as a variable in demographic data survey. Therefore the modeling of DSM program acceptance will use the relationship between the income level and the participation level.

The individual payback period criteria are often related to income level of the individual. By incorporating the information of individual payback period for the appropriate income level to the model, a model of participation level in relation with the perceived payback period can be

developed. The model can then be used to predict the participation probability for a certain level of payback period.

Since the payback period depends on the investment of conservation technology, and the purpose of utility financial incentive is to decrease the customer's investment cost, then the effect of the utility incentive on the participation level can be predicted by a participation probability model.

3.4.1. The Data

For a study case in developing a model that can be applied as generally as possible, general energy related data provided by the Energy Information Administration of the US Department of Energy will be used. The data is mainly the information about household conservation activity by income level, and taken from EIA's 1990 Residential Energy Consumption Survey (RECS). This study is limited to the residential sector because, according to the EIA, this sector accounts for more estimated energy saved and more utility program than the commercial or industrial sector (Energy Information Administration, 1994). The data, as it has been recompiled for a study of income distribution effect on DSM programs [6], is in Table 3.1.

Table 3.1. Participation in Utility DSM Program by Income Classes

Income	1990 Household		Percent Participation of
	Number	Percent	DSM programs in Income Class
< \$ 5,000	1330	4	1.05
\$ 5,000 - \$ 9,999	3290	9.8	1.95
\$ 10,000 - \$ 14,999	3930	11.7	5.68
\$ 15,000 - \$ 24,999	6020	17.9	5.85
\$ 25,000 - \$ 34,999	5880	17.5	5.4
\$ 35,000 - \$ 49,999	6510	19.2	5.7
> \$ 50,000	6710	19.9	8.84
Total	33670	100	

Source : EIA, 1990 RECS

Note : the household number is in term of sample size (Shuttherland, 1994).

In order to develop a model that show the relationship between the participation and the individual payback period, an appropriate data on the income level and the individual payback period is required. However, there is no recent report that contains such data. Therefore, the individual payback period data should be obtained indirectly from other form of data.

There is a close mathematical relationship between the payback period and discount rate. Thus, the available individual discount rate data can be used to obtain the individual payback period data. Hausman [4] in 1979 reported a research on the relationship between income level and individual discount rate. The report presented the distribution of discount rate on various income levels, as in Table 3.2. The research was based on a study of the relationship between individual discount rate and purchase of various quality classes of room AC [4]. The result of the study will be used as the source of payback period data.

**Table 3.2 Estimated Individual Discount Rate by
Income Classes**

Income Classes	Individual Discount Rate
< \$ 5,000	89.0%
\$ 5,000 - \$ 9,999	39.0%
\$ 10,000 - \$ 14,999	27.0%
\$ 15,000 - \$ 24,999	17.0%
\$ 25,000 - \$ 34,999	8.9%
\$ 35,000 - \$ 50,000	5.1%

Source : Jerry A. Hausman, "The Bell Journal of Economic" v.10.n.1, 1979

Payback period can be calculated from the individual discount rate by using life-cycle cost (LCC) analysis of an investment. By definition, life-cycle cost of an investment is defined as

$$LCC = PC + \sum_i^n \frac{OC}{(1+i)^i} \quad 3.34$$

where PC, OC, i and n are purchase cost, annual operating cost, the applied discount rate and the investment lifetime, respectively. The discounted operating cost is equivalent to

$$\begin{aligned} \sum_i^n \frac{OC}{(1+i)^i} &= OC \cdot \left(\frac{1}{r(1-(1+i)^{-n})} \right) \\ &= OC \cdot PWF \end{aligned} \quad 3.35$$

where PWF is the present worth factor of the annual operating cost. The selection of an investment option logically will be the minimum of the LCC. Since the purchase cost is fixed, then the minimization is based on the operating cost, such that

$$\frac{dLCC}{dOC} = \frac{dPC}{dOC} + PWF = 0 \quad 3.36$$

A simple payback period is defined as the time that is required to recoup an investment. In the above case, the payback period is equal to the increase of purchase divided by the decrease of the annual operating cost, or mathematically is,

$$\text{Payback} = \frac{\Delta PC}{\Delta OC} = - \frac{dPC}{dOC} = PWF \quad 3.37$$

By applying equation 3.37 for various individual discount rates on Table 3.2, and assuming that the air-conditioner lifetime is about 10 years as presented in the report [4], the individual expectation of payback period by income classes are obtained as in Table 3.3.

Table 3.3 Individual Payback Period by

Income	Individual Payback Period (years)
< \$ 5,000	1.12
\$ 5,000 - \$ 9,999	2.47
\$ 10,000 - \$ 14,999	3.36
\$ 15,000 - \$ 24,999	4.66
\$ 25,000 - \$ 34,999	6.45
\$ 35,000 - \$ 49,999	7.68
> \$ 50,000	---

Assuming that the households in Table 3.1. who participate the utility DSM program have individual payback period as in Table 3.3., then a set of data to develop the participation probability is completed, as follows,

Table 3.4. Data for Participation modeling

Income	1990 Household		Percent Participation of DSM programs in Income	Individual Payback Period
	Number	Percent	Class	(years)
< \$ 5,000	1330	4	1.05	1.12
\$ 5,000 - \$ 9,999	3290	9.8	1.95	2.47
\$ 10,000 - \$ 14,999	3930	11.7	5.68	3.36
\$ 15,000 - \$ 24,999	6020	17.9	5.85	4.66
\$ 25,000 - \$ 34,999	5880	17.5	5.4	6.45
\$ 35,000 - \$ 49,999	6510	19.2	5.7	7.68
> \$ 50,000	6710	19.9	8.84	---
Total	33670	100		

3.4.2. The Resulting Model

To express the participation probability of the above data, the following logit model of the participation probability is to be used,

$$P = \frac{1}{1 + \exp^{-(\alpha + \beta_1 x_1 + \beta_2 x_2)}} \quad 3.38$$

where,

P = probability a household participate the DSM program

x_1 = log income of a household

x_2 = payback period offered to the household, in years

Now, using the equation 3.17 through 3.20, the maximum loglikelihood estimation for the logit model parameter can be carried out. The model is constituted by the participation probability in the DSM program as the dependent variable, and the mid-value of log income and the payback period criteria of each income as the independent variables x_{1j} and x_{2j} respectively. The estimation process of α , β_1 and β_2 provides the iteration result as shown in Table 3.5.

Table 3.5. Iteration Result of Parameter estimation for logit Probability Model

iteration k	α	β_1	β_2	$ \alpha^{k+1} - \alpha^k $	$ \beta_1^{k+1} - \beta_1^k $	$ \beta_2^{k+1} - \beta_2^k $
0	-2.8111	0	0	-1.9E+01	2.18E+00	-5.86E-01
1	-21.5816	2.1828	-0.5859	-1.1E+00	1.10E-01	-1.76E-02
2	-22.6655	2.2925	-0.6035	-7.42E-02	7.61E-03	-1.11E-03
3	-22.7396	2.3001	-0.6046	-2.10E-04	2.11E-05	-2.28E-06
3	-22.7398	2.3002	-0.6046	-1.70E-09	1.65E-10	-1.05E-11
4	-22.7398	2.3002	-0.6046	8.96E-14	-1.08E-14	3.42E-15
5	-22.7398	2.3002	-0.6046	-2.86E-14	3.39E-15	-1.24E-15
6	-22.7398	2.3002	-0.6046	1.39E-16	-1.14E-16	-1.63E-16

which leads to a participation probability model of

$$P = \frac{1}{1 + \exp^{-(-22.7398 + 2.3002 x_1 - 0.6046 x_2)}} \quad 3.39$$

Based on the coefficient of each independent variable of the resulting model, for a fixed payback period x_2 , the probability increases as the income level increases. In the contrary, for fixed income classes x_1 , the probability decreases by the increase of payback period. This means that to improve the probability of participation it is necessary to reduce the payback period.

Figure 3.2. shows the graphical presentation of the participation probability in each income class. The percent of participation is in term of total population of all income classes.

The statistic significance evaluation is conducted for the resulting model using the concept of t-value and LR test as described in section 4.3. The result of the significance evaluation is as follows:

$$\text{Covariance matrix } \mathbf{V} = \begin{bmatrix} 33.8450 & -4.0858 & 1.3416 \\ -4.0858 & 0.4942 & -0.1635 \\ 1.3416 & -0.1635 & 0.0556 \end{bmatrix}$$

	Coefficient		
	α	β_1	β_2
value	-22.7398	2.3002	-0.6046
standard error	5.8176	0.7030	0.2358
t-value	3.9088	3.2720	2.5641

LR test = 28.63.

The t-value of each coefficient shows that the coefficients are significant since with 4 degrees of freedom, the *Student's* distribution value is 2.132 with 5% critical value or 95% confidence level. Therefore the coefficients are significant and the null hypothesis must be rejected.

The LR test is conducted by the LR test equation 3.22. Upon comparing the final loglikelihood and the base-line value, it is found that the RL test value is 28.63. With 2 degrees of freedom, this is quite significant, for 5% critical value of *chi-square* distribution value is 5.99. The absence of any coefficient is thus rejected

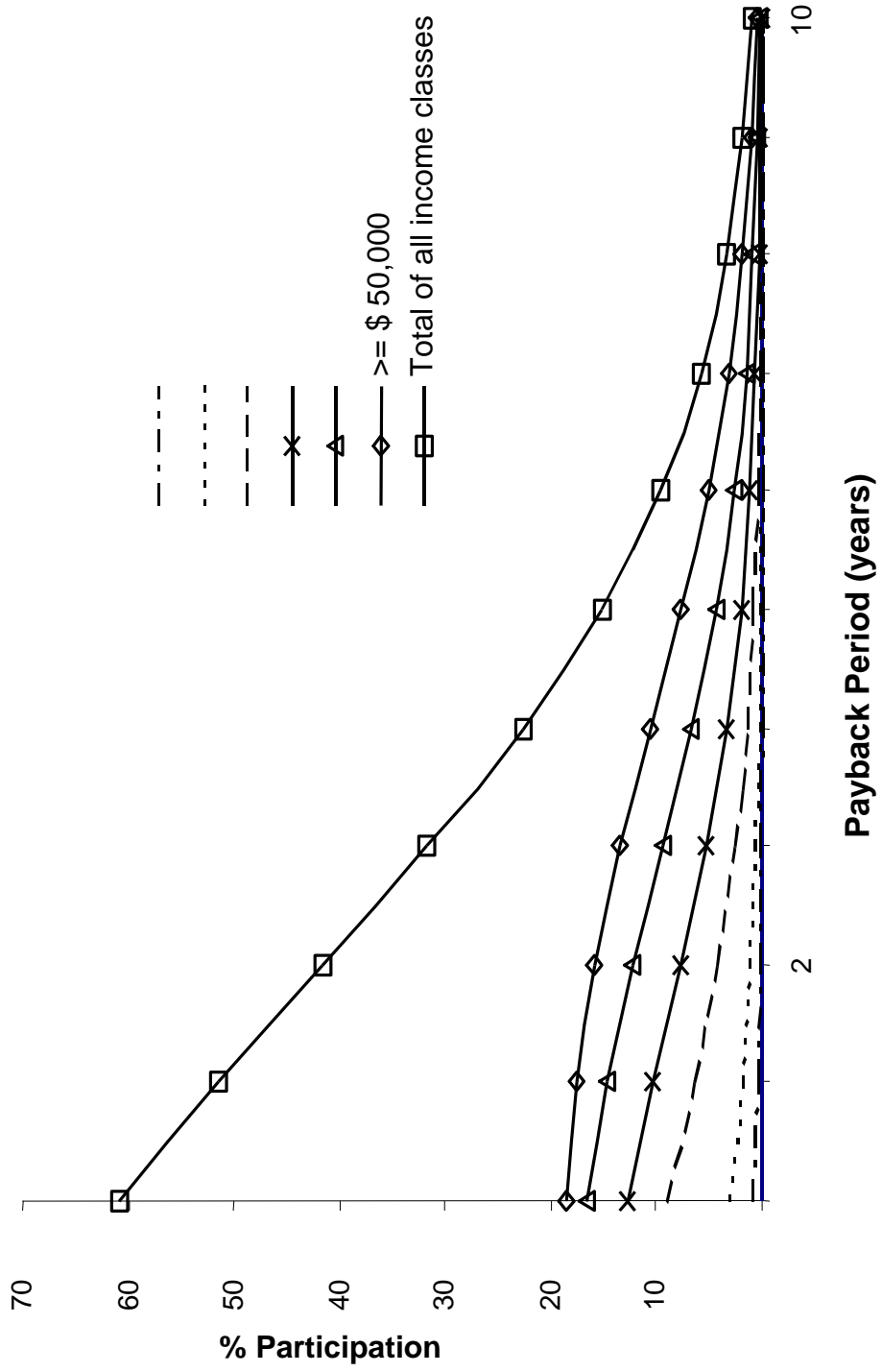


Figure 3.2. Customer Participation Probability by Income Classes

Finally, the model will be utilized to predict the effect of financial incentive in DSM programs on participation probability. From 3.37, it is shown that payback period depends on the incremental of investment and the decrement of operating cost. The operating cost decrement is fixed and set by the technical specification of the technology. But, the introduction of a financial incentive, such as purchase rebates, can reduce the increment of investment. Thus the payback period changes by the incentive. Using this relationship, the model represented by equation 3.39 can then estimate the participation probability changes due to incentive level changes.

The impact of the incentive on DSM programs and its optimum level can then be observed and determined using DSM program benefit and cost analysis. This analysis requires participation rate estimation resulted from the participation probability model. The analysis of benefit and cost of a DSM program, and the incentive impact analysis will be carried out in the next chapter.

3.5. Summary

Modeling the customer participation probability in utility DSM programs involves a regression of a multivariate, dichotomous dependent variable model. The dependent variable represents the customer participation with a value of 1 if the customer participates in the program and a 0 otherwise. In modeling the customer participation in a DSM program, a discrete choice estimation technique is the appropriate method.

The customer participation probability model in utility DSM programs was developed in this chapter. The model was developed using a logit function that represents a discrete choice model. The model uses the customer income and customer payback period requirement as the independent variables. The MLE method was utilized to estimate the variable coefficient. The significance evaluation of the estimated coefficients showed that they were significant. Therefore the association between the participation and both income and payback period is reasonably strong.

The objective of the modeling is to determine the statistical relationship between customer participation and customer characteristics. As shown in the resulting model, the customer participation is positively affected by their income level, while the payback period has a negative effect on participation. This means that customer participation is less if the perceived payback period is longer. To promote the customer participation, then, the payback period of a DSM program option has to be as short as possible.

The ultimate purpose of the model is to predict the customer participation level in the DSM program impact estimation. Given that the model explicitly express the relationship between participation and perceived payback period, the model can be used as a tool to estimate the change of the DSM program impact based on the change of the payback period. Since the payback period is inversely proportional to the utility financial incentive, the increase of incentives can be a driving factor for customer participation in DSM programs. In the next chapter, the customer participation probability model will be used to analyze the impact of incentives in DSM programs.

Chapter 4

DSM Cost-Benefit Determination and The Incentives Impact Analysis

4.1.Introduction

During the past several years, an increasing number of utilities have turned to energy-efficiency and demand-side management programs as alternative energy and capacity resources. However, with the increasing deregulation and competition in power markets in recent years, the momentum for DSM has slowed significantly [10]. It is therefore, becoming more important than ever for utility to closely assess the impact of their DSM programs. Evaluating programs is the key to ensuring that provide the resources expected in ways that are cost effective.

As described in chapter 2, cost-effectiveness evaluation plays a critical role in the design of DSM programs. A Utility should estimate the performance of DSM programs with the same competence and diligence with which they consider their supply side resources. DSM programs are not only expected to give the estimated impact on the energy and capacity reduction, but should also produce that impact in cost-effective ways. The tool used for determining DSM program impact is called the DSM programs impact evaluation. The evaluation measures program participation, participation acceptance of the recommended

DSM measures, performance of the DSM technologies, energy and load reduction performance, and program cost.

The cost-effectiveness of DSM programs is determined by the cost and the benefit of the program [2]. The purpose of the cost-effectiveness assessment is not only to ensure that the program is cost-effective, but also to estimate the net benefit that can be expected from the program. A cost-effective DSM program is one which yields a greater benefit obtained than the cost incurred by its implementation. Therefore it is important to identify all the costs and benefits of a DSM program. A cost-benefit analysis is required for assessing its cost-effectiveness, using all the costs and benefits of the program [11].

One of the important measures in assessing the cost-effectiveness of a DSM program is the achievable potential of DSM program saving [2]. The achievable potential of DSM program saving is a measure of the total energy and peak demand savings that are economically feasible. This takes into account the realistic estimation of customer participation rates. The estimated numbers of participants combined with the unit impact of DSM program options determine the aggregated DSM program impacts. In this regard, it is clear that the number of participant determines the achievable potential program saving. The effectiveness of a DSM program therefore ultimately depends on customer participation.

The customer decision to participate in a DSM program is effected by various factors. One major consideration on which customers base their decision is economic benefit. Specifically, customers are concerned with initial cost or investment recovery [7]. Therefore,

many utilities use the financial incentive method in their DSM programs implementation to encourage customer participation in these programs. The purpose of the incentive is to lower the initial cost so that a relatively faster investment recovery can be obtained. By lowering the initial cost, it is expected that participation rates will increase. A participation model based on a probability model is commonly used to estimate the participation rate under the incentive program influence [5,12].

Chapter 3 considers the modeling of customer participation. The model developed was based on a discrete choice probability model. Income level and discount rate were used as the variable for the participation probability function. The customer participation probability model will be used to estimate the participation rate.

The incentive impact on DSM programs will be analyzed in this chapter. The analysis begins by determining the unit cost and benefit of a DSM program. The aggregated DSM impacts can then be evaluated using unit cost and benefit, and the obtained customer participation rate. The net benefit, the difference between the benefit and the cost, can be used to analyze the impact of incentive. Since the participation level changes with the incentive level, the net benefit will fluctuate due to changes in the incentive level. The objective of this chapter is to analyze how the incentive level affect the net benefit of a DSM program and what other factors may influence it.

4.2. DSM Cost and Benefit Determination

In broad terms, cost-benefit analysis is the systematic enumeration of all benefits and all costs associated with a particular project. Its purpose is to guide decision-making. Cost-benefit analysis offers a logical framework for organizing information and stating the objective clearly. This does not necessarily simplify decisions and guarantee good results, but it does increase the likelihood of making informed decisions and considering all important factors.

A basic premise of the cost-benefit analysis approach is that one option is preferable to another if it results in a greater net benefit. In DSM program assessment, net benefit is defined simply as the difference between all benefits and costs associated with a DSM program option,

$$\text{Net Benefit} = \text{Total Benefit} - \text{Total Cost} \quad 4.1$$

In DSM program cost-effectiveness assessment, the benefit and cost associated with a particular DSM program option is viewed from the utility and/or the customer side. The assessment of the cost-effectiveness utilizes the benefit and cost from either utility or customer side, or both, depending on what type of test that is conducted.

In this research, the Ratepayer Impact Measurement (RIM) test and Total Utility Cost (TUC) test will be used as tools to analyze the impact of utility financial incentive on the net

benefit of a particular DSM program option. Justification for using the RIM test is not only that consider the incentive as a parameter in its component cost, but it also measures the difference between the change in utility revenue and the change of utility cost due to the implementation of DSM programs. Therefore, the impact can be analyzed in a wider context. The TUC test is used since it measures the net benefit of a particular DSM program from the utility point of view. Utilities consider DSM programs to be alternative resources. Therefore this test analyzes the impact of incentives on DSM programs as among a utility's alternative resources.

4.2.1. Benefits Determination.

The utility avoided cost is among the benefit components of DSM programs that are commonly used in both RIM and TUC tests include [2]. The utility avoided costs is generally defined as the expected costs of increased or decreased use of existing facilities or resources, or the expected cost of delaying or advancing additional resources [13,18]. The estimation of the DSM programs impact is generally based on the estimation of energy saving and peak capacity demand saving. Therefore, in this regard, the utility avoided cost will be the utility avoided energy cost and utility avoided capacity cost. Faruqi, et.al [2] suggests an estimation of the utility avoided costs as follows:

$$\text{Utility avoided energy cost} = \text{energy savings (kWh)} \times \text{marginal energy cost (\$/kWh)} \quad 4.2$$

$$\text{Utility avoided capacity cost} = \text{energy savings (kWh)} \times \text{marginal capacity cost (\$/kW)} \quad 4.3$$

where,

energy saving (kWh) = the aggregated impact of energy saving of DSM program implementation.

demand saving (kW) = the aggregated demand saving impact of DSM program implementation

The aggregate impact of a specific DSM program implementation is the total impact of the programs, taking into account the customer participation and other adjustment factors such as diversity and coincidence factor. Mathematically, the aggregate impact expressed in energy saving and demand saving can be estimated using the following formula [14] :

$$\text{Energy saving (kWh)} = \text{units} \times \left[\left(\frac{\text{kW}}{\text{unit}} \right)_{\text{base}} - \left(\frac{\text{kW}}{\text{unit}} \right)_{\text{ee}} \right] \times \text{FLH} \quad 4.4.$$

$$\text{Demand saving (kW)} = \text{units} \times \left[\left(\frac{\text{kW}}{\text{unit}} \right)_{\text{base}} - \left(\frac{\text{kW}}{\text{unit}} \right)_{\text{ee}} \right] \times \text{DF} \times \text{CF} \quad 4.5.$$

where:

units = number of technology unit installed under the DSM program, represented by participation rate

kW_{base} = load demand required by conventional equipment

kW_{ee} = load demand required by energy efficient equipment

FLH = full load operating hours

DF = demand diversity factor, factor that determined fraction of the total number of equipment that produce the maximum load

CF = coincident factor, fraction of measure demand saving that coincident with the utility system peak

Finally, for analyzing the benefit for a specific DSM program, the following determination is used:

$$\text{Benefit} = \text{Utility avoided energy cost} + \text{Utility avoided peak demand cost} \quad 4.6$$

If the energy savings and peak demand savings are determined on an annual basis, then the benefit will also be determined on an annual basis.

4.2.2. Costs Determination.

Formally, the cost components of a particular DSM program used in RIM and TUC tests include the energy and capacity costs, incentive expenses, and program costs paid by the utility [2,3]. The energy and capacity cost only occur when the DSM program is promoting the load growth, otherwise these costs are not considered for in the calculation. RIM test includes revenue losses incurred by the decrease of energy sales resulting from the implementation of DSM programs in its cost component.

The energy and capacity costs are calculated based on the increase of energy consumption and capacity demand. *Valley filling* and *strategic load growth* are the DSM program objectives that can produce such an increase [15]. The increase of energy consumption and capacity demand is usually estimated using an energy production

simulation with and without the existence of DSM programs. The difference of production cost between the two scenarios is the energy cost.

Through a strategic load growth, the load shape modification may also develop a new peak load demand. In that case, an additional cost will be required to provide additional capacity for covering the new demand. However, since the focus of this research is on the conservation strategies, the energy and capacity costs will not be explored further.

For the purpose of cost analysis in this research, the following cost determination is used:

RIM test : incentive expenses, cost paid by utility and revenue losses,

TUC test : incentive expenses and cost paid by utility.

Incentive expenses are the total expenses of incentives paid to the customer. The total expenses depend on the number of customers who participate in the program. As described earlier, the purpose of incentive is to reduce both the customer investment and the incremental investment cost of the higher efficiency technology option promoted by the programs. In the direct rebate program, the amount of incentive paid to each participant generally is a portion of the investment cost. The incentive expenses is expressed as follows:

$$\text{Incentive expenses} = \text{units} \times \text{incentive } (\$/\text{unit}) \quad 4.7$$

where:

units = number of technology unit installed under the DSM program,
represented by participation rate.

To estimate incentive expenses on an annual base, the incentive expenses should be converted to an annual equivalent value.

Other costs paid by a utility may include the cost of hardware owned by the utility, and administration and promotional cost. The amount of the cost may vary from one program or utility to another. However, the hardware investment cost is usually the main component of the overall cost. Therefore, this cost will be neglected for the program that does not require hardware investment in utilities.

Revenue losses accounted in RIM test are the decrease of energy sales by a utility due to implementation of DSM programs. The promotion of energy conservation objectives in DSM programs is intended to reduce the utility system energy consumption. Yet, the resulting decrease of energy consumption can reduce the utility revenue because of energy sales shrinkage. Total loss of revenue is simply the product of the electricity rate and the total energy saving, as expressed in the following:

$$\text{Revenue losses} = \text{energy saving (kWh)} \times \text{electricity rate (\$/kWh)} \quad 4.8$$

If the energy savings are determined on an annual basis, and if there is no

electricity rate change during the year, then the product of equation 4.8. is an annual revenue loss.

4.3. Effect of Financial Incentives in DSM programs

The aim of financial incentives in DSM program is to increase the participation rate by reducing the initial cost required for technology option purchases. The decrease of the initial purchase price will reduce the payback period (i.e. increase the rate of return), thus will make the investment more attractive. Incentives may also reduce the customer resistance to options without proven performance histories or options that will involve extensive modification of customer's lifestyle.

To analyze the impact of incentive on DSM programs, it is necessary to review the effect of financial incentives in the program. In general, there are two related incentive effects. The first, is the effect to the utilities, since incentives are intended to promote their DSM programs. The second effect of the incentives is to the customer as the target of the DSM program. The combination of both effects constitutes the incentive impact on the programs. The following describes each of the effects.

4.3.1. The Effect of Incentives upon Utilities

Utilities implement the financial incentives in their DSM programs to attract their customers to participate in the program. In most of the cases, the result will be a comparative increase of

participant rates compared. Likewise, the participation rate is expected to be higher when the level of incentives is increased. In general, the direct effect of incentives to utility are as follows:

Energy and peak demand saving impact – as described earlier, the level of incentive affect the participation rate. The higher the level of incentives the higher the participation rate, and therefore as the incentive level increases, the energy and peak demand saving impact can also be expected to increase. This can be also verified by equations 4.4 and 4.5.

DSM program cost impact – the cost of a DSM program can increase as the incentive level increases. Since the participation rates increases with the incentives, the total utility expenses for incentives will increase significantly as the program achieved a higher rate of participation. Moreover, the participation increase will decrease the utility revenue. This implies that higher participation rates caused by higher incentive levels could lead to a drawback in DSM programs by decreasing the net benefit of the program.

4.3.2. The Effect of Incentives upon the Customer.

In many cases, the initial costs for more energy-efficient technology options are higher than those for the less efficient units, but the operation and maintenance cost of the higher efficiency unit are usually lower. Therefore a large initial investment cost will result in saving later on, ultimately equaling and then exceeding the initial price difference. The implicit discount rate (or rate of return on investment) of utility customer as the buyer determines how soon the energy-efficient technology option must “payback” the differential initial investment. As a shorter the

payback is required, the individual customer's discount rate will increase, and the customer will be less willing to invest in energy-efficient option.

In the previous chapter, a mathematical approach was used to model the relationship between the payback period and the likelihood the customer participation in DSM program. This model verifies that the probability of participation is larger if the payback period offered from the energy-efficient option is shorter. This means that to overcome the low willingness to invest, there should be an effort to reduce the initial cost, thus decreasing the offered payback period. Using this model, one can ascertain not only the effects of other differences in performance characteristics on implicit discount rate, as well as demographic characteristics of customers.

It has been shown in the participation probability model that the payback period can effect the customer's probability to participate. In this concern, utility's financial incentive programs can induce the customer participation in the DSM program. It has been shown that the higher the incentive level, the shorter the payback period offered, and thus the higher the participation level.

However, taking into consideration the incentive affect upon the utility, there should be an analysis to determine the level of incentive. As explained earlier, the implementation of incentive program could lessen the value of DSM programs by decreasing the net benefit of the program. To determine the most cost-effective level of incentive for a particular energy-efficient technology, the change in the net benefit of the program should be evaluated over the change of incentive level. The most cost-effective level of incentive can be determined by using the

participation probability model to find the participation level and the calculation of the program cost and benefit implication,.

4.4. DSM Cost-Benefit Analysis.

Cost-benefit analysis will be used to analyze the impact of incentive to utility DSM programs. The cost-benefit analysis, as it has been described in the previous part of this chapter, is simply the analysis of the net benefit of a program. A methodology to analyze the incentive impact can be developed by using the cost and benefit determination of a DSM program, as described earlier:

1. Estimating the Participation Rate.

To estimate the participation rate, a participation probability model should be developed. It should implicitly express the relation between the incentive level and the participation probability. EPRI and relevant literature [4,9,12] suggest that discrete choice models based on the logistic probability function is the most appropriate model to represent the relationship.

2. Determining the Benefit and Cost of the Program.

As explained before, the benefit of the program consists of the utility avoided costs, as expressed in equations 4.4, 4.5 and 4.6. On the other hand, the costs of the program

consist of the incentive expenses and revenue losses, as in equation 4.7 and 4.8, depends on the type of test will be used.

3. Determining the DSM Option Payback Period.

A simple payback period is used to estimate the DSM option payback period as follows:

$$PB = \frac{\text{Incremental Customer Investment Cost (\$)}}{(\text{Annual energy saving (kWh)} \times \text{Electricity rate (\$/kWh)})} \quad 4.9$$

where PB is the DSM option payback period in years.

4. Determining the Incentive Range.

The DSM option payback period and the incremental customer investment cost determine the range of incentive that can be offered to the customer. Since the participation level is related to the payback period, therefore it is also related to the incentive level. The DSM option payback period determined by equation 4.9. can then be modified to meet with the customer's payback period requirement by decreasing the incremental investment cost by a certain level of incentive:

$$CPP = \frac{(\text{Incremental Customer Investment Cost (\$)} - \text{Incentive (\$)})}{\text{Annual energy saving (kWh)} \times \text{Electricity rate (\$/kWh)}} \quad 4.10$$

$0 \leq \text{Incentive} \leq \text{Incremental Customer Investment Cost}$ where CPP is the customer payback period requirement in years. The range of incentive level then is between zero to the value of incremental customer investment cost.

5. Simulating the Net Benefit Analysis of DSM Programs

Having determined the participation probability model, and the relation of the customer payback period and incentive level as in 4.10, the net benefit analysis is then conducted.

The analysis evaluates the change of net benefit due to the change of incentive level within its range. Using equation 4.4 through 4.8 the net benefit is:

$$\text{Net Benefit} = \text{Benefit} - \text{Costs} \quad 4.11$$

where Benefit is defined by 4.6 and Costs depends on the type of test,

RIM test, $\text{Costs} = \text{Incentive expenses} + \text{Revenue losses}$

TUC test, $\text{Costs} = \text{Incentive expenses}$

Since the incentive is related to the participation probability, changing the incentive will change the participation rate. The change of participation rates result in a change of net benefit. Therefore, the incentive effect on the net benefit of a DSM programs option can be observed.

4.5. Case Studies

To demonstrate the analysis methodology, two case studies of DSM program options will be conducted. The cases are the Peak Clipping Program by High EER Room AC and the Energy Conservation Program by High-Efficiency Refrigerator and Freezer. The cases use DSM program options data that are taken from several EPRI report [1,2,11]. The marginal energy and capacity costs as well as the electricity rate use typical values, which are taken from the report also. For both case studies, the participation probability function developed in Chapter 3, and the number of customer and their income characteristics [9] as described in the following table, will be used:

Table 4.6. Customer Characteristic

	Income Class Segment						
	1	2	3	4	5	6	7
Income (\$/year)	4,000	7,500	12,500	20,000	30,000	42,500	60,000
<i>Number of Customers</i>	1,330	3,290	3,930	6,020	5,880	6,510	6,710

Total Customer: 33,670

Customer participation probability function:

$$\text{Probability} = \frac{1}{1 + \exp^{-(-22.7396 + 2.3002 x_1 - 0.6046 x_2)}}$$

where:

x_1 = log income of income segment class

x_2 = payback period (years) offered by utility for a particular DSM program option.

4.5.1. CASE STUDY 1 : Energy Efficiency and Peak Clipping by High-EER AC

The objective of this DSM program is to provide peak clipping of the utility load shape. The utility plan to implement a financial incentive program to encourage its customer for participating in the program. The following assumptions are used in the analysis:

- The marginal energy cost, electricity rate and the capacity replacement cost are constant over the evaluation period.
- The incentives is considered as an investment from utility point of view, therefore the fixed charge rate will be use to obtain the annual equivalent value of incentive expenses.
- The energy saving characteristics of the option has been converted to an annual basis.
- The capacity saving characteristic of the option has accounted the diversity and coincidence factor, and also been converted to an annual basis.
- RIM test and TUC test will be used for the analysis.

The data that are used to analyze the impact are as follows:

Utility Characteristics:

Marginal Energy Cost (\$/kWh)	:	0.06
Residential Electricity rate (\$/kWh)	:	0.080
Marginal Cap.Replacement Cost (\$/KW)	:	90
Fixed Charge Rate, FCR (%)	:	15

Equipment Saving Characteristics:

Annual energy saving (kWh/unit)	:	1000
Annual peak load saving (kW/unit)	:	0.68
Incremental Customer Investment Cost (\$/unit):		400
Annual Energy Cost Saving (\$/year)	:	60
Annual Peak Demand Cost Saving (\$/year)	:	61.2
Annual Revenue Lost (\$/participant/year)	:	80
Annual Incentive Expenses (\$/participant/year):		FCR x incentive/participant

Implementing the methodology developed above, the result of incentive effect on the DSM program option is obtained as described in the following Table 4.2, 4.3 and 4.4.

The simulation result in Table 4.2 shows that the incentive increases the participation rate, since it reduces the payback period of the incremental customer investment cost. As a consequence, both the DSM program cost and benefit are increasing. However, the rate of increase of cost is higher than the rate of increase of benefit. The difference is due to the factors that affected the benefit and the cost. The total benefit is a product of a constant unit avoided cost and the participation rate. Whereas, incentive expenses that increase with the participation rates, affect the total cost. As a result, while the increase of total benefit only depends on the increase of participation rate, the increase of total cost is affected by both the increase of incentive expenses and participation rates.

Figure 4.1 and 4.2 show the impact characteristic of incentives for this program. In Figure 4.1, the evaluation with RIM test shows that the net benefit slightly increases by the increase of incentive, and it start decreases after reaching the a maximum point of utility net benefit. The maximum net benefit of this case is \$ 223,620 when the incentive is \$ 60. The TUC test result is shown in Figure 4.2. The result shows that the utility net benefit reaches it maximum at \$ 1,274,538 by a level of incentive of \$ 360.

Cost components of a RIM test include the incentive expenses and revenue losses. In the other hand, a TUC test includes only incentive expenses in its cost component. Since the benefits of both tests are the same, higher incentive is required to achieve maximum net benefit of TUC test than in the RIM test. These explain the difference of the RIM and TUC test result.

Even though have different values, both test results indicate that incentives do not always increase the net benefit; the increase becomes smaller as the incentive level is higher. Given these characteristics, the most cost-effective incentive level, in term of the maximum net benefit, can be determined for this particular DSM program.

Table 4.2. Incentive Effect on Participation Rate in Case Study 1

incentive (\$)	payback period (years)	probability to participate¹⁾	Number of participants²⁾
0	5.00	0.15	5,101
20	4.75	0.17	5,677
40	4.50	0.19	6,292
60	4.25	0.21	6,945
80	4.00	0.23	7,633
100	3.75	0.25	8,353
120	3.50	0.27	9,103
140	3.25	0.29	9,879
160	3.00	0.32	10,676
180	2.75	0.34	11,491
200	2.50	0.37	12,319
220	2.25	0.39	13,156
240	2.00	0.42	13,999
260	1.75	0.44	14,843
280	1.50	0.47	15,685
300	1.25	0.49	16,521
320	1.00	0.52	17,349
340	0.75	0.54	18,165
360	0.50	0.56	18,966
380	0.25	0.59	19,752
400	0.00	0.61	20,519

Table 4.3. Incentive Effect on Net Benefit in Case Study 1 (RIM Test)

incentive (\$)	Total Cost (\$)	Total Benefit (\$)	Total Net Utility Benefit (\$)
0	408,100	618,272	210,172
20	471,185	688,044	216,859
40	541,110	762,588	221,478
60	618,079	841,699	223,620
80	702,220	925,098	222,878
100	793,581	1,012,442	218,861
120	892,130	1,103,329	211,198
140	997,762	1,197,315	199,552
160	1,110,298	1,293,924	183,626
180	1,229,494	1,392,661	163,167
200	1,355,055	1,493,024	137,969
220	1,486,635	1,594,515	107,880
240	1,623,853	1,696,646	72,793
260	1,766,298	1,798,952	32,654
280	1,913,539	1,900,991	-12,548
300	2,065,130	2,002,350	-62,780
320	2,220,621	2,102,651	-117,971
340	2,379,558	2,201,545	-178,013
360	2,541,490	2,298,721	-242,769
380	2,705,977	2,393,901	-312,076
400	2,872,590	2,486,842	-385,748

Table 4.4. Incentive Effect on Net Benefit in Case Study 1 (TUC Test)

incentive (\$)	Total Cost (\$)	Total Benefit (\$)	Total Net Utility Benefit (\$)
0	0.0	618,271.7	618,271.7
20	17,030.8	688,043.7	671,012.9
40	37,751.9	762,587.8	724,835.9
60	62,502.4	841,698.9	779,196.5
80	91,593.9	925,098.3	833,504.4
100	125,302.2	1,012,441.7	887,139.5
120	163,860.7	1,103,328.6	939,467.9
140	207,455.5	1,197,314.6	989,859.1
160	256,222.5	1,293,923.7	1,037,701.2
180	310,246.3	1,392,661.0	1,082,414.8
200	369,560.5	1,493,024.3	1,123,463.8
220	434,150.1	1,594,514.9	1,160,364.8
240	503,954.4	1,696,646.4	1,192,692.0
260	578,870.7	1,798,952.2	1,220,081.4
280	658,759.2	1,900,990.9	1,242,231.7
300	743,447.0	2,002,350.5	1,258,903.5
320	832,732.9	2,102,650.7	1,269,917.7
340	926,392.7	2,201,544.9	1,275,152.3
360	1,024,182.6	2,298,720.9	1,274,538.3
380	1,125,844.6	2,393,901.0	1,268,056.5
400	1,231,110.0	2,486,842.2	1,255,732.2

4.5.2. CASE STUDY 2 : Strategic Conservation by Energy Efficient Refrigerator and Freezer

The objective of this DSM program is to provide strategic conservation over the utility load shape. The choice of the energy efficient refrigerator based on the fact that the operation of refrigerator is not significantly affected by weather, i.e. it apply during all time. Not as in the peak clipping objective, the strategic conservation peak load demand reduction is low, if any, and typically in the range of less then 0.5 kW [15]. The utility plan to implement a financial incentive program to encourage its customer for participating in the program. The assumptions that are used in the previous case study are applied in the analysis.

CASE STUDY 1 : Peak Clipping by High-EER

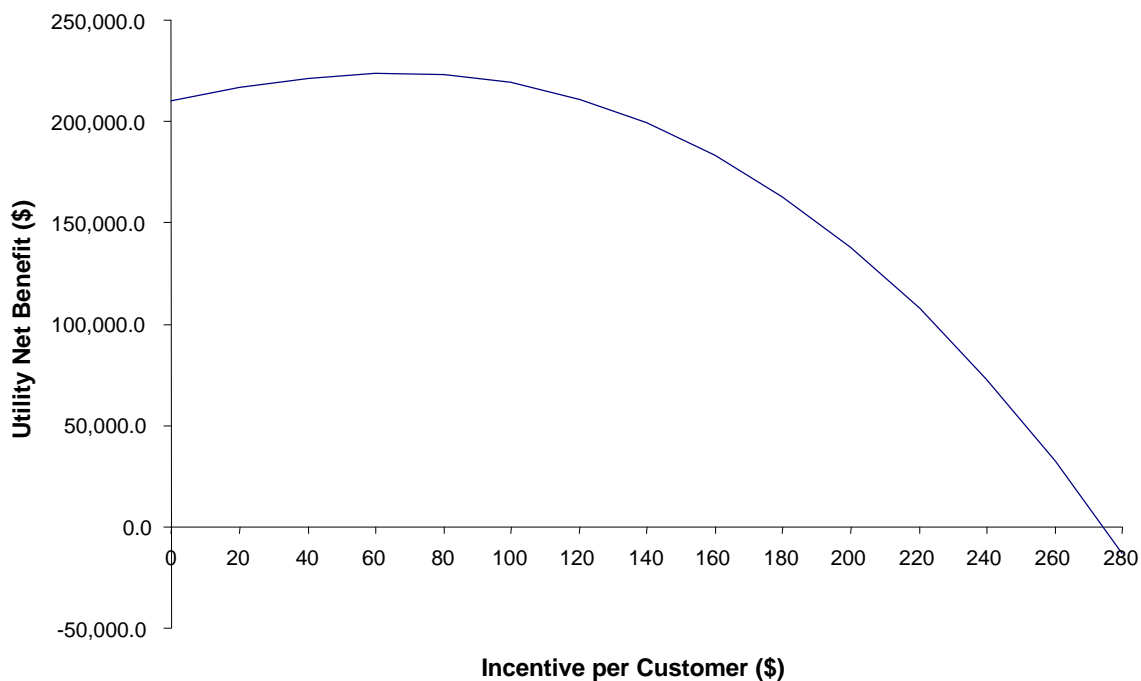


Figure 4.1. Incentive effect on net benefit for Case Study 1 (RIM Test).

CASE STUDY 1 : Peak Clipping by High-EER AC

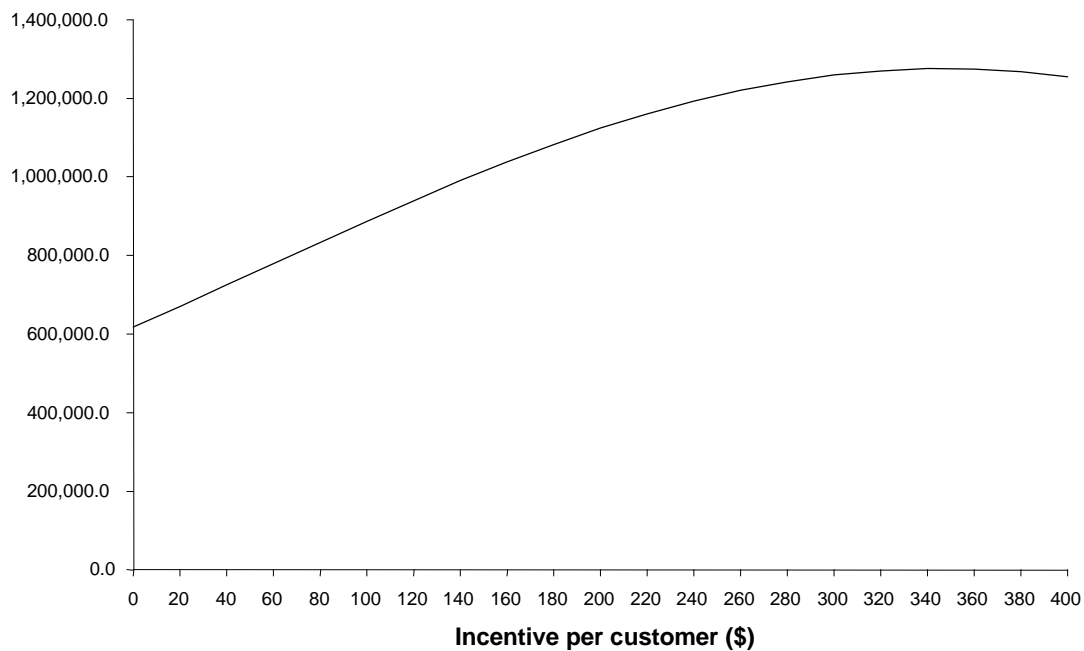


Figure 4.2. Incentive effect on net benefit for Case Study 1 (TUC Test).

Utility Characteristics:

Marginal Energy Cost (\$/kWh)	:	0.060
Residential Electricity rate (\$/kWh)	:	0.080
Marginal Cap.Replacement Cost (\$/KW):		90
Fixed Rate Cost (%)	:	15

Equipment Saving Characteristics:

Annual energy saving (kWh/unit)	:	600
Annual peak load saving (kW/unit)	:	0.40
Incremental Customer Investment Cost (\$/unit):		200
Annual Energy Cost Saving (\$/year):		36
Annual Peak Demand Cost Saving (\$/year):		36
Annual Revenue Lost (\$/customer/year):		48
Annual Incentive Expenses (\$/participant/year):		FCR x incentive/participant

Using the same methodology as in the previous case, the result of incentive effect on the DSM program option is obtained and described in the following Table 4.5, 4.6.and 4.7.

As what has found in the previous case study, the second case study results also show that the increase in incentive will increase the participation rate, but by a higher rate. The difference

occurs since the technology option in the second case study has lower original payback period, therefore the initial participation probability is higher than the first case.

In the cost and benefit point of view, both the DSM program cost and benefit are also increase, like what was obtained in the previous case. The same analysis of cost and benefit are also applied to this program. However, in this case the rate of increase of cost and benefit is lower than the first case. This is because that the cost saving characteristics of this option is lower than the previous case. Therefore, even though the initial participation rate is already high, the total cost and benefit are still low.

In the RIM test, the introduction of incentive improves the net benefit only at low level of incentive; higher level will decline it. The high initial participation rate causes a high revenue loss. Therefore the improvement of participation rate by the incentives will make the revenue loss even greater. This is shown in Figure 4.3 where the utility net benefits increase reaches the maximum point at \$ 175,423 with \$ 20 level of incentive.

TUC test results in a same pattern with the previous case, but with a different value. As it can be observed from the equipment saving characteristics, both cases are not the same. The second case has lower value of saving characteristic components. Therefore, lower total benefit is expected.

Table 4.5. Incentive Effect on Participation Rate in Case Study 2

incentive (\$)	payback period (years)	probability to participate	Number of participants
0	4.17	0.21	7170
10	3.96	0.23	7751
20	3.75	0.25	8353
30	3.54	0.27	8977
40	3.33	0.29	9618
50	3.13	0.31	10275
60	2.92	0.33	10946
70	2.71	0.35	11628
80	2.50	0.37	12319
90	2.29	0.39	13016
100	2.08	0.41	13717
110	1.88	0.43	14421
120	1.67	0.45	15124
130	1.46	0.47	15825
140	1.25	0.49	16521
150	1.04	0.51	17211
160	0.83	0.53	17894
170	0.63	0.55	18567
180	0.42	0.57	19230
190	0.21	0.59	19881
200	0.00	0.61	20519

Table 4.6. Incentive Effect on Net Benefit in Case Study 2 (RIM Test)

incentive (\$)	Total Cost (\$)	Total Benefit (\$)	Total Net Utility Benefit (\$)
0	344,173	516,260	172,087
10	383,663	558,055	174,392
20	426,027	601,451	175,423
30	471,267	646,309	175,042
40	519,358	692,478	173,119
50	570,259	739,795	169,536
60	623,908	788,094	164,186
70	680,226	837,201	156,975
80	739,121	886,945	147,824
90	800,486	937,154	136,668
100	864,202	987,660	123,457
110	930,144	1,038,300	108,156
120	998,177	1,088,920	90,743
130	1,068,161	1,139,371	71,211
140	1,139,952	1,189,515	49,563
150	1,213,404	1,239,221	25,817
160	1,288,370	1,288,370	0
170	1,364,702	1,336,851	-27,851
180	1,442,254	1,384,564	-57,690
190	1,520,881	1,431,417	-89,464
200	1,600,443	1,477,332	-123,111

Table 4.7. Incentive Effect on Net Benefit in Case Study 2 (TUC Test)

incentive (\$)	Total Cost (\$)	Total Benefit (\$)	Total Net Utility Benefit (\$)
0	-	516,260	516,260
10	11,626.1	558,055	546,428
20	25,060.4	601,451	576,390
30	40,394.3	646,309	605,914
40	57,706.5	692,478	634,771
50	77,062.0	739,795	662,733
60	98,511.7	788,094	689,582
70	122,091.9	837,201	715,109
80	147,824.2	886,945	739,121
90	175,716.3	937,154	761,438
100	205,762.4	987,660	781,897
110	237,943.8	1,038,300	800,357
120	272,230.1	1,088,920	816,690
130	308,579.8	1,139,371	830,792
140	346,941.9	1,189,515	842,573
150	387,256.7	1,239,221	851,965
160	429,456.7	1,288,370	858,913
170	473,468.1	1,336,851	863,383
180	519,211.4	1,384,564	865,352
190	566,602.8	1,431,417	864,815
200	615,555.0	1,477,332	861,777

4.5.3. Incentive Impact on DSM Programs at Different Marginal Energy Costs

The characteristics of utilities are usually different one to another. In most cases, the Marginal Energy Cost can fluctuate very often [12]. Therefore this cost may differ from utility to utility. In the following analysis, the impact of incentive on DSM program will be analyzed under different marginal energy cost. The purpose of the analysis is to provide the empirical association between the incentive level and the marginal energy cost.

CASE STUDY 2 : Strategic Conservation by Energy Efficient Refrigerator and Freezer

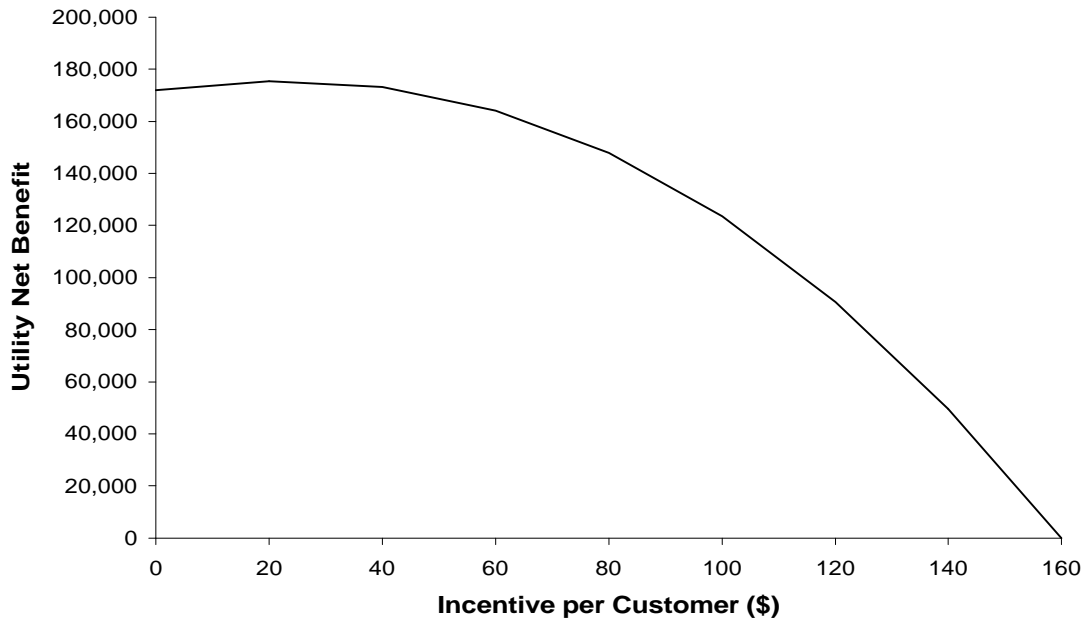


Figure 4.3. Incentive effect on net benefit for Case Study 2 (RIM Test).

CASE STUDY 2 : Strategic Conservation by Energy Efficient Refrigerator and Freezer

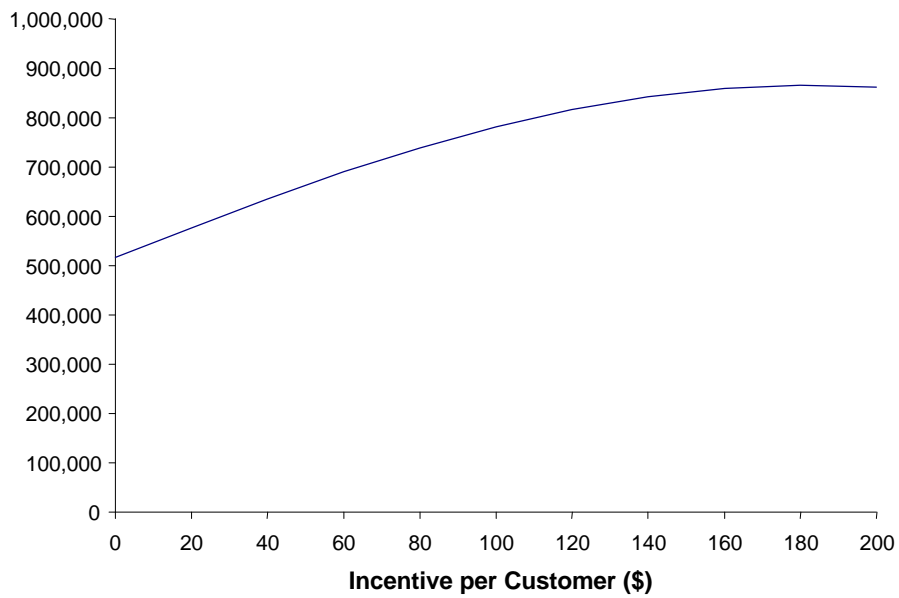


Figure 4.4. Incentive effect on net benefit for Case Study 2 (TUC Test).

To conduct the analysis, the two case studies above are used. The cases are again be evaluated, but over several value of marginal energy cost. The following is the result of the simulation.

CASE STUDY 1 : Energy Efficiency and Peak Clipping by High-EER AC

Utility Characteristics:

Marginal Energy Cost (\$/kWh) : varies

Equipment Saving Characteristics:

Annual energy saving (kWh/unit) : 1000

Annual peak load saving (kW/unit) : 0.68

Incremental Customer Investment Cost (\$/unit): 400

CASE STUDY 2 : Strategic Conservation by Energy Efficient Refrigerator and Freezer

Utility Characteristics:

Marginal Energy Cost (\$/kWh) : varies

Equipment Saving Characteristics:

Annual energy saving (kWh/unit) : 600

Annual peak load saving (kW/unit) : 0.40

Incremental Customer Investment Cost (\$/unit): 200

As already stated previously, the benefit of DSM program proportionally increases with the utility avoided energy and capacity cost as expressed in 4.6. While, the utility avoided energy

cost is linearly increase by the marginal energy cost, as expressed in 4.2. Therefore for a certain level of incentive, the benefit of higher marginal cost will greater than the lower one.

The results are presented in Table 4.8 and 4.9 for the RIM test, and Table 4.10 and 4.11 for the TUC test. As can be observed from the results, the incentive impacts the DSM program net benefit in a greater value at a higher marginal cost. Figure 4.5 and 4.6 show that incentives do not always give improvement in the utility net benefit. Lower marginal cost does not provide an adequate avoided energy cost for compensating the revenue loss. As a result, as the incentive increases, the net benefit does not improve but instead declines in value.

The performance of DSM program as a utility alternative resource is shown in Figure 4.7 and 4.8. These are the result of analysis using the TUC test. Both figure have a common pattern; incentives improve the utility net benefit significantly if the marginal cost is high. Also that there is a maximum value of incentive level. The increase of incentives will be followed by the increase of the participation rates, and this will result in a considerable increase in incentive expenses. Therefore, as a consequence, the higher the incentive, the lower the increase of net benefit is resulted, as can be seen in figure 4.7 and 4.8.

The simulation provides information to utilities in applying the incentive method in their DSM program. The information is particularly on whether or not the incentive method can improve the DSM program net benefit in a cost-effective way, taking into consideration of the utility marginal energy cost

Table 4.8. Impact of Incentive on DSM Program Net Benefit at Various Marginal Energy Cost level for Case Study 1 (RIM Test).

incentive (\$)	Marginal Energy Cost (\$/kWh)				
	0.05	0.055	0.06	0.065	0.07
	Total Net Utility Benefit (\$)	Total Net Utility Benefit (\$)	Total Net Utility Benefit (\$)	Total Net Utility Benefit (\$)	Total Net Utility Benefit (\$)
0	159,159	184,665	210,172	235,678	261,184
20	160,089	188,474	216,859	245,243	273,628
40	158,558	190,018	221,478	252,938	284,397
60	154,173	188,896	223,620	258,343	293,067
80	146,550	184,714	222,878	261,043	299,207
100	135,326	177,094	218,861	260,629	302,396
120	120,165	165,681	211,198	256,715	302,232
140	100,764	150,158	199,552	248,947	298,341
160	76,867	130,246	183,626	237,006	290,386
180	48,261	105,714	163,167	220,620	278,073
200	14,782	76,376	137,969	199,563	261,156
220	-23,681	42,099	107,880	173,660	239,440
240	-67,194	2,800	72,793	142,787	212,781
260	-115,774	-41,560	32,654	106,868	181,083
280	-169,395	-90,972	-12,548	65,876	144,300
300	-227,990	-145,385	-62,780	19,825	102,430
320	-291,457	-204,714	-117,971	-31,227	55,516
340	-359,658	-268,836	-178,013	-87,190	3,633
360	-432,433	-337,601	-242,769	-147,937	-53,106
380	-509,593	-410,835	-312,076	-213,318	-114,560
400	-590,933	-488,340	-385,748	-283,155	-180,563

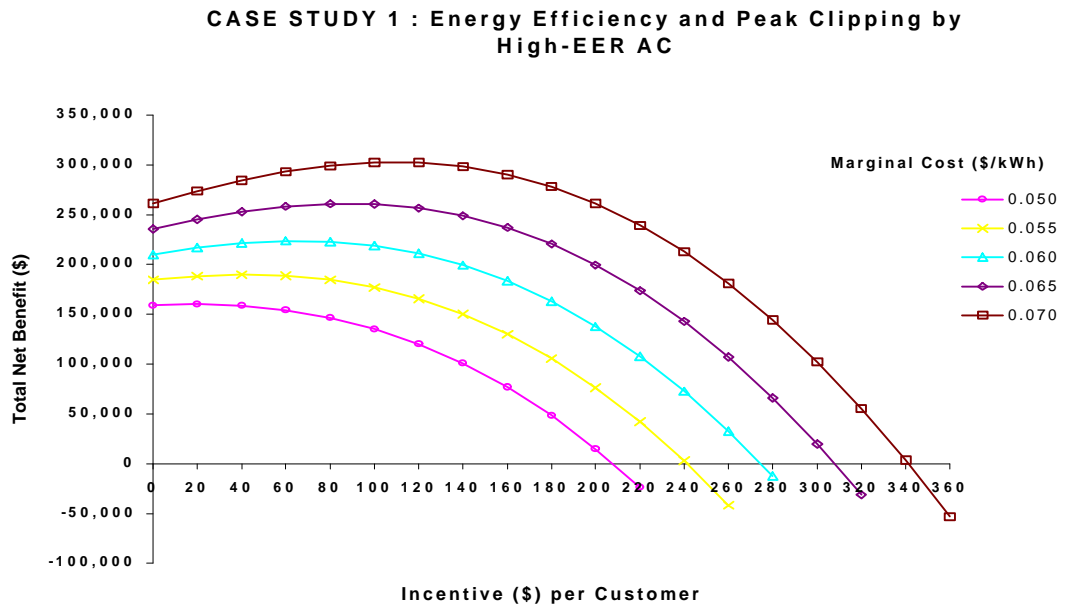


Figure 4.5. Incentive impact at various marginal energy cost for Case Study 1(RIM Test).

Table 4.9 Impact of Incentive on DSM Program Net Benefit at Various Marginal Energy Cost level for Case Study 2 (RIM Test).

incentive (\$)	Marginal Energy Cost (\$/kWh)				
	0.5	0.55	0.6	0.65	0.7
	Total Net Utility Benefit (\$)	Total Net Utility Benefit (\$)	Total Net Utility Benefit (\$)	Total Net Utility Benefit (\$)	Total Net Utility Benefit (\$)
0	129,065	150,576	172,087	193,598	215,108
10	127,888	151,140	174,392	197,644	220,897
20	125,302	150,363	175,423	200,484	225,544
30	121,183	148,112	175,042	201,971	228,901
40	115,413	144,266	173,119	201,973	230,826
50	107,887	138,712	169,536	200,361	231,186
60	98,512	131,349	164,186	197,023	229,861
70	87,208	122,092	156,975	191,859	226,742
80	73,912	110,868	147,824	184,780	221,736
90	58,572	97,620	136,668	175,716	214,764
100	41,152	82,305	123,457	164,610	205,762
110	21,631	64,894	108,156	151,419	194,681
120	0	45,372	90,743	136,115	181,487
130	-23,737	23,737	71,211	118,685	166,158
140	-49,563	0	49,563	99,126	148,689
150	-77,451	-25,817	25,817	77,451	129,086
160	-107,364	-53,682	0	53,682	107,364
170	-139,255	-83,553	-27,851	27,851	83,553
180	-173,070	-115,380	-57,690	0	57,690
190	-208,748	-149,106	-89,464	-29,821	29,821
200	-246,222	-184,667	-123,111	-61,556	0

CASE STUDY 2 : Strategic Conservation by Energy Efficient Refrigerator and Freezer

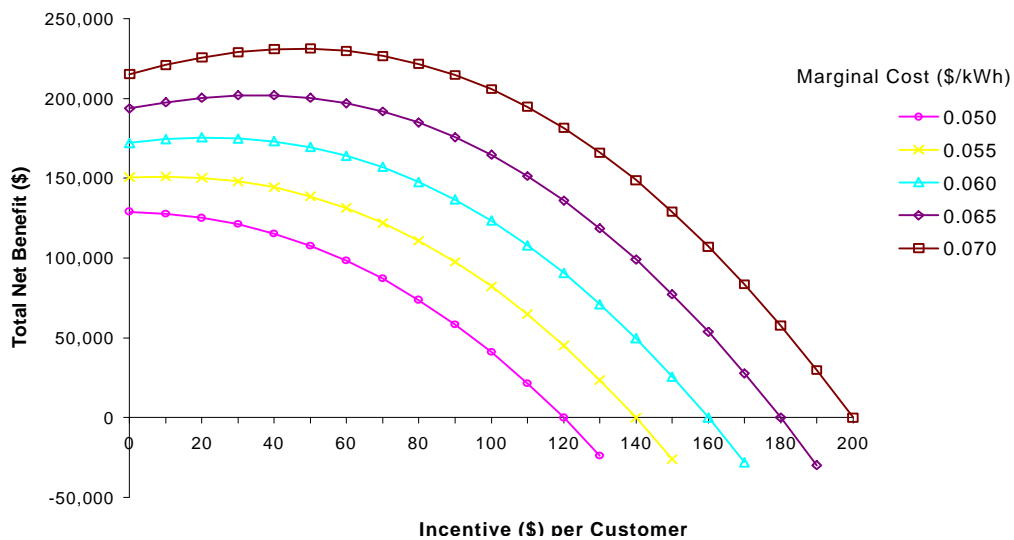


Figure 4.6 Incentive impact at various marginal energy cost for Case Study 2 (RIM Test).

Table 4.10. Impact of Incentive on DSM Program Net Benefit at Various Marginal Energy Cost level for Case Study 1 (TUC Test).

incentive (\$)	Marginal Energy Cost (\$/kWh)				
	0.05	0.055	0.06	0.065	0.07
	Total Net Utility Benefit (\$)	Total Net Utility Benefit (\$)	Total Net Utility Benefit (\$)	Total Net Utility Benefit (\$)	Total Net Utility Benefit (\$)
0	567,259	592,765	618,272	643,778	669,284
20	614,244	642,628	671,013	699,398	727,782
40	661,916	693,376	724,836	756,296	787,756
60	709,749	744,473	779,196	813,920	848,644
80	757,176	795,340	833,504	871,669	909,833
100	803,605	845,372	887,139	928,907	970,674
120	848,434	893,951	939,468	984,985	1,030,502
140	891,071	940,465	989,859	1,039,253	1,088,647
160	930,942	984,322	1,037,701	1,091,081	1,144,461
180	967,509	1,024,962	1,082,415	1,139,868	1,197,321
200	1,000,277	1,061,870	1,123,464	1,185,057	1,246,651
220	1,028,804	1,094,584	1,160,365	1,226,145	1,291,925
240	1,052,705	1,122,698	1,192,692	1,262,686	1,332,679
260	1,071,653	1,145,867	1,220,081	1,294,296	1,368,510
280	1,085,384	1,163,808	1,242,232	1,320,655	1,399,079
300	1,093,693	1,176,298	1,258,904	1,341,509	1,424,114
320	1,096,432	1,183,175	1,269,918	1,356,661	1,443,404
340	1,093,507	1,184,329	1,275,152	1,365,975	1,456,798
360	1,084,875	1,179,707	1,274,538	1,369,370	1,464,202
380	1,070,540	1,169,298	1,268,056	1,366,815	1,465,573
400	1,050,547	1,153,140	1,255,732	1,358,325	1,460,917

CASE STUDY 1 : Energy Efficiency and Peak Clipping by High-EER AC

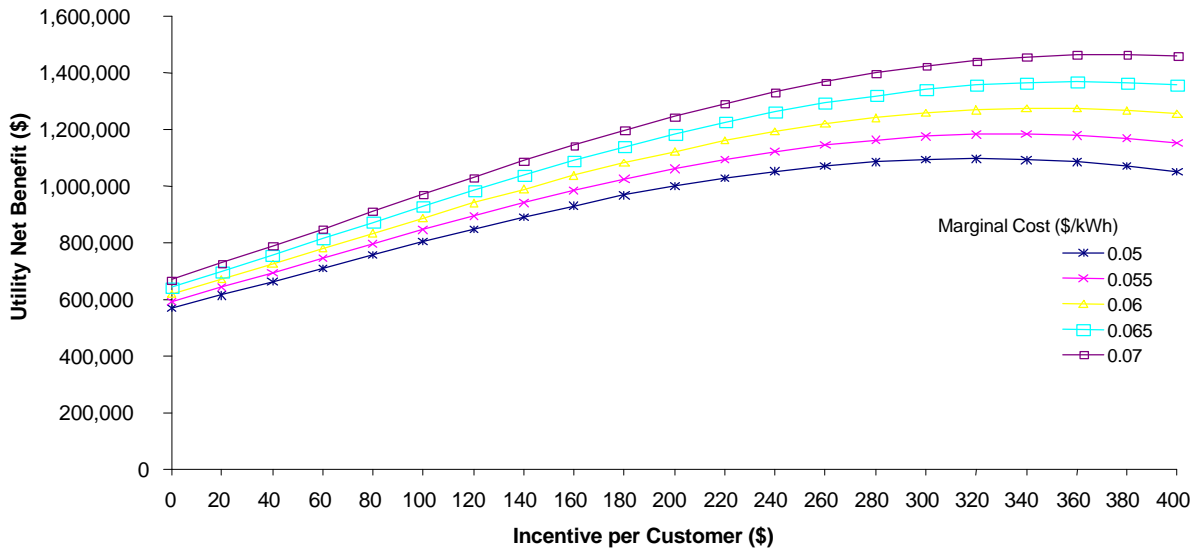


Figure 4.7 Incentive impact at various marginal energy cost for Case Study 1 (TUC Test).

Table 11. Impact of Incentive on DSM Program Net Benefit at Various Marginal Energy Cost level for Case Study 2 (TUC Test).

incentive (\$)	Marginal Energy Cost (\$/kWh)				
	0.5	0.55	0.6	0.65	0.7
	Total Net Utility Benefit (\$)	Total Net Utility Benefit (\$)	Total Net Utility Benefit (\$)	Total Net Utility Benefit (\$)	Total Net Utility Benefit (\$)
0	473,238	494,749	516,260	537,771	559,282
10	499,924	523,176	546,428	569,681	592,933
20	526,269	551,330	576,390	601,451	626,511
30	552,055	578,985	605,914	632,844	659,774
40	577,065	605,918	634,771	663,624	692,478
50	601,084	631,908	662,733	693,558	724,383
60	623,908	656,745	689,582	722,419	755,257
70	645,343	680,226	715,109	749,993	784,876
80	665,209	702,165	739,121	776,077	813,033
90	683,341	722,389	761,438	800,486	839,534
100	699,592	740,745	781,897	823,050	864,202
110	713,832	757,094	800,357	843,619	886,882
120	725,947	771,318	816,690	862,062	907,434
130	735,844	783,318	830,792	878,266	925,739
140	743,447	793,010	842,573	892,136	941,699
150	748,696	800,330	851,965	903,599	955,233
160	751,549	805,231	858,913	912,596	966,278
170	751,979	807,681	863,383	919,085	974,787
180	749,972	807,662	865,352	923,042	980,733
190	745,530	805,172	864,815	924,457	984,100
200	738,666	800,222	861,777	923,333	984,888

CASE STUDY 2 : Strategic Conservation by Energy Efficient Refrigerator and Freezer

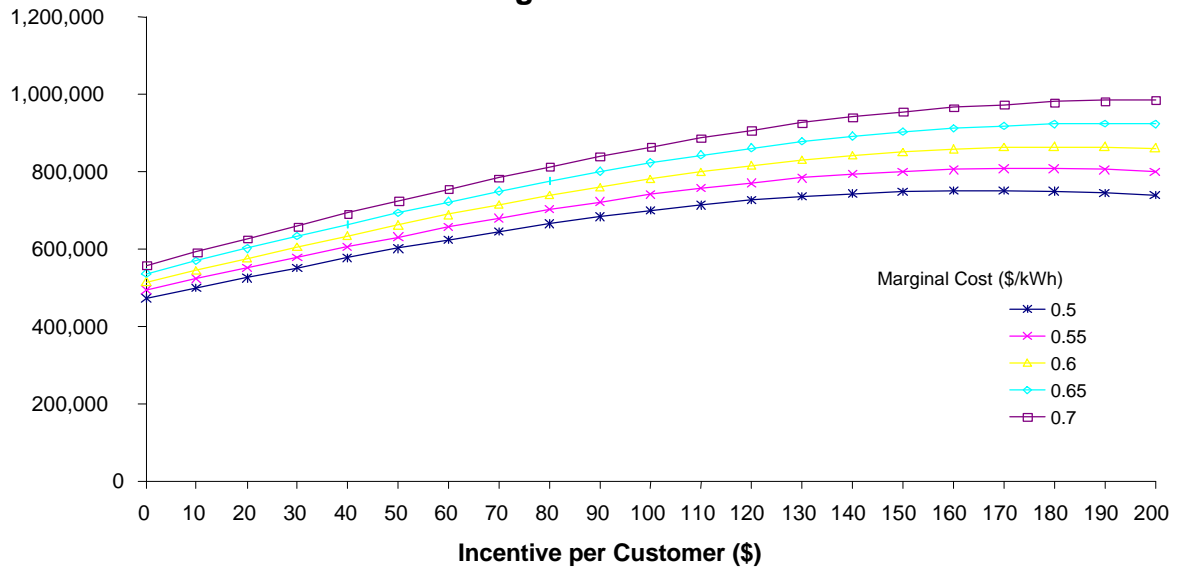


Figure 4.8 Incentive impact at various marginal energy cost for Case Study 2 (TUC Test).

4.6. Summary

The impact of financial incentives on the utility DSM program could result in declining cost-effectiveness of the program, in terms of the program net benefit. Yet the implementation of incentive is intended to promote the customer participation in the program. While the incentive could increase the customer participation, the utility cost due to the incentive expenses and revenue loss will rise as well. The increase in cost may exceed the benefit of the program, and may cause the decline of the program cost-effectiveness.

A simple analysis methodology was developed to analyze the impact of incentives on the utility DSM program. The methodology uses the customer participation probability model to estimate the effect of incentive on the participation rate. The commonly used cost-benefit analysis for DSM program evaluation was used to analyze the effect of incentive on the program net-benefit. In spite of the methodology simplicity and its straightforwardness in analysis, the methodology shows its effectiveness in assessing impact of incentive on the DSM program cost-effectiveness.

As it has been demonstrated in the case studies, the incentive does affect the participation and the net benefit of the programs. In both study cases, the incentive increases the participation rate more than 90% by implementing financial incentive of 50% of the incremental customer investment cost. However to obtain such increase of participation rate, taking into account the revenue losses, the program costs increase more than 150%, while the program benefits increase

only by less than 150%. As a result the increase of incentives improves the participation rate but decline the net benefit.

The incentive has different effects on DSM program net benefit for various marginal energy cost. This is shown in the simulation result of both case studies for various marginal energy cost. It is obtained that for both case studies the implementation of incentive will not improve the DSM program net-benefit if the marginal energy cost is low. In contrary, in higher marginal cost it may improve the net-benefit. This results show that the methodology may be used also to analyze whether or not the incentive program of DSM program promotion will be used, taking into account the fluctuation of marginal energy cost.

Chapter 5

Conclusions and Recommendations

An analysis of financial incentive impact on the utility Demand-Side Management (DSM) program has been conducted in this research. This analysis includes the modeling of customer participation probability in DSM program and the cost-benefit analysis for DSM programs. While the modeling of customer participation probability uses the discrete choice probability modeling technique, the cost-benefit analysis is used to analyze the total net benefit of the program under the incentive effect. The cost and benefit component outlined for the Ratepayer Impact Measurement (RIM) and Total Utility Cost (TUC) tests are used for the cost-benefit analysis.

Customer participation is an important factor for the success of utility Demand-Side Management (DSM) programs, because in such programs the desired change in utility's load shape depends on the change of the customer's use of electricity. The customer participation rate determines the achievable potential of the DSM program, which establishes a realistic target of DSM program saving. To achieve the expected customer participation, a utility should identify the factors that affect the customers' decision to participate. From that identification, an appropriate DSM program promotion can be designed.

Financial incentive programs are widely implemented on utility DSM programs to overcome the economics constraint on customer participation. Even though the economic factor

may not be the major aspect in the customers' decision to participate, it is almost always a determining factor. Financial incentive reduces the initial customer investment cost, making the DSM programs more attractive to the customer.

A mathematical model based on a discrete choice probability model has been developed to express the relationship between the incentive and the customer participation in a DSM program. The purpose of the model is to estimate participation level under the incentive program. A cost-benefit analysis is then conducted using the obtained participation level. Using the combination of the model and the cost-benefit analysis, the incentive impact is analyzed.

5.1. Conclusions

This analysis has been demonstrated in two case studies of typical DSM programs. Based on the result of these case studies, it can be concluded that:

1. From the customer participation probability model, it is shown that incentive programs indeed improve the customer participation in a DSM program option.
2. The cost-benefit analysis shows that incentive programs increase both the DSM program benefit and the cost to the utility.
3. The net benefit of DSM programs does not monotonically increase since the increment rate of the cost is higher than the benefit. The net benefit increases up to certain point and decreases beyond that point.

4. The incentive program does not significantly improve the net benefit of a DSM program option that requires low initial customer investment. Low investment requirements already have high initial customer participation.
5. The incentive program does not improve the DSM program net benefit if the utility operates with a low marginal energy cost. The increase of the program benefit is lower than the increase of the cost.
6. Despite its simplicity and straightforwardness, the methodology of analysis gives an adequate and effective way to assess the impact of incentive.

5.2. Recommendations.

This research develops a means to analyze the impact of the financial incentive on the utility DSM program. The methodology has shown its effectiveness in assessing the impact of financial incentive. The methodology also makes it possible to assess various factors that may have impact upon DSM programs, because the development of the customer acceptance model may not only be based on the incentive factor. Further research is recommended in the following directions:

1. Development of the customer acceptance model. The model developed here was based on simplified and limited data, and intended to show the possibility of providing a mathematical expression of customer decision preference. More accurate models can be achieved by broader and more detailed data.

2. The development of a better model for analyzing the cost effectiveness of DSM programs. Ideally, this model would incorporate the energy production cost changes due to load shape changes. This technique of analysis has not been investigated thoroughly in this research, but it is believed that it could further improve the research.
3. The study of the application of optimization method to obtain the most optimum incentive level. The analysis methodology in this research can be further developed to produce an optimization model of DSM program net benefit. The model can be developed, for example, by defining the net benefit as an objective function, and maximum energy production cost, minimum energy selling price, incentive range etc. as potential restriction functions.

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VITAE

Andhika Prastawa was born in Ujung Pandang, South Sulawesi – Indonesia on the twentieth of February 1965. He completed his undergraduate school in 1989 with a BS degree in Electrical Engineering from Bandung Institute of Technology, Bandung, Indonesia. He was involved in various feasibility studies and design activity of power plant projects in Indonesia and overseas when he was with an engineering and consulting firm until 1994. Since 1995 he has been a researcher for energy conversion and conservation at the Agency for the Assessment and Application of Technology of the Republic of Indonesia. His main expertise and interest are in the Power System Engineering and Design, and the Electric Energy Planning and Management.

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