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The Market Penetration of Energy-Efficiency Programs

Linda Berry

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ENERGY DIVISION

THE MARKET PENETRATION OF ENERGY-EFFICIENCY PROGRAMS

LINDA BERRY

APRIL 1990

Prepared for
Office of Energy Resources
Bonneville Power Administration

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SUMMARY

The focus of this report is on one source of resource planning uncertainty: the expected market penetration of DSM programs. Its purpose is to help refine planning assumptions and reduce uncertainty about the market penetration of utility DSM programs by: (1) investigating concepts and definitions of market penetration, (2) reviewing data that characterize patterns of variation (including ranges, averages and maximum levels) in program participation rates, (3) identifying the factors that affect participation, and (4) reviewing the structure and data requirements of models that forecast market penetration.

DEFINITIONS

In the analysis of DSM programs, the term market penetration is used in several different ways. In broadest terms, the concept refers to the portion of the total technical potential for peak demand reduction (kW) or energy savings (kWh) that can actually be captured. The amount of market penetration which is achieved by a DSM program is determined by two basic factors: the proportion of eligible customers who participate in the program and the amount of energy savings or load reduction which results from their participation. In this report, the focus is on the program participation decision. Although the issue of how much of the technical potential for energy-efficiency improvements program participants actually realize is an important one, it is not addressed here.

In data bases that are assembled to describe DSM program experience, program participation rates are invariably calculated by dividing the number of program participants by the number of eligible customers. All the data bases and surveys of program experience reviewed for this report used this approach.

Unfortunately, there are no standard definitions that are used in calculating and reporting program participation rates. Definitions of the eligible population and explanations of how membership in this population is assumed to change over time are typically not presented. For convenience and because of a lack of data, the eligible population is sometimes defined as all of the utility's customers (usually all residential or all commercial customers because a program is rarely targeted to more than one sector). In most cases, the number of customers who could actually install the measures will be smaller than the total customer base. Therefore, using the total number of customers as a denominator, often makes estimates of participation rates artificially small. On the other hand, if the number of customers defined as eligible is very small, participation rates may be inflated above

representative levels. These factors must be considered in comparing rates across programs.

The time period covered by rates is often unspecified. The number of participants and the number of eligible customers used to calculate a participation rate should represent the same time period. A clear distinction should be made between annual and cumulative rates. An annual rate covers one year increments from the program's starting date. A cumulative rate covers all of the time elapsed since the starting date. Since cumulative rates may include different lengths of time, it is difficult to compare them across programs. Cumulative rates would be more comparable if they were divided by the number of years the program operated to yield an average annual participation rate.

The use of standard definitions and the provision of complete explanations of the composition of the eligible population are essential steps for improving the usefulness of data on participation rates. The Northeast Region Demand-Side Management Data Exchange (NORDAX) data base makes an important contribution to the development of clear and consistent definitions. In this data base, definitions of terms are presented in great detail. Thus, NORDAX provides an initial model of a clear and comprehensive set of categories that can be used to collect and organize data on DSM programs in a standard format.

PATTERNS OF VARIATION

The most striking pattern in tabulations of the participation rates of programs is the high variability and broad range of results that is seen. Ranges of less than 1% to nearly 100% of eligible customers participating have been reported. Much of this variation may be due to definitional differences. It is not always clear if the data presented are annual or cumulative rates of participation. The number of years a program has operated may not be reported either.

For the vast majority of programs, annual penetration rates of a few percent and cumulative rates below 30% are typical. Cumulative participation rates rarely exceed 50%. Participation rates above this level tend to occur only when all factors are favorable to producing them. That is, they are most likely to occur in highly convenient programs, offering free services and direct installation, which are not supply-constrained, and which are marketed by trusted sponsors through direct, personal contact with customers. In addition, the programs with high participation rates tend to be targeted to customers or communities with above average receptivity.

The data suggest that average participation rates for commercial retrofit programs may be lower than for residential retrofit programs, although this could be due mainly to their more recent origin. There is no equivalent to the Hood River experiment (which sought to achieve the maximum possible participation in residential retrofit) for the commercial sector. Except for Hood River, no full-scale programs, in either the residential or commercial sector, have achieved cumulative market penetration rates higher than 50%-60%

DETERMINING FACTORS

The determinants of program participation rates include both the utility supply of services (program budgets, personnel, labor and materials) and the demand for these services by customers. Constraints on supply (budget, materials and manpower) often limit program participation more than any other factors. The absence of supply constraints and the commitment of sponsoring agencies to obtain high participation are probably the most important determinants of response levels. With high commitment, effective (and expensive) program features such as regular personal contact with eligible customers, comprehensive technical and financial assistance, and efforts to identify and remove the most salient barriers by market segment, will be implemented. Thus, participation rates depend primarily upon the utility resources devoted to programs.

The demand for available services also influences program participation rates, however. Customers will choose to participate in programs when the program offerings meet their energy-related needs. The better the fit between program design features and customer needs, the higher the demand for services. Some program features that influence demand include program sponsorship arrangements and the perceived credibility of the information source, communication techniques, financial incentives and the intensity of marketing. It may be that maximum achievable rates will differ by customer and community characteristics. For example, residential customers seem to be more likely to participate than commercial customers and rural communities more likely to respond at high rates than urban locations. Large commercial customers are more likely to respond than small ones. In addition, factors such as fuel prices and shortages, and political and social forces favoring conservation, can significantly impact customer levels of response.

MODELS

There is an extensive literature in the fields of economics, diffusion of innovations, and marketing on the theory and application of models of market

penetration. Classifications and reviews of the market penetration models most useful to utility analysts can be found in a number of sources.

There are several software packages (models) for use on personal computers that are designed to meet the specific needs of DSM program planners. These software packages have applied the methods developed in the literature on market penetration to construct routines that estimate customer acceptance of DSM programs. The features, objectives, strengths and limitations of the market penetration forecasting approaches of six PC-based models developed by three organizations are reviewed in this report. The models that are reviewed include: (1) the Alliance to Save Energy's "Demand-Side Management Program Design and Impact Assessment Model"(DSMPRO), (2) Synergic Resources Corporation's (SRC) "Comprehensive Market Planning and Analysis System" (COMPASS) and SRC's RESPEN and COMPEN models , and (3) EPRI's PULSE and market penetration analysis system models. All except one of the models became available within the last two years (1988-89). EPRI's market penetration analysis system will become available in 1991.

In general, economically-driven cost-minimization models, which are often combined with equipment stock models and embedded in larger end-use or integrated planning models, serve long-range planning needs (e.g. DSMPRO, COMPASS, RESPEN and COMPEN). Decisions about resource acquisition, including the identification of the optimal amounts and timing of conservation program efforts, are informed by the outputs of these models. They have little relevance to selecting the best program marketing mix.

Models using marketing research techniques and driven by customer preferences, in contrast, have little relevance to long-term resource acquisition decisions. These models do not deal with the timing of participation in DSM programs or with demand impacts. They provide valuable guidance, however, for decisions about how to design and implement programs that will obtain the desired market shares cost-effectively. EPRI's PULSE model is a good example of this type of approach.

For most end-uses, cost-minimization models are currently the only available tool for penetration forecasting as it relates to integrated resource planning. Market research techniques, such as conjoint analysis, which simultaneously vary both financial and nonfinancial program features and test customer response to the various combinations, have been applied for some program types.

Because it is difficult to quantify nonfinancial elements of program design, they are generally ignored in formal models. More attention should be given to factors such as program sponsorship, marketing, trust and convenience. Efforts to

quantify their effects can rely on market research techniques, such as conjoint analysis, and field experiments which simultaneously vary both financial and nonfinancial program features. Particular attention should be given to the interactions and trade-offs among incentive, marketing and administrative costs so that the most cost-effective combinations of program features can be identified for specific market segments. Models of market penetration which vary only the level of financial incentives and which rely only on a lifecycle cost-minimization principle to explain behavior will often miss the mark. In addition, program planning, design and implementation efforts which systematically study the probable effects of nonfinancial program features may discover low-cost and highly effective strategies for increasing market penetration. Thus, developing a broader perspective on how and why participation decisions are made will improve both program performance and one's ability to predict that performance.

At present the best approach to forecasting market penetration is a problem-oriented analysis in which concepts of cognitive psychology, theories of social influence, communication, and diffusion of innovations, marketing research and models, and traditional microeconomic theories all play a role. There is no currently available software which integrates all of the relevant approaches. Therefore, model results should be supplemented with empirical research that uses focus groups, market surveys, field experiments and program evaluations to clarify the expected market penetration of specific technologies and programs.

LIST OF ACRONYMS

APM	adoption process models
BPA	Bonneville Power Administration
C&I	commercial and industrial
COMPASS	Comprehensive Market Planning and Analysis System
COMPEN	Commercial penetration model
CPAM	Conservation Policy Analysis Model
CP&B	Customer Preference and Behavior
DSMPRO	Demand-Side Management Program Design and Impact Assessment Model
DSM	Demand-Side Management
EPRI	Electric Power Research Institute
GPU	General Public Utilities Service Corporation
MAT	Market Assessment Tools
NEES	New England Electric System
NMPC	Niagara Mohawk Power Corporation
NORDAX	Northeast Region Demand-Side Management Data Exchange
NYSEG	New York State Electric and Gas Corporation
PG&E	Pacific Gas and Electric Company
PC	Personal computer
RESPEN	Residential penetration model
RTI	Research Triangle Institute
SCL	Seattle City Light
SRC	Synergic Resources Corporation

1. INTRODUCTION

Incorporating energy efficiency into a utility's integrated resource plan requires an understanding of a complex, interactive system. The amount of cost-effective energy-efficiency resources available at any given time is a function of several sets of factors including the characteristics of (1) existing building and equipment stocks; (2) energy-efficiency technologies; (3) consumers (market segments) that install and use the technologies; (4) the utility or government delivery mechanisms (e.g., the program attributes including marketing efforts, staff development and training, content and format of the information provided, financial incentives, quality control, etc); and (5) the external environment (e.g., prices of fossil fuels and electricity, economic growth, mix of economic activities, and public attitudes on energy issues). These factors interact and change over time.

SOURCES OF UNCERTAINTY

The resource planning uncertainties facing electric utilities can be divided into two categories, external and internal factors, although these uncertainties actually fall along a continuum (Hirst and Schweitzer 1988). A variety of external factors, outside the utility's control, can substantially affect the need for additional resources as well as the availability, cost, and performance of these resources (Table 1). These uncertainties affect different resources in different ways. For example, higher inflation and interest rates increase the costs of facilities that take a long time to build. Thus, the cost of a large, baseload coal plant is much more sensitive to inflation and interest rates than are the costs of combustion turbines or load-management programs.

Internal factors are those over which the utility has some influence. The focus here is on the uncertainties that affect different types of demand and supply resources a utility can use to fill the gap between growing demand and existing resources: conservation programs, load-management programs (direct load control), construction of new generating plants, purchase of power from other organizations, and life extension of existing power plants.

Different resources expose utilities to different uncertainties (Table 2). Resources differ in construction times, unit sizes, capital costs, operating costs, and reliability. They differ in their flexibility during construction (ease with which plant sizes can be changed and construction schedules modified) and during operation (ability to use alternative fuels and to operate at partial versus full load).

Table 1. Planning uncertainties associated with external factors

Inflation and interest rates	Little effect on either demand or supply projects that are completed in a few years; possible large increases in construction costs for facilities that take many years to complete.
Fossil-fuel prices	Fuel-price increases raise the value of demand-side programs and of generating facilities that use fuels other than those whose prices increase; raise operating costs for plants that use the particular fuel.
Economic and load growth rates	Higher economic and load growth increases the value of all resources because the need for power is greater; also increases need for additional resources. Higher growth also increases benefits from (saved energy provided by) demand-side management (DSM) programs aimed at new buildings.
Amount and cost of purchased power	Greater supplies and lower costs of power from other sources reduce the value of and need for company-owned resources (both demand and supply).
Regulatory policies	Environmental regulations increase the cost of electricity generation or reduce the availability of certain fuels (e.g., restrictions on coal use because of concern about acid rain and global warming); problems with radon could increase the cost of conservation programs. Economic regulations could affect the financial incentives to utilities to acquire different types of resources. Regulations could affect the degree of competition among suppliers for electricity production and transmission.

Source: Hirst and Schweitzer 1988.

OVERVIEW OF REPORT

The focus of this report is on one source of resource planning uncertainty: the expected market penetration of DSM programs. Its purpose is to help refine planning assumptions and reduce uncertainty about the market penetration of utility DSM programs by: (a) investigating concepts and definitions of market penetration (Section 2); (b) reviewing data that characterize the typical patterns of

Table 2. Planning uncertainties associated with demand and supply resources

Demand-side resources	Supply resources
Customer participation in programs, costs and effectiveness of different marketing strategies	Construction time Construction cost
Customer adoption of recommended DSM actions	Regulatory approvals: siting, environmental, need for power
Program performance (effects on load levels and load shapes): durability measurement attribution	Operating costs fuel operations and maintenance additions and improvements
Public attitudes towards energy efficiency and utility DSM programs	Reliability forced outages premature retirement
	Public attitudes towards facility

Source: Hirst and Schweitzer 1988.

variation (including ranges, averages and maximum levels) in the participation rates achieved by programs of several types (Section 3); (c) identifying the factors that affect participation (Section 4); and (d) reviewing the structure and data requirements of computer models that forecast market penetration (Section 5). Section 6 presents conclusions and recommendations for additional research.

In the analysis of DSM programs, the term market penetration is used in several different ways. In broadest terms, the concept refers to the portion of the total technical potential for peak demand reduction (kW) or energy savings (kWh) that can actually be captured. The amount of market penetration which is achieved by a DSM program is determined by two basic factors: the proportion of eligible customers who participate in the program and the amount of energy savings or load reduction which results from their participation. In this report, the focus is on the program participation decision. Although the issue of how much of the technical potential for energy-efficiency improvements program participants actually realize is an important one, it is not addressed here.

Careful analysis of definitions of program-participation rates and of factors that determine participation can lead to more accurate predictions for planning purposes. Consider, as an example, data collected for the Electric Power Research Institute (EPRI) (Van Liere and Davis 1986) on annual participation rates in residential programs that offer financial incentives. As shown by the black bars in Fig. 1, there is substantial variation across the 50 utility programs, with participation rates ranging from less than 1%/year to over 35%/year. To some extent, this large variation occurs because the results reported by utilities implicitly used different definitions for participation rates (Section 2). In addition, these results differ because the programs differ in marketing, communication factors, utility characteristics, and customer characteristics (Section 4). The cross-hatched bars in Fig. 1 provide a hypothetical example of how the variation in the raw data could be reduced by imposing consistent definitions on the data and by analyzing the programs for important differences that affect participation rates.

The determinants of program participation rates include both the utility supply of services (program budgets, personnel, labor, and materials) and the demand for these services by customers. Constraints on supply often limit program participation more than any other factors. It is common to have a waiting list for program services and to discontinue marketing when the demand for services begins

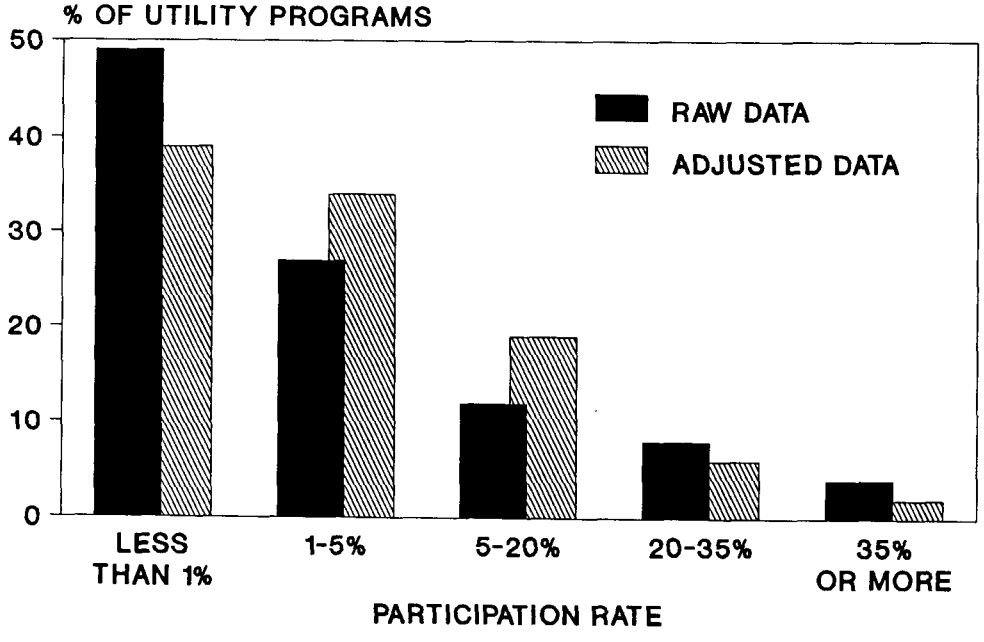

Fig. 1. Distribution of annual participation rates in residential financial incentive programs. The black bars show actual results reported by utilities and the cross-hatched bars show hypothetical results after adjustment for differences in definitions and program design and operation.

to exceed the supply. Thus, program participation rates often depend primarily upon the utility resources devoted to programs (Fig. 2). The demand for available services also influences program participation rates, however. Customers will choose to participate in programs when the program offerings meet their energy-related needs. The better the fit between program design features and customer needs, the higher the demand for services.

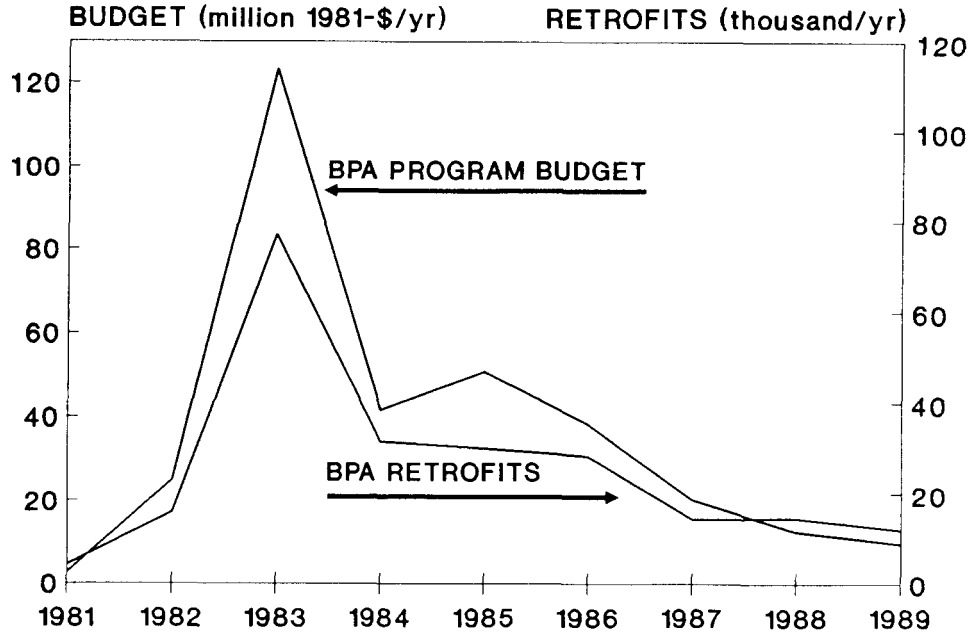

Fig. 2. Program participation depends on budgets. Participation in the Bonneville Power Administration's (BPA) residential retrofit program dropped sharply in 1984 when BPA cut its program budget.

2. DEFINITIONS

In data bases that are assembled to describe DSM program experience, program participation rates are invariably defined as the number of participating units divided by the number of eligible units (Northeast Region Demand-Side Management Data Exchange 1989; Electric Power Research Institute 1988a, 1988b, 1988c, 1988d; Burby, Didow, Marsden, Hanna, Bunn, and Johnston 1985). All the data bases and surveys of program experience reviewed for this report used this definition.

PARTICIPATING UNITS

The best definition of a participating unit varies among programs. In some cases, the number of customers (e.g., the number of homeowners or building owners participating) may be the most appropriate measurement unit. In other cases, the number of equipment purchases or of items installed through the program (such as the number of high-efficiency refrigerators, motors, ballasts or lamps) is the most appropriate measurement unit. Some programs deal with only one technology and one installation per customer (e.g., water-heater wraps or attic insulation). Others address several end-use technologies which are installed by a single customer. For many programs, both the number of customers served and the number of items installed may be relevant ways of tracking participation.

The definition of a participating unit may refer to a person, a building, a business, a meter, or an account. Since these varying definitions may produce quite different numbers, it is essential that the denominator (in terms of eligible customers, i.e., persons, buildings, meters, or accounts) be defined in the same way as the numerator of the participation rate.

Program participation is often defined as a customer's acceptance of any of the services or technologies provided by a DSM program. This definition, which uses the number of customers to track participation, is most useful for building audit and retrofit programs, for new construction programs, and for load control or rate programs. When the customer is used as the unit of measurement and several technologies are offered by a program, it is common practice to describe an average or typical package of measures and to base assumptions about demand impacts on this package (not on the separate impacts of individual energy-efficiency measures). This is done to reduce the recordkeeping burden and because it is often difficult to measure the demand effects of each of the energy-efficiency measures included in a program.

For some equipment programs (such as motor, ballast, or lamp rebates) participation rates are best defined as the number of items installed through a program divided by the total number sold in a year. Most utilities track equipment rebate program participation in terms of the number of measures installed or the number of rebate applications, not the number of unique customers requesting rebates. In these cases, penetration is not measured in terms of numbers of customers because a customer may use and purchase multiple units of a particular type of equipment (e.g., ballasts, lamps). In addition, since only a portion of the equipment is replaced each year and only a portion of annual purchases meet a program's rebate eligibility requirements, the number of high-efficiency items installed through a program can be compared to the number of lower-efficiency items still in use to determine the penetration to date for all of the equipment which could be replaced.

Audit programs combined with financial incentives for investment pose another definitional problem. In this case, the number of participants may be defined as: including both audit only and audit plus incentive users, or limited to the users of the financial incentives (with customers receiving only audits considered nonparticipants). The choice between these definitions has an important effect on the results. If, for example, 60 out of 100 eligible customers received audits and half of the audit recipients used incentives, the program participation rate would be 60% with the first definition and 30% (i.e., 0.60 multiplied by 0.50) with the second.

Audit-only customers may not be eligible for program incentives because of physical barriers or because they do not meet cost-effectiveness tests. They also may chose not to accept the incentive offers for which they qualify. Puget Power, for example, has provided several levels of conservation services through its commercial audit/grant program, ranging from pre-screening walk-through audits to grants for the installation of conservation measures. Basing market penetration on the number of audits yields different results than basing it on the number of customers who install measures (Jackman 1989). At Puget Power, audit records are kept only for customers for whom the audit identified significant cost-effective conservation potential and to whom a grant was offered for the installation of measures. About 8% of potentially eligible customers (i.e., those considered potentially eligible before screening) received audits by this definition. No information is available on the number of customers receiving audits in buildings that do not have significant cost-effective potentials. Program managers report, however, that most of the large commercial buildings in the service area have received at least a pre-screening audit (Jackman 1989). If participation is defined as using Puget Power's program grants to install conservation measures, about 4% of eligible customers participated from 1980 to 1988.

In BPA's pilot residential retrofit program, the average percentage of eligible customers requesting audits was 18% and the percentage of audits leading to installations was 55%; yielding a result of 10% of eligible customers installing measures (Lerman, Bronfman, and Tonn 1983). Thus, in the analysis of audit plus incentive program participation rates it is important to specify whether participants are defined as all customers receiving an audit or as only the audited customers who make installations. In both of the examples discussed above, about half of the customers receiving an audit and an offer of financial assistance went on to install recommended measures.

Usually program planners do not know the proportion of buildings with cost-effective conservation potentials until after a large number of audits are completed. Thus, the most useful definitions of program participation will incorporate these uncertainties and provide for their resolution as more data become available. For example, three types of participation rates could be defined as follows: (1) out of 100,000 commercial buildings built before 1985, 10,000 (10% of eligible customers) have requested an audit in the past 10 years; (2) 7,000 (7% of eligible customers) received retrofit financing offers; and (3) 4,000 (4% of eligible customers) made installations through the program. Assembling information on all three proportions: (1) the percentage of eligible customers requesting audits, (2) the percentage of eligible customers having significant cost-effective potential, and (3) the percentage of eligible customers installing measures will greatly assist planning efforts. By using all three proportions one can develop reasonable estimates of how many customers will participate and to what degree (Jackman 1989).

ELIGIBLE CUSTOMERS

Defining the number of eligible customers (the denominator for a program participation rate) is more difficult both conceptually and in practical terms than defining the number of participants. Market surveys, appliance saturation surveys, building inspections, and the collection of sales data are often needed to estimate the number of customers who could install specific DSM measures. Eligibility may depend on fuel choice, (e.g., the number of customers who use electricity for water heating). For some technologies, it is difficult to determine the number of eligibles. It may not be possible, for example, to determine the number of buildings which could physically and cost-effectively install a technology without inspecting a large sample of buildings. As another example, information on the number of motors operating in a utility service area is rarely collected. Definitions of eligibility may change over time. The number of customers who are eligible, with a given definition, will usually change over time as some of the eligible units install the technology and some buildings/appliances are retired.

For convenience and because of a lack of data, the eligible population is often defined as all of the utility's customers (usually all residential or all commercial customers because a program is rarely targeted to more than one sector). In most cases, the number of customers who could actually install the measures will be smaller than the total customer base. Therefore, using the total number of customers as a denominator will often make estimates of participation rates artificially small. This effect may be especially significant in the commercial and industrial (C&I) sector because customers who have more than one meter at a facility may be counted several times or because minimal-use facilities may be incorrectly counted as eligible customers (e.g., a phone booth or a billboard may have a meter and an account). Minimal-use facilities can account for about 40% of C&I customers and multiple meters at the same facility may account for as many as 10% of C&I accounts (Nadel 1990).

In audit programs, the participation rate is quite sensitive to whether eligibility is defined as all customers who could receive audits or as only those found eligible after an audit is performed. Krause, Vine, and Gandhi (1989) give two examples of how definitions of eligibility affect participation rates. Both programs were C&I lighting programs. In the Sacramento Municipal Utility District program, the cumulative participation rate based on the total customers in the targeted rate class was 25%. When participation is calculated on the basis of eligibility as determined through on-site audits, the rate becomes 58%. In the New England Electric System (NEES) program, there are similar effects: 34% based on the whole target group and 55% based on audit-determined eligibility.

While counting all accounts as eligible often reduces rates below their correct value, a rate also may be artificially high because the number of customers defined as eligible is very small. A few commercial programs designed to target only the service area's largest customers, for example, report participation rates close to 100%. In these cases, the number of customers defined as eligible includes only a few buildings. Therefore, the results cannot be generalized to larger markets. Similarly, there are examples of low-income residential retrofit programs which provided free, direct installation to all eligible households in small, isolated, rural communities. The number of eligibles in such settings is from 100 to 200 households. Again, the very high rates which result cannot be expected in large, urban service areas.

In interpreting participation rates, it is important to understand how both the number of participating and eligible units are determined. Consistent definitions should, of course, be used for both the numerator and denominator of a rate. When comparisons across programs are made, the consistency of definitions must be examined. Another consideration is that programs that are pilot efforts may produce artificially high or low rates. Pilot programs may not be intended to

achieve high penetration and may purposely limit the supply of services, producing low participation rates. Alternatively, a pilot effort may target only a small number of eligible units, producing a high participation rate. The effectiveness of a program design is, therefore, not necessarily reflected in the magnitude of its penetration rate. Comparisons of rates across programs must consider these factors.

TIME PERIODS

The number of participants and the number of eligible customers used to calculate a participation rate should represent the same time period. A clear distinction should be made between annual and cumulative rates. An annual rate covers one year increments from the program's starting date. A cumulative rate covers all of the time elapsed since the starting date. Since cumulative rates may include different lengths of time, it is difficult to compare them across programs. Cumulative rates would be more comparable if they were divided by the number of years the program operated to yield an average annual participation rate. Cumulative rates are useful for seeing how much of a market is tapped and how much is still available. Since both annual and cumulative rates have important uses, both should be reported. If program operating periods are specified, annual rates can be used to calculate a cumulative rate.

RETROFIT VERSUS REPLACEMENT MARKETS

The eligible market, depending on the type of program, may include retrofits, replacements or new construction, or some combination of the three applications. The dynamics of market penetration differ for retrofits versus replacements and new construction (Tables 3 and 4; Figs. 3 and 4). While it is feasible to achieve high levels of cumulative penetration (i.e., 80% or more) in several years for retrofits, a replacement or new construction market saturates over a longer time frame. A complete turnover of the existing stock is necessary for a replacement market to reach saturation. Therefore, a decade or more may be required before all of the potentially eligible equipment wears out and opportunities for replacement occur.

For retrofit programs, the number eligible may be defined as all customers who could physically accept the load-control device or the energy-efficiency measures. Alternatively, eligibility may be limited to customers who meet certain cost-effectiveness criteria, who use electric space heat or who consume a large amount of electricity. Eligibility also may be limited to certain building types or to buildings constructed before a certain date. All of the eligible buildings or

Table 3. Numerical examples of definitions of market penetration rates for a retrofit market. Assumed attrition rates are 3% (top) and 1% (bottom).

year (A)	Eligible units[a] (B)	Units removed from stock by attrition (C)	Number of participants (D)	Cumulative number of participants (E)	Annual rate[d] (F)	% of Cumulative rate (% current stock)[e] (G)	(% of base year stock with attrition)[f] (H)	(% of base year stock no attrition)[g] (I)
1	1000	30[b]	10	10	1	1	1	1
2	960	29	20	30	2	3	3	3
3	911	27	40	70	4	8	7	7
4	844	25	50	120	6	14	13	12
5	769	23	50	170	7	22	19	17
6	695	21	40	210	6	30	24	21
7	635	19	20	230	3	36	27	23
8	596	18	15	245	3	41	30	25
9	563	17	7	252	1	45	31	25
10	536	16	0	252	0	47	32	25
1	1000	10[c]	10	10	1	1	1	1
2	980	10	20	30	2	3	3	3
3	950	10	40	70	4	7	7	7
4	901	9	50	120	6	13	12	12
5	842	8	50	170	6	20	18	17
6	783	8	40	210	5	27	22	21
7	735	7	20	230	3	31	24	23
8	708	7	15	245	2	35	26	25
9	686	7	7	252	1	37	27	25
10	672	7	0	252	0	37	27	25

[a] $B_i = B_{i-1} - C_{i-1} - D_{i-1}$

[b] Units retired at a rate of 3%/year ($C_i = 0.03 * B_i$)

[c] Units retired at rate of 1%/year ($C_i = 0.01 * B_i$)

[d] $(D_i / B_i) * 100$

[e] $(E_i / B_i) * 100$

[f] $(E_i / (B_i + E_i)) * 100$

[g] $(E_i / 1000) * 100$

Table 4. Numerical examples of definitions of market penetration rates for a replacement market. Assumed attrition rates are 5% (top) and 3% (bottom).

Year (A)	Eligible units (B)[a]	Units removed from stock by attrition (C)	Number of purchases (first + replacement) (D)	Cumulative number of purchases (E)	Number of program participants (F)	Cumulative number of program participants (G)	Annual market penetration (% of annual sales) (H)[d]	Cumulative percentage of purchases (I)[e]	Cumulative market penetration (% of current stock) (J)[f]
1	1000	50[b]	0	0	0	0	0	0	0
2	950	48	52	52	1	1	2	2	0
3	954	48	49	101	2	3	4	3	0
4	953	48	50	151	3	6	6	4	1
5	952	48	50	201	5	11	10	5	1
6	949	47	50	250	8	19	16	8	2
7	943	47	49	299	10	29	20	10	3
8	935	47	49	348	12	41	24	12	4
9	926	46	49	397	14	55	29	14	6
10	914	46	48	445	15	70	31	16	8
12	901	45	48	493	17	87	36	18	10
13	887	44	47	540	19	106	41	20	12
14	870	44	46	586	20	126	43	22	14
15	853	43	45	631	20	146	44	23	17
16	836	42	44	675	20	166	45	25	20
17	818	41	43	719	21	187	48	26	23
18	800	40	43	761	21	208	49	27	26
19	781	39	42	803	21	229	50	29	29
20	763	38	41	844	21	250	50	30	33
1	1000	30[c]	0	0	0	0	0	0	0
2	970	29	32	32	3	3	10	10	0
3	970	29	31	63	3	7	11	10	1
4	968	29	31	94	4	11	13	11	1
5	966	29	31	125	5	15	15	12	2
6	964	29	31	156	5	21	17	13	2
7	960	29	31	187	7	27	22	15	3
8	956	29	31	218	8	35	25	16	4
9	950	28	31	248	9	44	29	18	5
10	943	28	30	279	9	53	30	19	6
12	936	28	30	309	11	64	35	21	7
13	928	28	30	339	12	76	40	22	8
14	918	28	30	368	13	89	45	24	10
15	907	27	29	398	15	104	50	26	11
16	894	27	29	427	15	118	50	28	13
17	882	26	29	455	14	132	50	29	15
18	870	26	28	484	14	147	50	30	17
19	858	26	28	511	14	160	50	31	19
20	846	25	27	539	14	174	51	32	21

[a] $B_i = B_{i-1} - C_{i-1} + D_{i-1} - F_{i-1}$
[b] Units are retired at a rate of 5%/year ($C_i = 0.05 * B_i$)
[c] Units are retired at a rate of 3%/year ($C_i = 0.03 * B_i$)
[d] $(F_i / D_i) * 100$
[e] $(G_i / E_i) * 100$
[f] $(G_i / B_i) * 100$

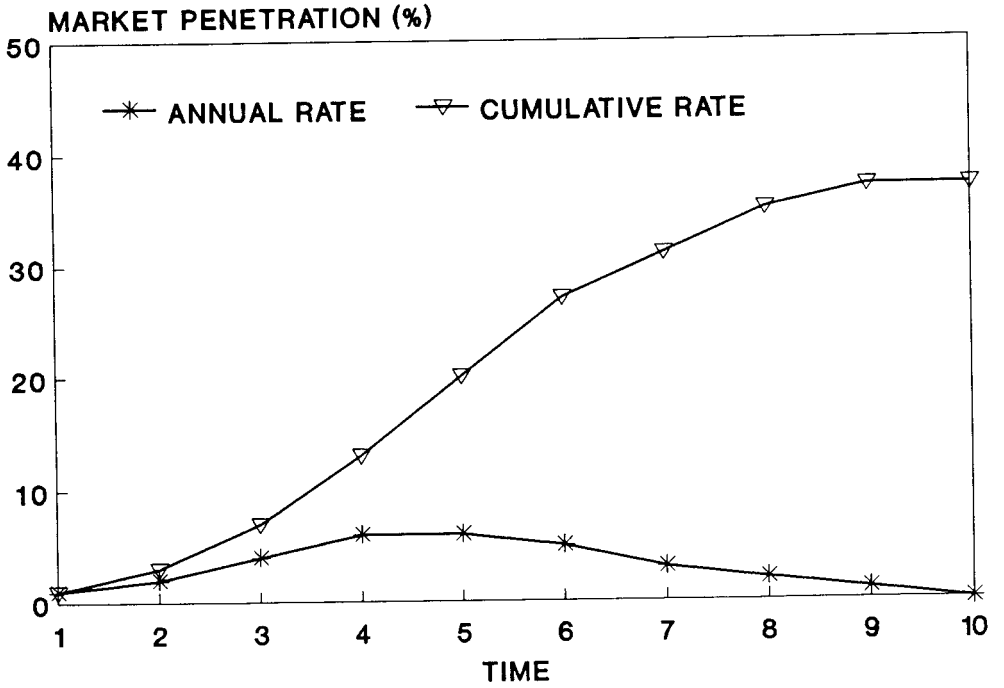

Fig. 3. Comparison of annual (Col. F, Table 3) and cumulative (Col. G, Table 3) market penetration rates for a retrofit market.

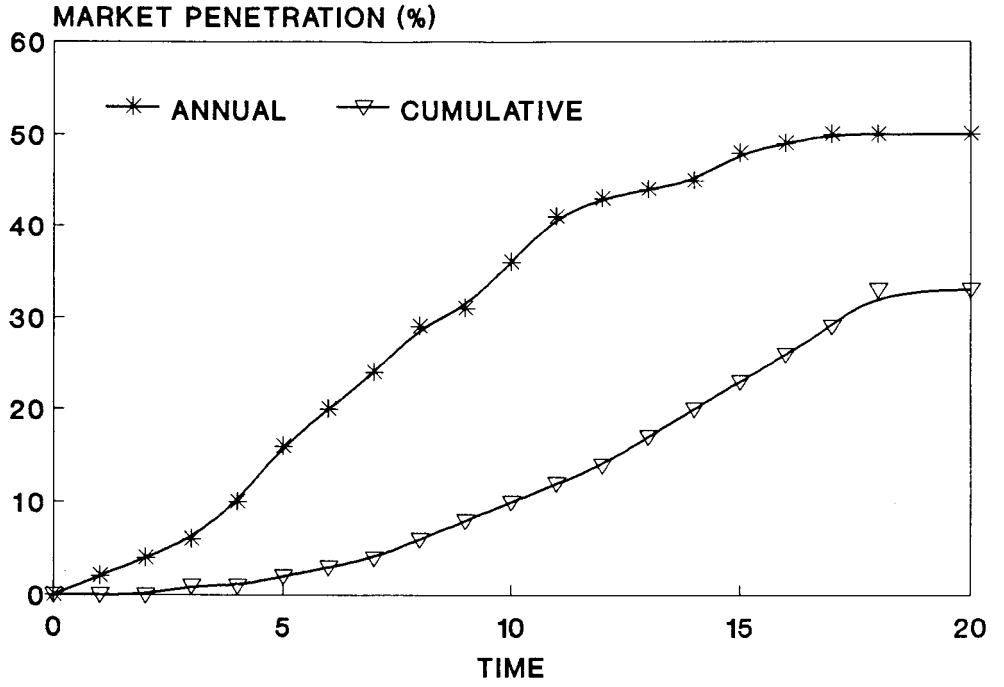

Fig. 4. Comparison of annual (Col. H, Table 4) and cumulative (Col. J, Table 4) market penetration rates for a replacement market.

equipment that have not yet installed the measures may participate during any given year. An attic insulation program, for example, may target all homes with less than R-19. The pool of customers who are eligible will generally contain much of the same membership over the lifetime of the program. The number of eligible units will, however, decrease over time as measures are installed. The number of eligible units also will decrease at the demolition or retirement rate (Table 3).

Direct load control and rate programs are like retrofit programs in that much of the same pool of customers remains eligible over the lifetime of the program. Annual rates of participation tend to be higher, however, because customers who began participating in an earlier year (and are still participating in the current year) are typically counted as participants in each subsequent year. Thus, annual rates for load control and rate programs have magnitudes similar to cumulative rates. In building retrofit programs, in contrast, annual rates are typically much smaller than cumulative rates (Table 3).

Annual rates are defined as the number of participants divided by the number of eligibles in a given year (Table 3). Cumulative rates may be defined in at least two ways: the cumulative number of participants since program inception divided by the eligible stock in the current year and the cumulative number of participants since program inception divided by the base year stock (with or without attrition). The first definition shows how much of the potential for efficiency improvements in the current stock has been captured. The second definition shows what percentage of the units that were initially eligible have participated in the program (Table 5). With the same number of participants, cumulative rates may vary by as much as 10% depending upon the rate of attrition and the definition of the eligible population that is used (Table 3). The inputs to the top and bottom portions of Table 3, for example, differ only in the assumed rate of attrition (3% versus 1%). In Table 4 the attrition rate for the top portion is 5% and for the bottom portion 3%.

For replacement or new construction markets, the membership in the pool of eligibles changes almost completely each year. For appliances, the fraction of the stock that has failed and has to be replaced will constitute most of the market in a given year (Table 4). In addition, new purchases or early replacement purchases (a number small enough it is often ignored) will contribute to the pool of eligibles. High-efficiency refrigerators, water heaters, or air conditioners are good examples of this type of market. The initial stock of end-use equipment and the rate at which the stock is being replaced determine the size of the eligible market (i.e., the number of customers making purchase decisions in a given time period). In this case, the number of eligibles used for determining annual rates should be defined as the number of customers eligible for the program who replaced the equipment in question during that year. It is sometimes defined,

Table 5. Alternative definitions of program participation rates

RETROFIT		
Annual		$\frac{\text{Number of participating units in year i}}{\text{Number of eligible units in year i}}$
Cumulative	(1)	$\frac{\text{Number of participating units since program inception}}{\text{Number of eligible units from program inception year that are still eligible (base year minus attrition minus participants)}}$
or		
	(2)	$\frac{\text{Number of participating units since program inception}}{\text{Number of eligible units in the base year}}$
REPLACEMENT (Appliances, equipment, or new construction)		
Annual		$\frac{\text{Number of participating units in year i}}{\text{Number of appliance purchases (or new units constructed) in year i}}$
Cumulative	(1)	$\frac{\text{Number of participating units since program inception}}{\text{Number of purchases (or new units constructed) from year program started to year i}}$
or		
	(2)	$\frac{\text{Number of participating units since program inception}}{\text{Number of eligible units currently in service (base year minus attrition minus participants plus eligible units added to stock since base year)}}$

however, as only those customers who purchased a high-efficiency model of the program technology (e.g., only buyers of high-efficiency refrigerators instead of all buyers of refrigerators, regardless of their efficiency level). This definition is misleading. In a rebate program, for example, the rebates are intended to influence buyers who would not otherwise purchase high-efficiency units, not the buyers who would choose high-efficiency units anyway. Thus, annual rates should be defined as the number of high-efficiency purchases divided by the total purchases made in the current year (Table 4, column H).

Cumulative rates may be defined in at least two ways: the number of high-efficiency purchases to date divided by the total number of appliance purchases to date, or the number of high-efficiency purchases to date divided by the stock of eligible appliances in the current year. The first definition shows the cumulative

percentage of appliance buyers who participated in the program. The second definition shows the percentage of high-efficiency units in current stock (Table 5). For replacement markets, annual rates tend to be higher than cumulative rates because the denominator, annual purchases, is smaller (Table 4). Cumulative rates may vary by 10% or more depending upon the attrition rate and the definition of the eligible population that is used.

For new construction, the number of buildings which could incorporate the technology and which are built during the time period being considered form the eligible population. Annual rates are calculated by dividing the program-approved buildings constructed (e.g., Good Cents Homes) by all buildings constructed during a given year (Table 4). Cumulative rates are defined in the same manner as discussed above for appliances: all program-approved high-efficiency buildings constructed since program inception divided by the total number of buildings constructed since program inception or the number of program-approved high-efficiency buildings constructed since program inception divided by the stock of buildings in the current year. The first definition shows the percentage of newly-constructed buildings participating in the program during a given time period. The second definition shows the percentage of high-efficiency units in the current stock of buildings (Table 5).

Because of differences in the dynamics of retrofit versus replacement markets, their patterns of annual and cumulative rates differ. These patterns are shown in Figs. 3 and 4, which plot the rates calculated in Tables 3 and 4, respectively. For retrofit markets, annual rates increase over time, typically peaking in the middle phase of a program's lifetime, and then begin to decline as fewer units are eligible for the measures. Cumulative rates increase following an S-shaped curve until a saturation level is reached (Fig. 3). For replacement markets, annual rates increase over time as knowledge about the program spreads among eligibles. Cumulative rates also increase over time, but take longer to reach maximum levels (Fig. 4).

NEED FOR STANDARD DEFINITIONS

Unfortunately, there are no standard definitions that are used consistently in reporting program participation rates. Definitions of the eligible population and explanations of how membership in this population is assumed to change over time are typically not presented. The time period covered is often unspecified. As a result, it is difficult to know how comparable information from various sources on participation rates may be. The use of standard definitions and the provision of complete explanations of the composition of the eligible population are essential steps for improving the usefulness of data on participation rates.

The Northeast Region Demand-Side Management Data Exchange (NORDAX) data base makes an important contribution to the development of clear and consistent definitions. In this data base, definitions of terms are presented in great detail (Table 6) Thus, NORDAX provides an initial model of a clear and comprehensive set of categories that can be used to collect and organize data on DSM programs in a standard format. NORDAX definitions of annual penetration rates are the same as the ones presented in Table 5 for retrofit and replacement markets. NORDAX definitions of cumulative rates are the same as the first definition given in Table 5 for cumulative rates in both the retrofit and replacement markets.

Table 6. NORDAX definition of market penetration terms and rates

DEFINITION OF TERMS

Market size	number of eligible customers
Customer unit	type of units in which people or buildings targeted by a given DSM program will be counted, (e.g., for residential number of single-family dwellings, for commercial number of office buildings)
Measurement unit	type of units in which end-use appliances or equipment targeted by a given DSM program will be counted (e.g., lamps, tons of air conditioning, refrigerators) The ratio of the measurement unit should approximate the average number of tons, lamps, etc. per typical customer
Eligible customer	the number of customers who qualify for the program according to preset eligibility requirements, (e.g., to participate in an air conditioner load-control program customers must own air conditioners)
Base technology	existing or standard technology being replaced by the utility DSM program
Program technology	high efficiency or new technology
Phase	the successive periods or stages a program may go through over its lifetime, phases are most often one year long

DEFINITION OF PENETRATION RATES

Penetration $\frac{\text{\# of customers who participate}}{\text{\# of eligible customers}}$

OR $\frac{\text{\# of measurement units that participate}}{\text{\# of eligible measurement units}}$

The penetration rate may be calculated by phase (analogous to annual rate as shown in Table 3)

OR A cumulative penetration rate may be calculated by combining information from all program phases in one of two ways:

$$\text{RETROFIT} = \frac{\sum_{t=0}^{n} AP_t}{EM_t}$$

$$\text{REPLACEMENT} = \sum_{t=0}^{n} \frac{AP_t}{EM_t}$$

where: AP_t = Annual participation measured in units at a time t

EM_t = Eligible market at time t

Source: NORDAX 1989.

3. DATA ON PROGRAM PARTICIPATION RATES

Several studies of participation rates in residential and commercial retrofit and new construction programs are available. Some of these studies are based on case studies of especially successful programs (Berry, Hubbard, and White 1986; Kreitler 1986). Others report participation data based on surveys of from 50-200 programs (Electric Power Research Institute 1988a, 1988b, 1988c, 1988d; Van Liere and Davis 1986; Vine and Harris 1988; Northeast Region Demand-Side Management Data Exchange 1989; Nadel 1990).

VARIABILITY

The most striking pattern in these tabulations of the participation rates of programs is the high variability and broad range of results that is seen (Table 7 and Figs. 5-8). Ranges of less than 1% to nearly 100% of eligible customers participating have been reported. Much of this variation may be due to definitional differences. It is not always clear if the data presented are annual or cumulative rates of participation. The number of years a program has operated may not be

Table 7. Variation in annual market penetration rates (%/year)

	Average	Minimum	Maximum
Residential			
Audit[a]	3.2	0.03	31
Incentive[a]	5.5	0.02	59
Direct load control[a]	26.0	0.01	100
Time-of-use rates[a]	24.0	0.1	100
Home energy rating systems[b]	40.0	2.0	100
Commercial			
Audit[c]	3.6	0.01	50
Incentive[c]	2.4	0.13	32
Direct load control[c]	0.3	0.12	0.57
Time-of-use rates[c]	1.1	0.10	100

[a]EPRI 1988a and 1988b.
[b]Vine and Harris 1988.
[c]EPRI 1988c and 1988d.

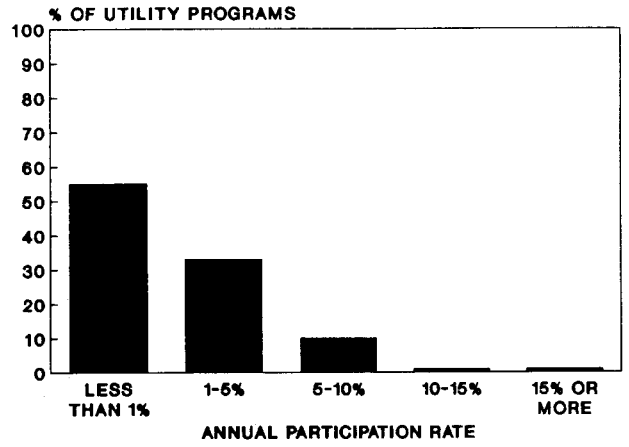

Fig. 5. Distribution of participation rates in residential audit programs

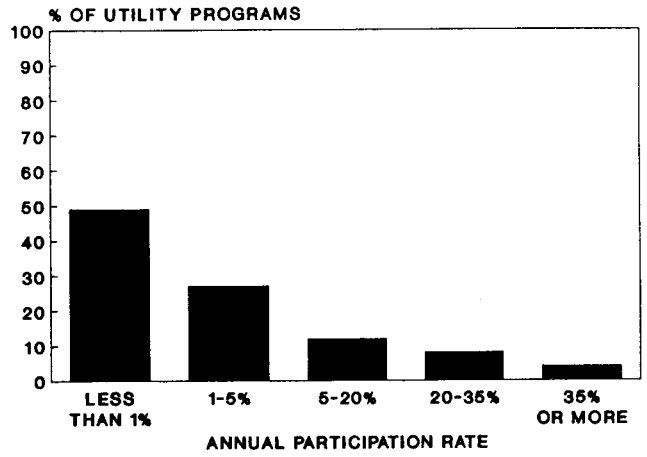

Fig. 6. Distribution of participation rates in residential financial incentive programs

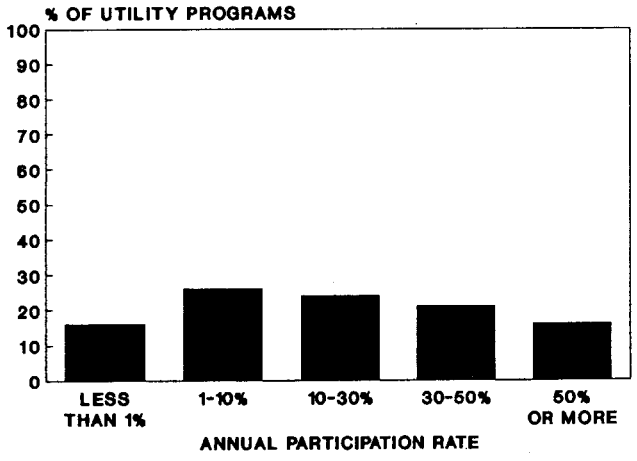

Fig. 7. Distribution of participation rates in residential load control programs.

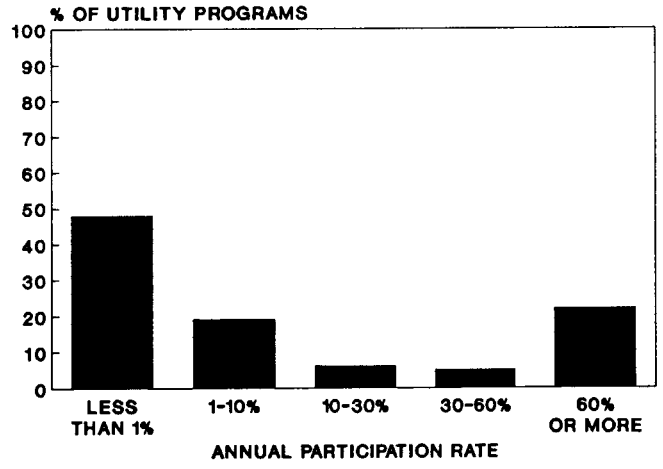

Fig. 8. Distribution of participation rates in residential rate programs.

reported. It is usually unclear how the eligible population and, therefore, the rates are defined. In most of the data bases examined for this report, the number of eligible customers was presented without an explanation of how eligibility was defined or determined. Therefore, the denominator for some rates may be all residential customers, while for others it may be only those customers with the end-use in question.

AVERAGE AND MAXIMUM RATES

A majority of residential audit programs, in a 1988 EPRI (1988a and 1988b) data base, had annual participation rates of less than 1% (Fig. 5). The average rate for audits was 3.2% and the highest rate was 31% (Table 7). Financial incentive programs (including both weatherization and appliance rebates) had higher participation with an average of 6% and a maximum rate of 59%, but almost half of the programs had rates of less than 1% (Fig. 6, Table 7). Home energy rating systems, direct load control, and time-of-use rate programs had higher average rates (24% to 40%) and maximum rates of 80% to 100%[1] (Figs. 7 and 8; Table 7). Differences by program type are summarized in Figure 9, which shows that most annual rates for all program types were below 30%. Figure 9 also shows that all audit and incentive rates were below 60%, while a few direct load control and rate programs reached participation rates of between 80% and 100%.

Commercial programs included in the EPRI data base (EPRI 1988c, 1988d) had lower average and maximum participation rates than residential programs, except for audit programs which had about the same average rate and a higher maximum (Table 7 and Fig. 10).

The maximum cumulative rates found in any of the data sources are shown in Table 8. Some intensively marketed residential programs, including the Hood River Conservation Project (residential retrofit) and the Gulf Power Good Cents Program (new residential construction), achieved over 90% cumulative penetration in one to three years. Seattle City Light's (SCL) residential weatherization program achieved a cumulative penetration of 42% of eligible buildings weatherized in 7 years. The community of Fitchberg, Massachusetts, relying largely on volunteers, organized an intensive door-to-door conservation effort in which 60% of the residents participated in a few weeks time (Sant, Bakke, and Naill 1984). Several

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[1]Recall that customers whose participation began in earlier years are counted among the current year's participants in the calculation of rates for direct load control and time-of-use rate programs. In addition, some rate programs are mandatory, guaranteeing 100% participation.

Table 8. Maximum cumulative market penetration rates in residential and commercial/industrial sector

Program type and sponsor	Highest cumulative rate
Residential retrofit	
Financial incentive for retrofit	
Hood River Conservation Project[a]	over 90%
Fitchberg, Massachusetts[b]	60%
Several major California utilities[c]	50%
Water heater wraps	
New England Electric System[d]	52%
Seattle City Light[e]	60%
Residential construction	
Home energy rating systems	
Gulf Power[f]	95%[g]
Public Service of New Mexico[h]	100%[g]
Kansas City Power and Light[h]	100%[g]
Commercial/industrial retrofit	
Audit and load control	
Sacramento Municipal Utility District[i]	50%
High-efficiency lighting	
New England Electric System[j]	60%[k]
Sacramento Municipal Utility District[l]	57%
City of Austin[l]	50%
Commercial/industrial construction	
Energy-efficiency awards and design assistance	
Florida Power Corporation[f]	20%[g]

[a]Hirst 1989.
[b]Sant, Bakke, and Naill 1984.
[c]Schultz 1989.
[d]Spellman 1989.
[e]Newcomb 1989.
[f]Kreitler 1986.
[g]These rates are defined as the percentage of buildings constructed in the most recent year that received the high-efficiency rating.
[h]Vine and Harris 1988.
[i]EPRI 1988d; this program was targeted to large commercial and industrial customers. About half of the 850 customers have been audited in the ten years the program has operated. Main goal is to reduce summer peak. Air conditioning, refrigeration, and lighting systems are targeted.
[j]Nadel 1988.
[k]This program is a one-stop lighting give-away program that ran from August 1985 to December 1986 in 20 economically depressed communities. Free audits were provided and free installation of lighting retrofits was provided if a cost-effectiveness test was passed. Audits were requested by 60% of eligible customers but only 34% qualified for the lighting improvements because of the stringency of the cost-effectiveness test (Nadel 1988).
[l]Gettings and MacDonald 1989. Both of these programs installed high-efficiency lighting measures at no cost to the customer. They were targeted to small commercial establishments.

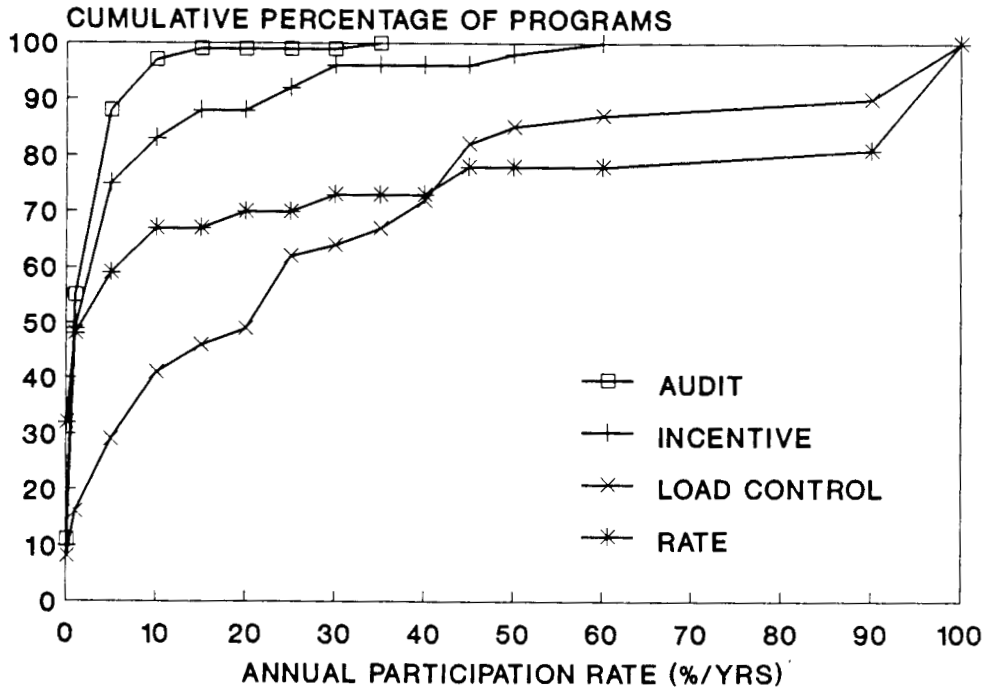

Fig. 9. Distribution of annual participation rates for four residential program types.

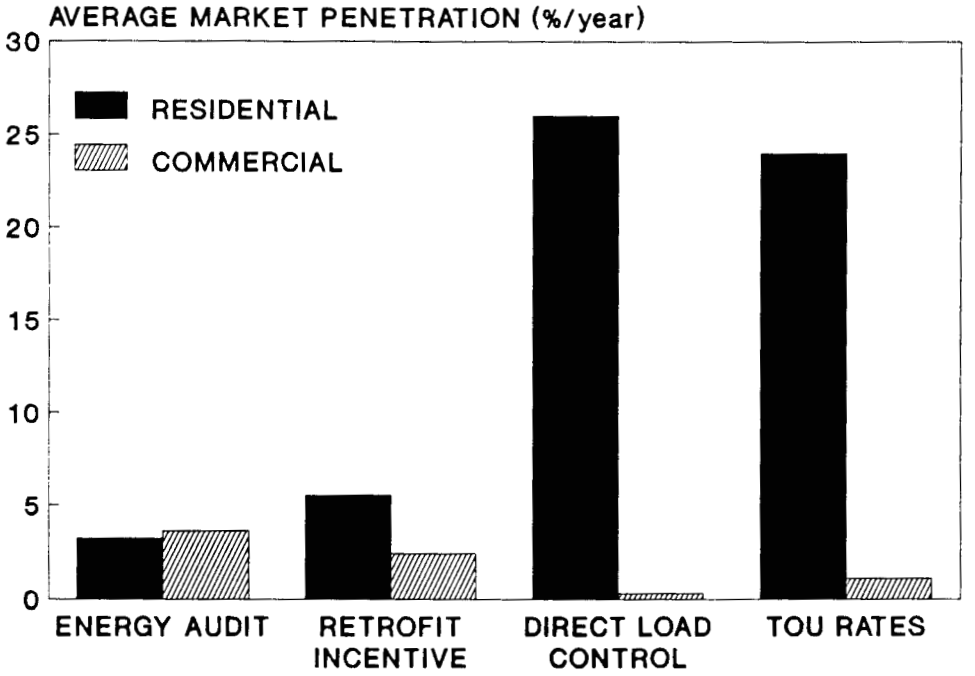

Fig. 10. Comparison of average annual rates for residential versus commercial programs.

residential retrofit programs, that were implemented by major California utilities for eight to ten years (mid-1970s to mid-1980s), achieved cumulative penetration rates approaching 50% (Schultz 1989). Marketing by independent (nonutility) contractors and free, direct installation were key elements in the high penetration achieved by the California utility programs (Berry, Hubbard, and White 1986). A variety of measures were included in the California programs such as caulking and weatherstripping, water heater blankets, duct wrap, and attic insulation. Some analysts believe that close to 90% of the buildings which could cost-effectively install some of the measures (e.g., attic insulation) did so during the lifetime of these programs. More market research and data are needed to support this estimate. A large DSM market research and data base development effort is expected to begin among the California utilities in 1990. It should help resolve issues related to market penetration as well as a variety of other DSM planning issues (La Riva 1989).

The data suggest that average participation rates for commercial retrofit programs may be lower than for residential retrofit programs, although this could be due mainly to their more recent origin. There is no equivalent to the Hood River experiment (which sought to achieve the maximum possible participation in residential retrofit) for the commercial sector. Except for Hood River, no full scale programs (in either the residential or commercial sector) have achieved cumulative market-penetration rates higher than 50%-60% (Table 8). The NEES programs may exceed this level in the future, because of the intensive marketing and aggressive free, direct installation approach being used. One of their pilot commercial lighting programs, after about one year of operation, achieved a penetration rate of over 30% (Nadel 1988). A few small-scale pilot programs, aimed primarily at large commercial customers, have achieved rates above 80%.

Data on the market penetration rates of energy-efficiency rebate programs for appliances are largely unavailable. Based on their survey of 132 utilities (from which detailed information on 59 energy-efficiency rebate programs was collected), Berman, Cooper, and Geller (1987) concluded that most utilities are unable to estimate the percentage of appliances sold locally that could qualify for rebates or the additional number of purchases of efficient models resulting from their programs.

One utility that collected sales data from appliance distributors before and after a rebate program was implemented, found that only 40% of buyers of high-efficiency models actually applied for a rebate. Some of those who applied were undoubtedly free-riders, although this proportion is not reported (Berman, Cooper, and Geller 1987). Niagara Mohawk Power Corporation's (NMPC) evaluation of its appliance rebate pilot programs found that the percentage of buyers of high-efficiency appliances who claimed their rebates ranged from 5% to

44% depending on the type of appliance. Since rebates are intended to influence all buyers of covered appliances to select more efficient models, the eligible population is more correctly defined as all appliance buyers regardless of the efficiency of the model they choose. If the number of eligible customers is defined as all appliance buyers, instead of only buyers of high-efficiency models, the percentage of the eligible customers using rebates clearly would be much lower. Data on market penetration using this definition were not reported by Berman et al. or by NMPC (1989). Data reported in an EPRI survey on acceptance of rebate offers for heat pumps and high-efficiency air conditioners by all buyers of the technologies showed average annual market penetration rates of 4% (EPRI 1988a).

PACIFIC NORTHWEST PROGRAMS

In the Pacific Northwest, participation rates for residential programs implemented by the BPA and by investor-owned utilities seem to be higher than the averages suggested by the EPRI survey data (EPRI 1988a and 1988b; Dornbush 1985). In residential weatherization programs, which usually offer subsidies of about 70%, for example, cumulative penetration rates of 26% to 42% have been reported (Jackman 1989; Newcomb 1989). The percentage of eligible buildings audited in these programs is higher than the percentage weatherized. This occurs because cost-effective opportunities do not always exist in the audited buildings and because audited customers may choose not to install the recommended measures. SCL's Blanket Seattle free water heater wrap program obtained 60% participation in three years (Newcomb 1989). A residential new construction program at Puget Power achieved 23% participation in its first year of operation. Part way through its second year the penetration rate was 65% (Jackman 1989).

Data on commercial programs in the Pacific Northwest are not relevant to defining long-term planning assumptions, because most of the programs have participation rates of less than 5% and because participation is limited by the available supply of services. Similarly, because the NORDAX data base contains information mainly on pilot programs with participation rates of less than 5%, examination of this data base did not yield relevant results.

4. FACTORS AFFECTING PARTICIPATION RATES

Most currently used market-penetration models are based on traditional microeconomic analysis (Section 5). The analysis of tradeoffs between capital and operating costs which drives these models is clearly one important set of determinants. Yet, these models cannot account for the range of variation that has been observed. The structure of a life-cycle cost-minimization model cannot, for example, explain why free conservation measures are often accepted by less than half of the eligible customers (NMPC 1989). Nor, can it explain why identical financial incentives and DSM measures offered by different sponsoring agencies may produce from two to five fold variations in customer response (Burby et al. 1985; Stern 1986).

As Spellman (1989) explains, traditional microeconomic (cost-minimization) models do not perform well in situations where the utility will pay 100% of the costs of measures. With these levels of incentives, rate of return or payback calculations no longer have any meaning. Utility DSM market penetration models need to be developed which can tackle the behavioral issues (Spellman 1989).

Stern (1986) has cogently described the difficulties of reducing the analysis of energy use to an application of economic theory (often further simplified to produce tractable models). He shows how economic concepts of behavior direct attention selectively to some determinants of behavior but restrict understanding concerning other determinants. As Stern points out, the central theoretical concepts of available economic theories of consumer behavior, such as elasticity, discount rate, and lag, provide a convenient mathematical shorthand for describing important economic processes but ignore behavioral variables that are powerful levers for policy. Some of the critical noneconomic factors influencing program participation that Stern (1986) identifies are: communication, trust, convenience, commitment, program implementation, the various dimensions of information, and consumer misperceptions of energy.

As Stern argues, an overreliance on economic concepts often results in overlooking promising policy options based on concepts from other social science disciplines (e.g., social psychology-persuasive communication). There is a substantial literature, based mainly on case studies, which illustrates the importance of a broad range of determinants of DSM program participation (e.g., Berry, Hubbard, and White 1986; Condelli, Archer, Aronson, Curbow, McLeod, Pettigrew, White, and Yates 1984; EPRI 1988a, 1988b, 1988c, 1988d; Kreitler 1986; Stern and Aronson 1984; Yates and Aronson 1983). The sections below draw on this literature to identify and discuss several important determinants of participation rates. The

emphasis is on factors that can be manipulated in the design of conservation programs.

PROGRAM SPONSORSHIP AND SOURCE OF INFORMATION

Identical information will have different impacts depending upon the perceived trustworthiness, credibility, or motives attributed to the source. A classic example described by Stern (1986) is summarized below:

> In August 1976, two marketing professors conducted a study in which they sent a brochure on how to cut energy use to hundreds of New York City apartment dwellers who owned air conditioners. Half of the brochures were mailed out on the stationery of the New York Public Service Commission; the other half were mailed out on the stationery of the local electric company, Consolidated Edison. In the next month, the first group of homes saved 7% on their electricity bills; the other group saved nothing. The difference is probably attributable to the relative credibility of the sources (Stern 1986, p. 206).

Another example discussed by Burby et al. (1985) is an experiment conducted in New York in which:

> each customer served by Consolidated Edison was sent one of three letters with his electric bill asking him to enroll in a load-control program. One letter was from Con Ed, the second was from the state public service commission, and the third was from the Cooperative Extension Service at Cornell University. Positive responses from customers were markedly higher, almost double, when the letter enlisting their cooperation did not come from Con Ed (Burby et al. 1985, p. 202).

A third example concerns a county government (Hennepin County, Minnesota) that was five times as effective as an energy company in enrolling participants in a novel shared-savings program. In this program, the company installed home retrofits at no cost to the household and earned money by collecting a share of the value of the energy saved. In this case, after Hennepin County:

> decided to initiate a shared-savings program, it contracted with a private company to do the energy audits and retrofits. As an experiment, homes were solicited by a single random mailing of one of three types: a letter on the company's letterhead with no

> mention of the county's involvement, the same letter with added mention of the county's role, and an essentially identical letter on county letterhead signed by the chairman of the county Board of Commissioners. Requests for energy audits came from 6, 11, and 31%, respectively, of households receiving the three types of letters, and shared-savings contracts were signed by 1.7, 2.7, and 9.3% of the households, respectively. In short, one sponsoring arrangement was five times as effective as another (Stern 1986, p. 212).

Polich's (1984) study of alternative implementation arrangements for the Residential Conservation Service Program in Minnesota offers another instance of the significance of program sponsorship arrangements. In this case, energy audits were conducted in three different ways: by utility employees, by a private energy firm, and by community groups. Programs in which the audits were conducted by community groups received three to four times as many audit requests as the other two arrangements.

The large impacts on market penetration rates which may result from varying the source of the program offering suggest that nonutility sponsorship or support can often increase participation dramatically. This is especially true for hard-to-reach residential market segments such as low-income and elderly households (Berry, Hubbard, and White 1986; Berry, Schweitzer, and Freeman 1988). Market research and field experiments can clarify the sponsorship arrangements which can be expected to produce the highest customer response in various market segments in specific locations and time periods. Cooperative marketing efforts with trade allies, community organizations, and local governments will often be an effective means of increasing market penetration.

COMMUNICATION FACTORS

Based primarily on social psychology and communication theory, the following recommendations concerning actions utility representatives can take to increase participation have been proposed:

- Personalized and vivid information is more likely to influence behavior; thus, hands-on demonstrations and accounts of homes in the same neighborhood, or of establishments in the same business, are effective.

- People are more sensitive to current loss than to future gain; thus, avoidance of the loss of money should be stressed.

- The more concrete and specific the recommendations and the clearer the path to be taken, the greater the influence on behavior.

- People are frequently swayed more by the report of a single individual than they are by a comprehensive data summary.

- Ongoing commitments can be obtained from people by first soliciting a smaller commitment (the foot-in-the-door approach).

- Allowing a choice increases the commitment to the chosen action.

- Recommendations should be presented in person by a representative trained in sales techniques.

Research supporting many of these recommendations was reviewed by Stern and Aronson (1984) and by Coltrane, Archer, and Aronson (1986). Experimental results support many of the recommendations. For example, Gonzales, Aronson, and Costanzo (1986) conducted an experiment which demonstrated that an auditor training program increased customer response. In their study, a group of auditors received training in social psychological principles and communication techniques designed to increase response to incentive offers. The training sessions focused on providing vivid information, using role models, and framing conservation recommendations in terms of loss rather than gain. In comparison to a control group of auditors who received no special training, the experimental group obtained a 20% higher enrollment rate for postaudit financing offers.

Research on communication effects in commercial programs is less extensive than for residential programs. An EPRI survey of commercial program experience, however, offered many of the same recommendations: present audit results in person in terms the customer understands and can relate to, use peer testimonials and trade allies in marketing, and provide sales training for program personnel (EPRI 1988c).

FINANCIAL INCENTIVES

Evidence on the effects of financial incentives on program participation is inconsistent. Several researchers report little association between incentives and acceptance rates for DSM programs. Heberlein's (1981) study of load-control programs, for example, found that size of the incentive was not nearly as important as the way in which the program was marketed. He concluded that it is possible to obtain high rates of adoption with no incentives, if the program is well marketed. Burby et al. (1985) reached the same conclusion in their study of load-control

programs. Among the 64 programs for which they collected data on financial incentives and market-penetration rates, there was little association between the two variables. The analysis by Burby et al. showed that financial incentives alone do not assure high rates of penetration. The utility offering the highest monthly incentive payment for control of air conditioners, for example, gained program acceptance in only one percent of the eligible residences. In contrast, of the eleven programs that were accepted by nearly 100% of the eligible households, only three offered any financial incentive. A Pacific Gas and Electric Company (PG&E) experiment, which involved offering bill discounts ranging from $4 to $12 per month to customers eligible for a load-control program, found no difference in response by incentive level (Fernstrom 1989). In a NMPC experiment, a low-rebate group ($0.40 for each reduced-wattage lamp) and a high-rebate group ($0.80 per lamp) both had participation rates of about 3% (Clinton and Goett 1989).

Several reviews of the effects of incentives on program participation that examined mainly residential weatherization programs (Berry 1982; Stern, Berry, and Hirst 1985; Stern, Aronson, Darley, Hill, Hirst, Kempton, and Wilbanks 1987), concluded that participation rates are influenced less by the size of the incentive than by the way that programs are implemented and marketed. These studies found that participation rates in programs offering identical financial incentives vary by as much as ten-fold. A BPA zero-interest loan program for residential weatherization implemented by local public utilities in different locations, for example, produced response rates that varied from 8% to 90% of eligible households. Data on a loan program implemented by nine New York utilities showed a similar range (Stern 1986). A comparison of three U.S. grant programs which offered a median incentive of 77% of measure costs with five foreign programs which offered a median incentive of 50%, found that the foreign programs had twice the median participation rate of the U.S. programs: 8% versus 4% per year (Stern 1986). Thus, in these instances, the size of the incentive was not the principal determinant of participation rates. Factors such as trust, commitment, program sponsorship, marketing, consumer protection features, and simplification of program procedures influenced participation rates more strongly than the size of the incentive.

In their review of implementation experience with 69 conservation programs for new residential and commercial buildings, Vine and Harris (1988) concluded that the size of incentives did not seem to be correlated with program participation rates. Vine and Harris (1988) also concluded that the presence of an incentive may be more important than its size and that incentives are more effective if they are combined with technical assistance, training and education.

Geller's review of appliance rebate experiments (1988), in contrast to the studies discussed previously, concluded that the size of an incentive is closely related to participation rates. Geller reviewed experiments conducted by four utilities to test the effects of varying the size of appliance-efficiency rebates. The results of these experiments (including those described in NMPC 1989) clearly showed that larger rebates were accepted by more customers. Geller noted, however, that there were still important unresolved issues. In particular, it was impossible to state how large an incentive was necessary to obtain a given level of participation, or to state how large an incentive was optimal. Geller suggested additional research to determine optimal delivery mechanisms and to minimize free riders.

An experiment conducted by the BPA on the relative effectiveness of promotion versus incentives for obtaining market acceptance of heat pump and solar water heaters, indicated that both factors had positive effects. While both incentives and promotion stimulated customer acceptance they were most effective when used together (BPA 1989).

In the BPA experiment four treatments were tested by randomly assigning utilities to the cells of the matrix (Table 9). The interaction effect between the high-promotion and high-incentive levels is striking. The high-promotion treatment involved the use of posters, counter cards, sales brochures, bill stuffers, newspaper ads and radio spots developed by an advertising agency. The low-promotion treatment consisted of a smaller budget that was used directly by utility staff to advertise the program. The low incentive to the customer was $200 and the high $500.

In this experiment, none of the utilities obtained acceptance from more than a fraction of a percent of the eligible customers, largely because the solar and heat pump water heaters had very long paybacks (often over 100 years). Nevertheless, this study clearly demonstrated the synergy between incentives and promotion.

Table 9. Number of solar/heat-pump water heater sales by treatment condition.

	Incentive levels	
Promotion levels	Low	High
Low	4 sales	47 sales
High	56 sales	802 sales

Another study which suggests a positive (although weak) relationship between incentives and participation rates was conducted by Camera, Stormont, and Sabo (1989). In this study, data from the NORDAX data base were used to plot market penetration rates as a function of the utility incentive fraction (defined as the ratio of incentive cost to capital cost for the technology). The incentive fraction for the programs varied from zero (i.e., the customer pays the full initial cost) to one (i.e., the utility pays the full initial cost). As the incentive fraction increased from zero to one, the annual market-penetration rates rose from 0 to 4.9% (Fig. 11). Most of the programs in the NORDAX data base offered appliance rebates and had been operating for less than one year.

Kreitler's (1986) review of the effectiveness of various utility conservation designs (based on case studies of several program types) concluded that financial incentives significantly increase penetration rates. Incentives were considered especially effective in increasing participation among low-income customers.

The inconsistency in the studies discussed above may occur, in part, because of differences in methods and program types (although even when these factors are

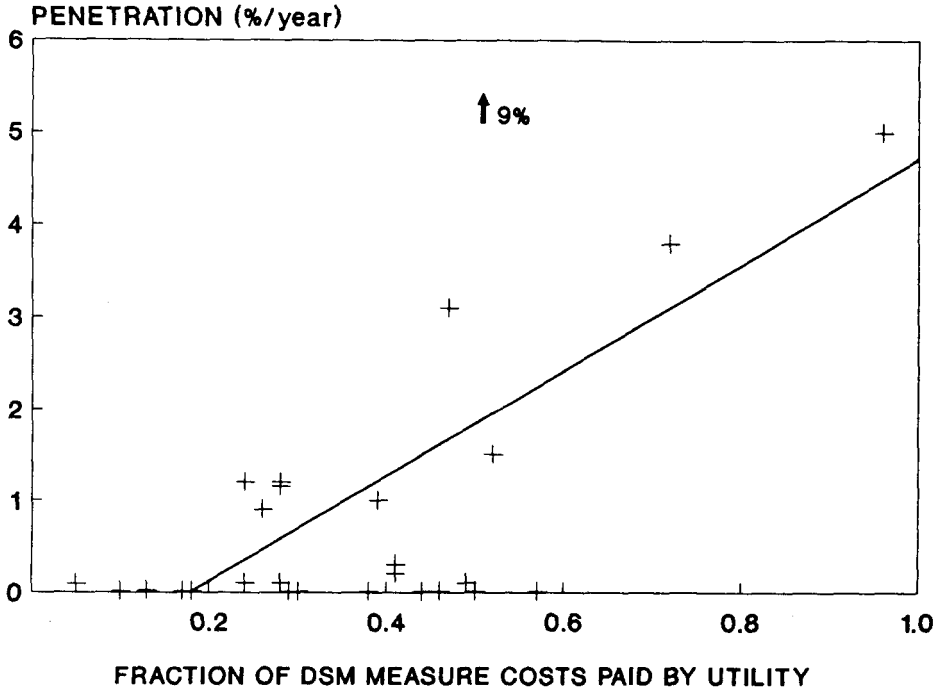

Fig. 11. Penetration rate by incentive fraction (i.e., incentive cost/capital cost) for programs in the NORDAX data base. (One point, which has a penetration rate of 9% and a incentive fraction of 0.5 is not plotted to improve the readability of the graph.)
Source: Camera, Stormont, and Sabo 1989.

considered some inconsistency remains). The experimental studies, reviewed by Geller, varied appliance rebate levels while holding other program features constant. Kreitler's review compared a mandated audit-only program (the Residential Conservation Service), which had low penetration rates, to program designs developed voluntarily by utilities, which included financial incentives. In the two studies of load control programs (Heberlein 1981; Burby et al. 1985), incentive levels varied but the programs were implemented by different utilities in a variety of communities. Other reviews based on observational studies, such as those by Stern et al. (1985 and 1987), compared mainly residential weatherization incentive programs from various regions, nations, and time periods that were implemented by diverse organizations. Although these programs often had identical incentive levels, other program features may have varied substantially. Therefore, these results are consistent with the conclusion that the effect of a financial incentive depends on the conditions of its implementation (Stern, Berry, and Hirst 1985). When nonfinancial program features and the general program context are held constant, the influence of incentives is apparent. When nonfinancial features (such as program sponsorship and marketing, guarantees of consumer protection, or the complexity of program procedures) or contextual features (organizational commitment, customer trust, and type of community) vary, their influence may mask the effects of the incentives. It also is possible that first cost is more salient to decisions about appliances than to decisions about building retrofits, as suggested by Sinha and Rao (1988).

It is clear that meeting a customer's economic criteria for acceptance is a necessary, but not sufficient, condition for inducing participation. Because other factors can act as a veto on the decision to participate or to make an energy-efficient investment, it is often difficult to discern the independent influence of incentives. In short, financial incentives are only one factor influencing customer participation in DSM programs, and often not the most important one.

MARKETING

A data base compiled for EPRI (1988a; 1988b) from a survey of more than 100 utilities, which included information on 316 residential programs, was analyzed to identify the most important determinants of program participation. In this study, the influence of utility, customer, and program marketing characteristics on participation rates was examined with multivariate statistical techniques. Program marketing characteristics explained participation most effectively. The two variables that best explained variations in participation were the duration of the program and the marketing expenditures per customer. The intensity of the marketing efforts was the best explanatory variable. Five residential program types were considered in this study: energy audit, financial incentive (for building retrofit and for heating

and cooling systems), trade-ally cooperation, rates, and direct-load control. Guidelines for achieving higher penetration levels for these residential program types are presented in the analysis of the data base (EPRI 1988b). The specific recommendations vary by program type but all reflect the importance of selecting appropriate marketing and communication techniques.

A data base on commercial programs was assembled using a similar approach (EPRI 1988c and 1988d). Because of the diversity of commercial program features and the limited number of programs of specific types, however, little quantitative analysis was performed with this data set. A qualitative analysis identified several key influences on participation. Programs that addressed a variety of barriers (related to economic payback, financing, customer-time requirements, and concerns about comfort, noise, aesthetics, security, and business disruptions) were the most successful. By far the most important factor was the extent to which program implementors understood and met a variety of customer needs. Risk aversion and uncertainty about the reliability and performance of DSM technologies were especially important barriers to participation. Programs which addressed these concerns through extended warranties or other forms of guaranteed performance obtained higher participation rates.

Choice of marketing strategies also was important. One program manager reported, for example, that mass media advertising led to about a 5% response rate while direct personal contact with customers produced a 95% response rate. Two experiments showing the effectiveness of personal contact were conducted by NMPC and New York State Electric and Gas (NYSEG). The NMPC experiment offered identical lighting rebates to customers - one offer by mail and one in-person by a utility representative. Response to the mail offer was about 3% and to the in-person offer 21% (Clinton and Goett 1989). The NYSEG experiment, in a commercial audit program, showed that personal contact produces much higher response than telephone and mail contacts at three incentive levels (Fig. 12; Xenergy 1989).

TRADE-OFFS BETWEEN INCENTIVES AND MARKETING

Because both incentives and marketing have important impacts on penetration, it is important to consider the trade-offs between these two approaches. As utility incentives covering direct energy-efficiency measure costs increase, program marketing and administrative costs may decrease. In some cases, paying 100% of the energy-efficiency measure costs reduces the other program costs enough to make the total cost per kWh saved less than it would be at lower incentive levels. An experiment conducted by NMPC, for example, compared the market penetration and total electricity savings resulting from a free offer of

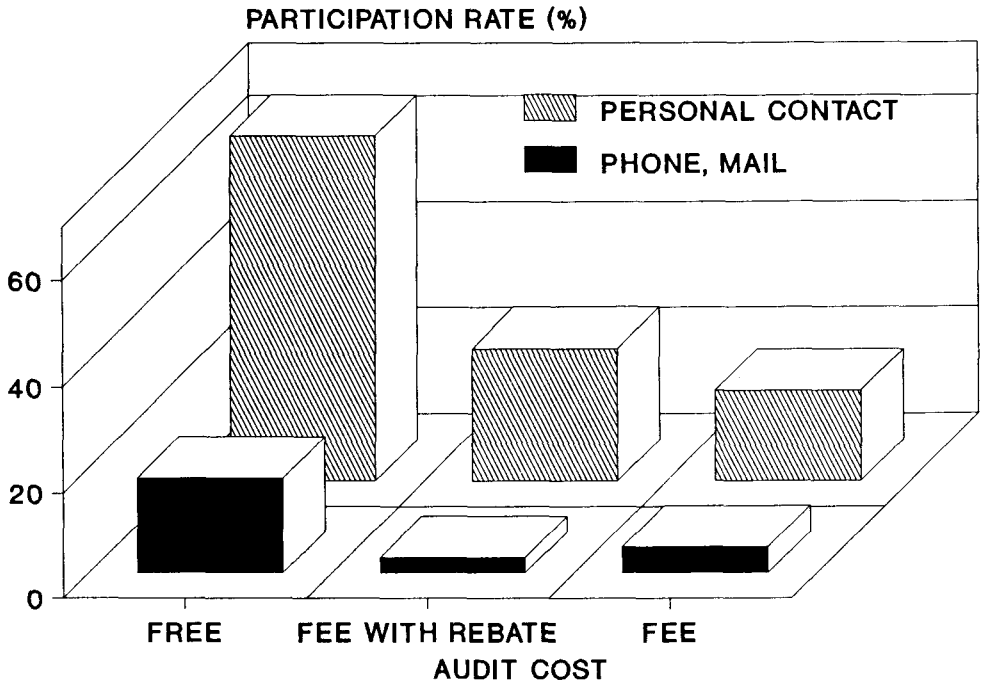

Fig. 12. NYSEG experiment shows effectiveness of personal contact at three incentive levels.
Source: Xenergy 1989.

low-cost electric-water-heating measures with those of a 50% incentive, and a shared-savings offer (in which the cost of the measures was repaid to the utility by the customers at zero-interest over a two year period). All of the offers were made to residential customers by direct mail. Market penetration was five times higher for the free offer and total costs per participant were less (Fig. 13). Because more penetration was achieved at less cost, savings due to the free offer were ten times higher, at a per kWh cost that was nearly five times less, than consumption reductions from the shared-savings offer (Flaim, Miedema, and Clayton 1989). Condelli et al. (1984) supported the same general point in their report of an insulation program for low-income housing in which promotional and advertising costs were greater in absolute terms than the costs for free, direct installation of the measure would have been.

Nadel (1988) reports related findings in his comparison of three NEES lighting programs for the commercial/industrial sector. One of the programs, which offered free installation of lighting measures, achieved ten times the market penetration (34% versus less than 3%) of the programs offering a smaller incentive

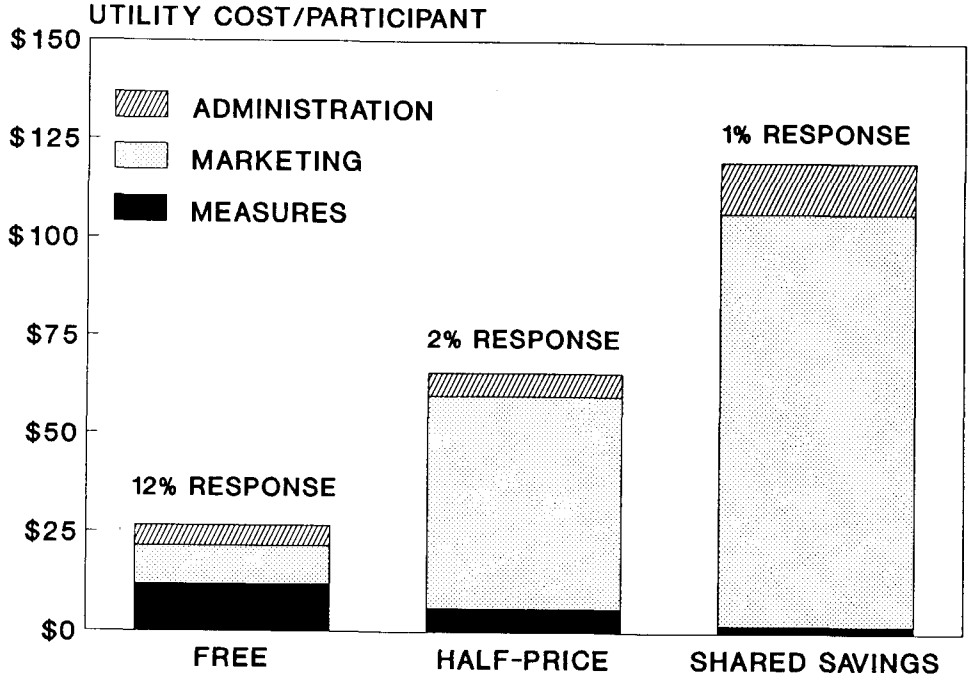

Fig. 13. Comparison of utility costs per participant for low-cost measures offered free, at half-price, and as shared savings. Source: Flaim, Miedema, and Clayton 1989.

through customer or dealer based rebates. In this case, however, the free installation program had the highest cost/benefit ratio (0.61 versus 0.21 to 0.50). Nadel (1988) noted that the direct installation program was the most complicated for the utility to operate and had the highest administrative costs. The program was heavily marketed with two mailings to all eligible customers, telephone calls, and site visits to customers located in large towns.

In general, in-person offers, telemarketing and door-to-door canvassing produce much higher response rates (30-60%) than direct mail (typically less than 5%); these techniques are, of course, much more costly. Nevertheless, the costs per participant may be less with personal contact techniques. A NYSEG study found, for example, that the cost per commercial audit completed with personal contact marketing was $52, which was considerably lower than the cost per audit completed with direct mail solicitation ($170) (Xenergy 1989; Fig. 12).

Selecting and designing the most cost-effective programs requires an understanding of how to minimize total costs while achieving the desired levels of market penetration and electricity savings. More data on the trade-offs between the incentive, marketing and administrative costs per kWh saved would help

planners to achieve this goal. Additional field experiments which systematically vary incentive, marketing and administrative expenditures to determine the most cost-effective combination should be conducted. In the BPA experiment (discussed on p. 34), the most cost-effective program design was the high incentive/low promotion condition, but the high incentive/high promotion condition was the only program design to achieve significant penetration (BPA 1989). If high incentives increase penetration enough to produce significantly higher electricity savings, they may be more cost-effective than lower incentives. On the other hand, intensive marketing (such as telemarketing and door-to-door canvassing) may sometimes be more cost-effective than offering free measures. Obviously, to maximize market penetration intensive personal-contact marketing and the offer of free measures must be combined. While this combination is the most expensive, it may be the best choice if very high levels of market penetration and energy savings are desired.

DIRECT INSTALLATION

The most aggressive and successful DSM programs often offer free, direct installation of measures. With this approach the utility offers a specific preplanned installation of energy-efficiency measures at no charge to the customer. Direct installation makes the decision to install energy-efficiency measures part of the decision to participate in the program and requires no technical or financial expertise of the customer.

NEES, which began implementing one of the most aggressive DSM efforts in the nation last year, is using this approach for many of its programs (Destribats 1989). NEES believes direct installation is the best means of achieving high market penetration because many customers lack the time, funds, motivation or expertise to make energy-efficiency improvements. By relieving customers of both financial and administrative burdens, NEES programs are designed to capture energy-efficiency opportunities that are more economically attractive than building new generating facilities (New England Electric System and the Conservation Law Foundation of New England 1989). By providing simplicity, convenience and complete financing, NEES hopes to achieve annual market-penetration rates of 30% or more for several of its programs.

Nadel's (1988) study of a pilot program for commercial lighting (in which all the customer had to do was say yes to the utility offer in order to receive free, direct installations) reported that 34% of eligible customers received lighting improvements and over 60% requested an audit during the approximately one year of program operation. Gettings and MacDonald (1989) also discussed the concept of direct installation of energy-efficiency measures as an important approach for DSM programs aimed at commercial buildings. Their review of the City of Austin's

Small Commercial Direct Implementation Pilot Project and the Sacramento Municipal Utility District's Commercial Lamp Installation Program concluded that direct installation programs provide large customer incentives for participation and offset utility costs by producing predictable reductions in demand and energy consumption. Both of these programs achieved measured energy savings that were very close to predicted savings.

INTERNAL UTILITY PROMOTION AND PROGRAM MANAGEMENT

Program success depends not only on matching design features with customer needs, but also on the commitment, effectiveness and motivation of program managers and employees. Coltrane, Archer, and Aronson (1986) concluded their review of the key elements of successful conservation programs with the observation that the commitment of the sponsoring agency may be the most important determinant of effective programs. Top management support and adequate funding are of obvious importance. Constraints on budget and manpower often limit market penetration more than any other factors. If institutional commitment to program success is high enough, means of achieving high market penetration will be found.

Some specific strategies that can increase employee effectiveness and motivation include: providing training in communication and sales techniques for employees who have direct contact with customers and providing recognition (and perhaps monetary rewards) for meeting goals related to program participation. Utilities that implement these strategies find that they produce significant increases in market penetration (EPRI 1988c).

NEES has, for the last several years, used DSM program participation and electricity savings as part of the basis for determining the annual bonuses paid to senior management. As a result, intensive efforts and considerable progress have been made toward achieving high participation. When PG&E offered an employee incentive program for successful selling of program services, their levels of audit requests and loan and rebate usage increased markedly. In the PG&E employee incentive system, credits were awarded for each sale made and the credits could be redeemed for catalog merchandise. Top sales people at PG&E won trips to Hawaii. The PG&E incentive system was discontinued when customer response reached levels that exceeded budgets for the conservation programs (Brown, Berry, White, and Zeidler 1986).

CUSTOMER CHARACTERISTICS

A number of evaluations of home energy audit programs show that customers who choose to obtain audits have higher educational and income levels than the general population. Another typical characteristic of audit program participants is a greater interest, awareness, and concern with energy issues. Higher educational and income levels are associated with a greater understanding of energy problems. Positive correlations between education, income, and conservation behavior have been extensively documented (Tonn and Berry 1986). Age of household head also is associated with energy conservation behavior. This variable has a curvilinear relationship with conservation, as young and elderly households take fewer actions than those in their middle years. In general, the same factors that explain the audit-participation decision, also explain the decision to use financial incentives (loans, rebates). Middle-aged households with high education and income are more likely to use loans for residential retrofit.

In addition to the demographic factors differentiating residential program participants from nonparticipants, a variety of surveys, pilot studies and social experiments have assessed customer attitudes and decision-making processes. A national survey, sponsored by EPRI as part of its Customer Preference and Behavior (CP&B) project, for example, was used to develop six needs-based residential market segments. A survey instrument and model (CLASSIFY™) was developed that enables utilities to segment their customers and to use this information for program planning with the PULSE model (EPRI 1989a; Section 5).

The commercial sector is very heterogenous. Several customer characteristics are good predictors of the likelihood of participation. Among them are size, business type, organizational structure, business ownership status, energy intensity, magnitude of the energy bill, age of the building, length of lease, and complexity of the decision process. Small firms are much less likely to participate than large or medium sized firms. Retail establishments are generally the least likely to participate, while hotel/motel establishments have the highest level of interest (EPRI 1988c and 1988d).

PROGRAM CONTEXT AND SOCIETAL CLIMATE

Contextual factors that may influence participation include the rural-urban character of the community, fuel prices and shortages, and various political forces or social norms related to conservation. In a PG&E load-control program, for example, the city of Davis (which is well-known for its conservation ethic), had a participation rate of 80% while other communities participated at rates of 20%-40% (Fernstrom 1989). Higher response rates in rural areas have been

reported by several investigators. Since rural areas are often supplied by electric cooperatives that enjoy high levels of customer trust, they are, therefore, able to promote programs very effectively (e.g., Burby et al. 1985).

SUMMARY OF FACTORS RELATED TO HIGH PARTICIPATION

Many factors influence participation rates in energy-efficiency programs (Table 10). The absence of supply constraints and the commitment of sponsoring agencies to obtain high participation are probably the most important. With this commitment, effective (and expensive) program features such as regular personal contact with eligible customers, comprehensive technical and financial assistance, and efforts to identify and remove the most salient barriers by market segment, will be implemented.

When supply constraints are not an issue and effective programs are implemented, however, some adjustment may still be necessary to account for differences in the demand for program services. It may be that maximum achievable rates will differ by customer and community characteristics. For example, residential customers seem to be more likely to participate than commercial customers and rural communities more likely to respond at high rates than urban locations. Large, commercial customers are more likely to respond than small ones. In addition, factors such as fuel prices and shortages, and political and social forces favoring conservation, can significantly impact customer levels of response. If such broad societal influences change, demand for past programs may not predict future demand well.

Little evidence is available on how determinants of participation vary by market segment and program type. Most of the evidence on determinants of participation is based on studies of audit and loan programs for residential retrofit. Some studies of determinants deal with residential appliance-rebate and load-control programs. There are very few studies of commercial programs. More research is needed to clarify the patterns of variation by market segment and program type.

Some studies suggest that incentive size is more closely associated with participation in appliance-rebate programs than in load-control or residential-retrofit programs. There is general agreement that paying the full cost of measures is necessary to obtain participation among low-income residential customers. The relation of incentives to participation in commercial programs is unclear. Future research should address this issue through focus groups, customer surveys, program experience surveys, and field experiments. In addition, the interactions among

incentive, marketing and administrative costs must be explored if the most cost-effective combinations of program features are to be identified.

Table 10. Characteristics associated with high program participation rates

Program context
- High commitment of sponsor (including top management)
- Not supply constrained (enough budget, manpower, and materials to meet demand)
- Rising energy prices
- Expected energy shortages
- Favorable political and social climate

Program features
- Trusted, credible sponsor (e.g., local community groups, trade allies)
- Simplicity and convenience (one-step, direct installation)
- Financial incentives (no cost to customer)
- Marketing
  - Most effective techniques used (direct personal contact, door-to-door canvassing, telemarketing)
  - Market segmentation used
  - Targeted groups involved in program planning
  - Features matched to customer needs by market segment
  - Variety of barriers addressed
- Duration (program lasts 5 years or more)
- Sales training and rewards for program personnel
- Communication factors
  - Vivid, personalized information
  - Peer testimonials
  - Stress current loss instead of future gains
- Risk reduction
  - Quality control
  - Warranties
  - Guaranteed savings

Customer characteristics
- Residential
  - High income
  - High education
  - Middle-aged
  - Homeowner
  - Attitudes and lifestyle match program features
- Commercial
  - Large size
  - Hotel/motel

Community characteristics
- Rural, often with public power
- Well-integrated
- Conservation ethic

5. MARKET PENETRATION FORECASTING MODELS

A few general-purpose utility-planning models integrate demand and supply resources. Most of these models (e.g., LMSTM, MIDAS, and UPLAN), however, require substantial exogenous analysis of DSM programs. For example, the number of participants, the dynamics of participation, and the demand impacts of DSM programs typically must be determined exogenously and provided as inputs to integrated planning models. A notable exception is the Conservation Policy Analysis Model (CPAM), developed for the BPA (Ford, Bull, and Naill 1987; Ford and Geinzer 1988).

CPAM is a fully-integrated model that simulates the demand for electricity, the production of electricity, addition of new power plants, utility finances, and rates for the Pacific Northwest electric system. The basic building block on the demand side is a set of conservation supply curves. These curves show the tradeoffs between cumulative electricity savings and the marginal cost-of-conserved energy (in ¢/kWh). Decisions on energy efficiency are made within the model, based on the tradeoff between capital and electric-operating costs, given exogenously specified discount rates.

Three types of conservation programs can be handled with CPAM. Financial incentives reduce the capital cost of conservation measures. Information programs are assumed to lower the consumer discount rates. Finally, standards can be imposed that set maximum levels of electricity use for different end uses.

CPAM includes a logistic curve to simulate adoption of conservation over time. Two exogenously specified parameters determine the speed of technology adoption. Thus, the supply curves determine equilibrium values of efficiency while the logistic curve determines the dynamics of savings over time. CPAM includes, therefore, the two basic elements of a market penetration forecast: an equilibrium value and a logistic curve.

A variety of models have been developed and applied to the problem of forecasting market penetration (Green, Tull, and Albaum 1988; Lilien and Kotler 1983; Mahajan and Wind 1986). Many forecasting techniques are available. They range from subjective estimates by planners to complex quantitative methods. Classifications and reviews of the market penetration models most useful to utility analysts can be found in EPRI (1982 and 1987), Bentley (1986), Burby et al. (1985), Henneberger and Kendall (1989), Gellings and Chamberlin (1988), Komor and Wiggins (1988-89), Synergic Resources Corporation (1989a), and a recent draft report on the first phase of an EPRI project to develop a market-penetration analysis system (EPRI 1990). Each of these sources presents a somewhat different

model classification scheme. Most of these models were originally developed to forecast the sales of new technologies or products. They can be applied, however, to the problem of forecasting participation rates for utility-sponsored DSM programs.

There is extensive literature in the fields of economics, diffusion of innovations, and marketing on the theory and application of models of market penetration which is discussed in the literature reviews mentioned above. Because these reviews are comprehensive and readily available, no effort will be made here to repeat the details of their coverage.

There are several PC models that are designed to meet the specific needs of DSM program planners. These software packages have applied the methods developed in the literature on market penetration to construct routines that estimate customer acceptance of DSM programs. Some of these models deal only with customer acceptance of DSM options. Other models have broader objectives related to the screening, planning and analysis of the impacts of DSM programs. The focus here is only upon the market-penetration forecasting components of these models. Examination of these components should clarify some alternative approaches and help planners select among them. Outputs of these market-penetration forecasting models also can be used to supply, or modify, the inputs on DSM program penetration required by integrated models such as LMSTM, MIDAS, CPAM, or UPLAN.

The features, objectives, strengths and limitations of the market penetration forecasting approaches of six models developed by three organizations are reviewed in this Section. The models are: (1) the Alliance to Save Energy's "Demand-Side Management Program Design and Impact Assessment Model" (DSMPRO); (2) SRC's "Comprehensive Market Planning and Analysis System" (COMPASS), residential penetration (RESPEN), and commercial penetration (COMPEN) models; and (3) EPRI's PULSE model and market penetration analysis system. All except one of these models became available within the last few years. EPRI's market penetration analysis system is under development and will be available in 1991.

The market penetration forecasting components of the six PC-based models address two basic questions: what proportion of all possible adoptions (e.g., all technically possible applications of a high-efficiency device or all customers who could participate in a DSM program) will eventually (the time period is not specified) occur and when will they occur. The first question deals with estimating equilibrium market shares (also called steady-state or ultimate-market shares and the willing market fraction). Equilibrium market share estimation does not deal with the timing of technology adoption or program participation. It only establishes

a final expected value for market penetration. Timing is determined separately with diffusion models (also called a logistic or S-shaped curve) which assume that penetration will follow a characteristic time path. Mahajan and Peterson (1985) and Mahajan and Wind (1986) discuss various types of diffusion models in detail. The maximum value reached by a diffusion curve, over time, is equal to the equilibrium market share.

The primary objectives of the PC-based models include DSM program screening based on economic criteria (DSMPRO), the design of DSM programs that will capture the desired market share (PULSE), and the performance of an integrated equipment stock and diffusion analysis of the impacts on energy demand of alternative DSM program packages (COMPASS, RESPEN, COMPEN). EPRI's market penetration analysis system focuses exclusively on forecasting market potential and penetration. It provides a general structure for the collection of primary data and for the application of both primary and secondary data to the development of market share estimates and time-dependent market penetration forecasts.

THE ALLIANCE TO SAVE ENERGY: DSMPRO

DSMPRO allows utilities to duplicate the analysis procedure presented in an Alliance report (1988) in which the model is used as a DSM program screening tool. Development of this model began when the Alliance worked with General Public Utilities Service Corporation (GPU) to conduct a comprehensive analysis of GPU's DSM opportunities. The goal was to select DSM options that would minimize GPU's revenue requirements without raising the total costs to society of providing energy services.

The market penetration component of DSMPRO (Table 11) operates under the assumption that the rate at which a product penetrates the market is largely a function of its internal rate of return (which depends upon tradeoffs between higher capital and lower operating costs). Other things being equal, the higher the internal rate of return, the faster the rate of market penetration. DSM program incentive levels ranging from 10-90%[2] of capital costs can be analyzed with DSMPRO. The incentive values must be no larger than the amount of their electric energy and demand savings valued at the utility's marginal energy and capacity costs (The Alliance to Save Energy 1988, p. xviii).

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[2]The model cannot deal with incentives of 100% because then all customers would adopt the technology (clearly an unrealistic forecast).

Table 11. Market penetration component of the DSMPRO model

OBJECTIVES
- Select DSM options that minimize revenue requirements without raising total societal costs.

APPROACH
- Market share is determined solely by the economic attractiveness of the DSM options
- Penetration over time is estimated with a Mansfield-Blackman diffusion curve that is adjusted judgmentally

INPUTS
- Rate at which existing stock is replaced
- Rate at which stock grows over time
- Initial and operating costs of equipment
- Lifetime of equipment
- Distribution of consumer discount rates

OUTPUTS
- Market share estimates for each year of the forecast

STRENGTHS
- Accounts for market-induced and incremental program effects on penetration
- Estimates free riders

LIMITATIONS
- Ignores noneconomic factors

To apply the model, the following data are needed on each DSM option: initial cost, useful life, purchase and replacement assumptions, current market penetration, and energy and peak demand savings. Utility specific information also is collected on avoided costs, rates, end-use sales and peak demands, customer investment criteria, and load forecasts. The model hypothesizes a distribution of implicit discount rates, which consumers use to assess higher-initial-cost energy-efficiency options that reduce subsequent operating costs. These discount rates are used to define the steady-state (ultimate) market penetration of a new end-use device without utility intervention. A logistic curve (based on Mansfield

1961 and Blackman 1974) is then used to specify the rate at which efficiency is improved voluntarily over time. Next, the utility incentive is specified as a percentage of the initial cost of the efficiency improvement. This reduces the initial cost to consumers and therefore increases the ultimate penetration (given the same distribution of implicit discount rates). Finally, a logistic curve is used again to determine the timing of penetration with the incentive.

This method of forecasting market penetration ignores noneconomic factors such as customer preferences and marketing methods. Decisions are based solely on the relationships between initial and operating costs. There is little evidence to support the distribution of discount rates used in this model and none for the applicability of the specific logistic curve and its parameters to DSM options. Nevertheless, this model's logical consideration of retirements from the stock of equipment, increases in sales, voluntary efficiency improvements, and the incremental effects of the utility program provide a useful way of structuring the problem of forecasting market penetration.

EPRI: PULSE AND MARKET PENETRATION ANALYSIS SYSTEM

The EPRI CP&B project is a multiyear research effort designed to improve understanding of customer behavior, their energy needs and the factors that motivate their choices. It uses that understanding to improve DSM program design and acceptance. PULSE, which was developed for EPRI by National Analysts, is a CP&B output that focuses on the residential sector.[3] The EPRI market penetration analysis system, which is under development at Research Triangle Institute (RTI), will be available in 1991.

PULSE

The PULSE model (Table 12) predicts market shares based on program characteristics and customer preferences. PULSE helps utility analysts to select, design, target and position programs for the residential sector. PULSE can estimate market shares for six types of residential end-use programs: central forced-air heating, central air conditioning, water heating, clothes drying, rates (time-of-use or volume), and load control (central air conditioners).

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[3]A major EPRI effort is underway to develop market segmentation and penetration estimation tools for the commercial sector as well.

Table 12. Key features of PULSE

OBJECTIVES	Estimate the market share[a] of alternative DSM programs and program configurations Select, design, target, and position programs to maximize their market share potential
APPROACH	Choice modeling[b] Test several program scenarios Assess customer sensitivities to specific program features Identify the likelihood of participation by specific market segments
INPUTS	Define program type[c] Define program features[d] Define the eligible population[e] Define customer mix[f] Set awareness/availability levels[g]
OUTPUTS	Relative market share (e.g., percent selecting electric heat pump vs. gas furnaces vs. electric furnaces) Customer sensitivity (e.g., responsiveness to alternative incentive types) Customer participation by market segment
STRENGTHS	First comprehensive nationally-based application of choice modeling techniques to DSM program penetration EPRI case studies indicate that using PULSE can help utilities design programs with higher participation (10%-35% more) than programs designed without choice modeling
LIMITATIONS	Currently limited to residential sector and six end-uses Does not address dynamics of market penetration or demand impacts

[a]Market share is defined as the cumulative percentage of the total market captured over an indeterminate time period.

[b]Choice modeling simulates customer behavior by using information about their preferences for, and tradeoffs among, potential program features.

[c]Six possible choices: central forced air heating, central air conditioning, water heating, clothes drying, rates, and load control.

[d]Initial and operating costs of equipment, program incentive type and level, awareness levels.

[e]Set up to four screens, (e.g., customers who own air conditioners, customers who operate air conditioners more than four hours per day).

[f]Customer mix is defined in terms of demographics and energy needs. May use national data base or set weights to reflect own service territory.

[g]Percent of population aware of program and percent offered the program.

PULSE was developed from analyses of national customer surveys that included conjoint analysis experiments (EPRI 1989a). Conjoint analysis[4] (Table 13 and Fig. 14) provides the partworths associated with different levels of program attributes. The partworths for attributes can be combined to simulate customer tradeoffs and to estimate market shares. Thus, PULSE's probabilistic choice model simulates decision processes for customer acceptance of alternative program scenarios to produce estimates of market shares for specific technologies promoted with specific combinations of program features. PULSE can be tailored to reflect a utility's own characteristics by reweighting the national data base.

PULSE can estimate results for "what-if" program scenarios, such as how much will the market share for electric water heaters increase if a zero-interest loan is offered instead of a 20% rebate. Or, how much will market share increase if the proportion of eligible customers aware of the program is raised from 40% to 60%. The analyst also can set utility-specific program eligibility requirements and customer program awareness/product availability levels.

Most commonly, PULSE would be run for a base case situation in which the utility offers no customer incentives, and for one or more cases in which incentives of different magnitudes are provided. By simulating the market shares resulting from various program designs and marketing mixes, the most effective combination of features can be selected. Thus, with PULSE, planners can estimate market shares for several program scenarios and test trade-offs in marketing mix components (i.e., product, price, promotion, and place) to identify the most effective combination. The model provides the information needed to develop benefit/cost ratios that identify the most cost-effective programs. For example, a manager may wish to balance the amount of incentive paid against benefits to the utility. The optimal solution may well not be the same as the maximum penetration solution.

The market segments (as defined in CLASSIFY™ [EPRI 1989b] which is a related market segmentation model) most and least likely to participate also can be identified with PULSE. If a manager wishes to reach a defined market segment, (e.g., in a load control program, those customers most likely to set their air conditioner thermostats at 70° or below), a program configuration can be identified that has the highest penetration in that segment. PULSE can provide market share estimates by a number of segmentation variables, including key

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[4]Conjoint analysis is discussed in Green, Tull and Albaum 1988; Lilien and Kotler 1983; Green and Srinivasan 1978; Cattin and Wittink 1982; and Green 1984. Applications in DSM include Berkowitz and Haines 1982: Kreitler 1988; and Sinha and Rao 1988.

Table 13. Conjoint Analysis: An example from EPRI's CP&B National Residential Survey[a]

Conjoint analysis is a quantitative technique for determining which attributes and attribute levels of a product or program are most appealing to customers. In the EPRI CP&B National Residential Survey, conjoint analysis was used to evaluate customer preferences for alternative designs of six DSM products and programs under a variety of delivery and incentive conditions. In the case of clothes dryer programs, 8 attributes (each with 2 to 4 levels) were evaluated, as shown below:

- Fuel used (electricity, gas)
- Fuel cost, including delivery ($300, $400, $500, $640)
- Brand (Whirlpool, Sears Kenmore, General Electric)
- Temperature settings (two, three)
- Moisture sensor (present, absent)
- Cost of use (9¢ per load, 18¢ per load)
- Rebate (none, $50 from manufacturer, $50 from utility company, $100 from utility company)
- Installation (covered by utility company, not covered by utility company)

Analysis of customer ratings of different configurations of the clothes dryer program, using combinations of the above attributes levels, showed among other things that:

- Fuel type and retail cost are more important determiners of preference shares than are rebates or operating cost (importance values of 23%, 21%, 18%, and 8% respectively)

- There is clearly a difference of opinion over whether an electric clothes dryer is more desirable than a gas clothes dryer -- as evidenced by the fact that the range of mean partworths for fuel type is considerably less than the corresponding range for retail cost (Fig. 14)

- Finally, the tested brands of clothes dryers are only moderately important determinants of customer preference (13%) -- due in part to differences of opinion across respondents as to which brands are most attractive, as reflected by the relatively flat mean partworths plot for that attribute (Fig. 14)

[a]This example was supplied by Thomas Henneberger of EPRI.

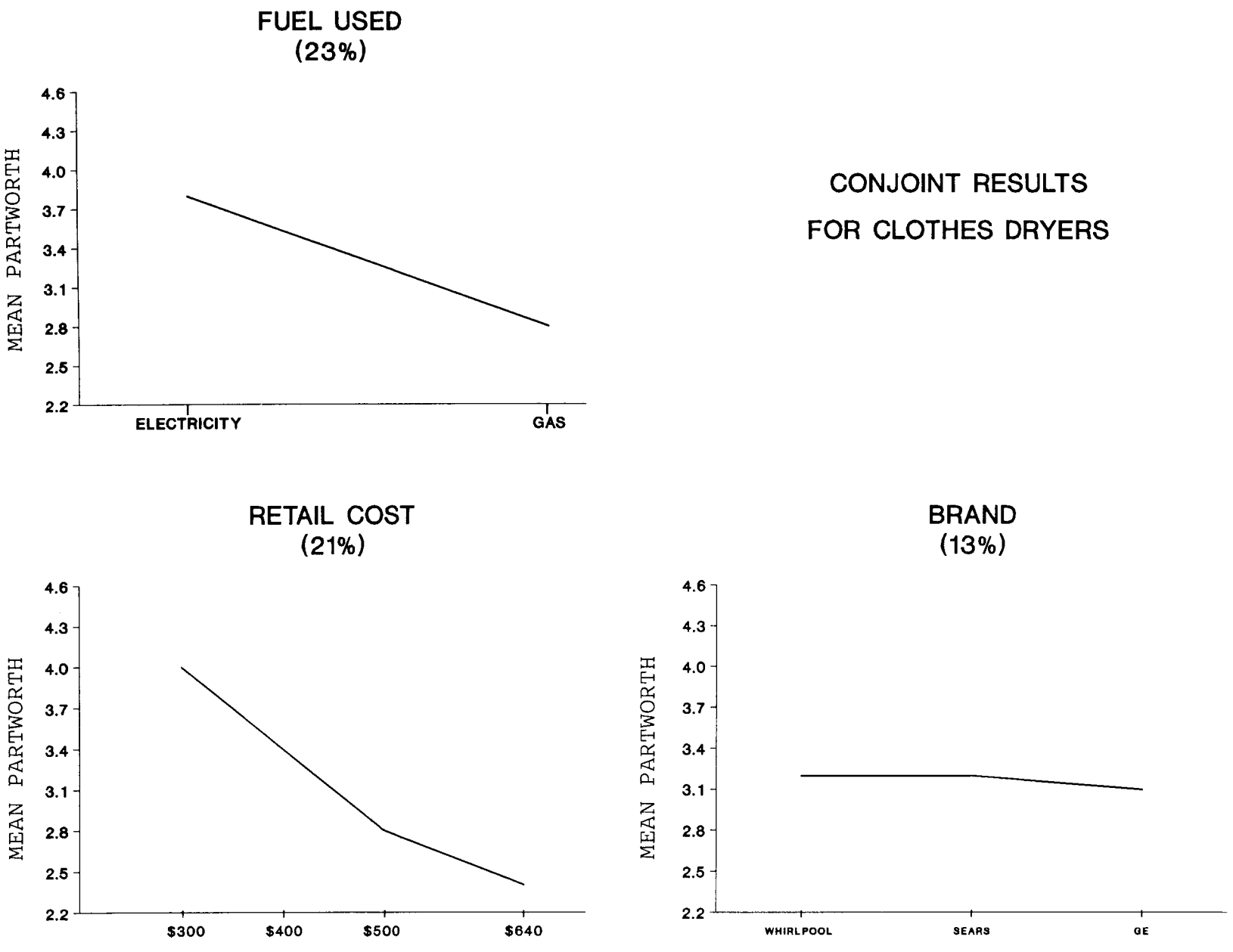

Fig. 14. Example of conjoint analysis results from EPRI's CP&B National Residential Survey

demographic, fuel use, and appliance saturation data. Thus, the synergism between PULSE and CLASSIFY™ offers a method of investigating how key determinants of participation vary by market segment and program type.

PULSE is a valuable addition to the library of market assessment and penetration models. It represents the first comprehensive nationally-based application of market research techniques to estimating DSM program penetration. Planners can use PULSE to screen program options without expensive market tests, to identify promising market segments, and to optimize program design.

PULSE does not address the issue of the timing of market penetration or of impacts on energy demand. It is currently limited to the residential sector and to six end-use technology/program combinations. Projects are underway, however, to develop similar tools for the commercial sector. Future plans also include a second version of PULSE that will allow planners to develop tradeoff data on additional DSM programs from their own customers. Conjoint analysis has inherent limitations because it relies on customer survey data that lack validation with actual field experience. Several utility case studies (EPRI 1989a and 1989b) that deal with the validation of PULSE show it to be an effective tool.

Market Penetration Analysis System[5]

Another EPRI-sponsored project, "Market Penetration of Technologies and Services (RP2864)," is developing software, guidebooks, and marketing research instruments to assist utility analysts in forecasting market potential and penetration. The project is currently underway at RTI. The working name of the software being developed is MAT (Market Assessment Tools). This project focuses exclusively on the related problems of forecasting market potential and the rate of market penetration as a function of marketing-mix variables such as price, advertising, promotion, etc. EPRI's market penetration analysis system contains a general conceptual framework and a set of methodological approaches for forecasting market size and timing (Table 14) that can be applied to any type of end-use technology, utility service, or DSM program. The software will include an expandable historical analogy data base (including a database manager), several analytical modules for developing both market potential and market penetration forecasts, plus special modules for conducting sensitivity analysis and Monte Carlo uncertainty analysis. The package will also include guidebooks that show, by example, how to use secondary data and primary marketing research for forecasting

[5]This information was provided by the RTI Principal Investigator, David Kendall (1989) and by the EPRI Project Manager, Thomas Henneberger (1989).

Table 14. EPRI's market penetration analysis system

OBJECTIVES

- Estimate market size (both technical potential and expected proportion of actual adopters)
- Estimate market penetration timing with adoption process and diffusion process models

APPROACH

- Chain ratios combined with choice modeling
- Diffusion and adoption process models

INPUTS

- Define total market population
- Define chain ratios
- Define proportions of population occupying various adoption stages
- Define a characteristic time path for a diffusion curve (if possible by historical analogy[a])

OUTPUTS

- Estimates of expected actual market size (at equilibrium)
- Yearly market penetration forecasts

STRENGTHS

- Allows estimates to be determined as a function of level of marketing effort
- Includes an expandable historical analogy data base
- Includes tools for sensitivity and uncertainty analysis
- Incorporates all available market data (including primary data collected by the user) to determine the chain ratios
- Flexible structure, linked to PULSE and DSManager (an EPRI cost benefit model)

LIMITATIONS

- Still in pilot stages of development
- Demand impacts are determined exogenously

[a]An historical analogy is a similar product (to the one for which the forecast is being developed) that diffused in a similar market under similar conditions.

market potential and penetration. Included in the software are on-line prototype marketing research instruments especially developed and pretested for developing primary data required for market potential and penetration forecasting.

The EPRI market penetration analysis system addresses two issues: estimating current and future market size (i.e., the concept of market size deals both with how many potential adopters there are in the market and with how many of them will eventually adopt) and forecasting market timing, (i.e., when will the adoptions occur). The systems's methods explicitly include the effects of marketing-mix variables on market potential and penetration.

The general framework for estimating and forecasting market size relies on a chain-ratio approach combined with choice modeling. The method begins with a count of the geographic population of interest -- the total number of households in the residential sector, for example. Using a set of screening ratios, the analyst reduces the geographic population to a smaller upper bound called the market population. The market population includes only those who will eventually make a decision to adopt or not adopt. It excludes those for whom the analyst believes the decision is irrelevant. For example, residential customers without ductwork might be excluded from the market population for high-efficiency heat pumps. So might households with family incomes of less than $10,000 per year. The exact chain of screening ratios used will vary with the specific market being analyzed, the analyst's needs for precision, and the availability of appropriate data for estimating screening ratios.

As an example, if the geographic population in a utility's service territory is estimated at 400,000 households, and if 70 percent have ductwork while 80 percent have income above $10,000, then the market population is estimated at (.7)(.8)(400,000)=224,000 households, assuming these are the only two screening ratios used.[6] Screening ratios are generally estimated from readily available secondary data and may be based on technical, economic, or perceptual criteria. Geographic population and screening ratios may be static, or the analyst may build a dynamic framework where these variables change with time. The market analysis systems' guidebooks will provide guidance concerning how to select and define screening ratios.

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[6]If the intersection between households without ductwork and households with income below $10,000 is likely to be large, then an estimate of the intersection proportion must be subtracted to avoid double counting. For example, if 10 percent of the geographic population are in the intersection, then (.1)(400,000)=40,000 should be subtracted from 224,000, yielding 184,000 households.

In a final step, the analyst estimates market potential by multiplying market population by an estimated long-run choice probability. In this framework, market potential is the expected cumulative number of customers who will eventually adopt. In the example above, if the long-run choice probability is estimated to be 0.4 then (.4)(224,000)=89,600 households are expected to eventually adopt, and therefore, these households are the market's potential. In this framework, market potential is an upper bound on the number of cumulative adopters. That upper bound may be static or dynamic, depending on the market being analyzed.

The choice probability may be constant or may be dynamically modeled. It may be estimated judgmentally or using model-based methods driven by primary marketing research. The software offers several ways to calibrate the choice probability, including logit and regression choice modeling using concept-test data.

The system includes two general methods for forecasting the timing of market penetration, diffusion process models and adoption process models. The **MAT** software includes two diffusion models (Bass and Mansfield-Blackman) and eight adoption process models (APMs). Each approach may be calibrated judgmentally, with data-based methods, or with historical analogy.

Adoption-process models are discrete simulation-models that assume potential adopters progress through a series of states such as unaware, aware, interested, evaluate, adopt, or reject. To make APMs operational, users estimate the proportions of the market population that initially occupy each state. The complete system includes marketing research instruments and methods for accomplishing this task. Alternatively, users may estimate initial state proportions judgmentally or with pre-existing data. Users must also calibrate a set of Markov transition probabilities to conduct APM simulations. Transition probabilities specify how likely it is that members of the market population will move from one state to other states in the model. Transition probabilities may also be estimated judgmentally or with data-based approaches that are demonstrated in the guidebooks.

Diffusion models assume that market penetration follows a characteristic time path (generally the S-shaped logistic curve or some other sigmoid form) that can be represented by a single-equation model with one, two, or perhaps three parameters. Generally, the parameters specify the rate of penetration in terms of differential adoption probabilities for innovators and imitators (Mahajan and Wind 1986). The exact parameters used can be estimated econometrically, judgmentally, or with historical analogy.

The market-penetration analysis system software and guidebooks, although not yet complete, are being pilot-tested with a few utilities in 1990 and should be

available to EPRI members in 1991. The system's emphasis on creating a general structure that analysts can tailor to specific applications seems likely to be especially valuable. The detailed and systematic attention given to methods for estimating the timing of penetration as a function of marketing-mix variables should be an important addition to currently available tools as well.

SYNERGIC RESOURCES CORPORATION: COMPASS, RESPEN AND COMPEN

SRC's COMPASS model includes an integrated analysis of the impacts of alternative packages of DSM programs. Using information on load shapes, market profiles, technology options, and electricity rates COMPASS can be used to design DSM programs, to estimate the number of free riders by modeling a measure's market adoption both with and without a program, and to calculate program impacts on electricity demand.

RESPEN and COMPEN (SRC 1989b) are forerunners of COMPASS which were developed specifically for the residential and commercial sectors, respectively (SRC 1989b). Conceptually, all three models are similar and all provide forecasts of both an equilibrium market share (based on economic attractiveness) and of the time pattern of penetration (based on a Lawrence-Lawton diffusion curve).

COMPASS includes an integrated market diffusion and equipment-stock model. Three broad categories of information are used to derive estimates of market penetration: (1) market-related parameters: stock growth, replacement, and saturation rates; the initial size of the eligible market; and the economic paybacks acceptable to customers; (2) measure characteristics: energy and demand impacts, equipment lifetimes, and incremental capital and operating and maintenance costs; and (3) promotional strategy: incentive and information levels, marketing and implementation costs, program duration and start-up dates (Sinha and Camera 1988; Sinha 1989).

The market penetration component (Table 15) offers four approaches to determining market share estimates. In the first approach, payback-acceptance schedules, derived from an empirical study (EPRI 1988e) on implicit customer discount rates and previous market research, are used to calculate the willing market fraction (i.e., the fraction of the eligible market that would be willing to adopt the DSM measure if it was fully informed about it; this is the same as an equilibrium market share). Incentives are accounted for by computing the payback with the incentives added in. An annual market share in year t of the program is derived by applying a Lawrence-Lawton (1981) diffusion curve. In this manner, the number of adoptions in the market is estimated first in the no-program and then

Table 15. Market penetration component of the COMPASS model

APPROACH
- Four options for obtaining long-run market share
  - Pay-back acceptance curves (endogenous)
  - Multi-attribute model results (determined exogenously)
  - User input of a percentage (determined exogenously)
  - User input of number of customers (determined exogenously)
- Three options for obtaining diffusion curve
  - Apply Lawrence-Lawton diffusion curve (endogenous)
  - User input of ramp rates (determined exogenously)
  - User input of annual number of customers (determined exogenously)

OUTPUTS
- Market share estimates for each year of the forecast

STRENGTHS
- Very flexible system
- Allows for linkages with many types of forecasting models

LIMITATIONS
- Effects of noneconomic factors must be determined exogenously

in the program case. The difference between the two is claimed as the program-induced adoption.

The COMPASS payback-acceptance approach is essentially the same as the one used by SRC's RESPEN and COMPEN and the Alliance's DSMPRO model as well as by CPAM. All are driven by an assumed distribution of economic criteria (discount rates or payback-acceptance schedules) used for customer decision making, all incorporate program financial incentives by reducing capital costs for high-efficiency equipment, and all apply logistic curves developed for other products, to account for the timing of penetration. In short, all use a traditional microeconomic model of behavior. The limitations of this approach include the following: the results are not empirically validated; the customer decision-making process is represented by a single attribute, namely the payback acceptance schedule; and the diffusion curve is not expressly calibrated for energy-efficiency products (Sinha and Camera 1988).

SRC is currently conducting a project to calibrate diffusion curves with actual DSM program experience for some program types. This project will also develop a model which accounts for the effects of utility-marketing efforts on penetration. The model will be available in mid-1990 (SRC 1989a).

A second approach involves the application of multiattribute-model results (similar to PULSE) to the estimation of market shares. These results must be obtained exogenously. If they are available, COMPASS allows them to be input to the model and used, along with the usual logistic curve, to forecast market penetration.

Two more approaches involve the direct input of market shares (expressed as percentages) or of the expected number of customers assumed to adopt. To use these approaches, the percentages or numbers must be obtained exogenously. Users also can specify annual values or ramp rates, obtained exogenously, instead of applying the endogenous Lawrence-Lawton diffusion curve. These direct input features allow users to incorporate the results of any market penetration forecasting technique into the COMPASS structure.

Thus, in COMPASS endogenous calculations of equilibrium market share and diffusion rely on a traditional microeconomic model and on the application of a Lawrence-Lawton diffusion curve, respectively. COMPASS has the flexibility, however, to allow for the input of the results of other approaches to developing market share and diffusion estimates.

SUMMARY OF MODEL FEATURES

In general, economically-driven cost-minimization models, which are often combined with equipment stock models and embedded in larger planning models, serve long-range planning needs (e.g., DSMPRO, CPAM, COMPASS, RESPEN, and COMPEN). Decisions about resource acquisition, including the identification of the optimal amounts and timing of conservation program efforts, are informed by the outputs of these models. They have little relevance to selecting the best program marketing mix (Table 16).

Models using marketing research techniques and driven by customer preferences, in contrast, have little relevance to long-term resource acquisition decisions. These models do not deal with the timing of participation in DSM programs or with demand impacts. They provide valuable guidance, however, for decisions about how to design and implement programs that will obtain the desired market shares cost-effectively. EPRI's PULSE model is a good example of this type of approach.

Table 16. Summary of key features of market penetration components of models

	Estimates equilibrium market share		Tests responsiveness by market segment	Tests sensitivity to non-economic program attributes	Forecasts timing of participation		
	by assuming cost-minimization behavior	based on market research results			by applying an already calibrated diffusion model	with an individually calibrated diffusion model	Estimates demand impacts
DSMPRO	X				X		X
COMPASS[a]	X				X		X
PULSE		X	X	X			
MAT	X	X	X	X		X	

[a]RESPEN and COMPEN are forerunners of COMPASS with the same major features. COMPASS can include noneconomic factors but their values must be determined exogenously.

For most end-uses, cost-minimization models are currently the only available tool for penetration forecasting as it relates to integrated resource planning. Market research techniques, such as conjoint analysis, which simultaneously vary both financial and nonfinancial program features and test customer response to the various combinations, have been applied for some program types (Berkowitz and Haines 1982; Sinha and Rao 1988; Kreitler 1988; EPRI 1989a). The structure of COMPASS allows one to use the results of studies of this type to determine market shares. EPRI's market penetration analysis system also will combine marketing research techniques with cost-based approaches to forecasting market potential and dynamics.

At present the best approach to forecasting market penetration is a problem-oriented analysis in which concepts of cognitive psychology, theories of social influence, communication, diffusion of innovations, marketing research techniques and models, and traditional microeconomic theories all play a role. There is no currently available software which integrates all of the relevant approaches (Table 16). Therefore, model results should be supplemented with empirical research that uses focus groups, market surveys, field experiments, and program evaluations to clarify the expected market penetration of specific technologies and programs.

The flexibility of COMPASS and of the EPRI market penetration analysis system reflect efforts to incorporate a broader range of methods into models. Such

emphasis on creating general structures that the analyst can tailor to specific applications seems likely to be especially valuable. In addition, the SRC effort to calibrate diffusion curves with actual program experience and to develop a model which includes the effects of utility marketing on diffusion should advance the current state-of-the-art. The development of a data base of historical analogies for the EPRI-sponsored market penetration analysis system, also should help to calibrate DSM program diffusion curves with appropriate examples.

6. CONCLUSIONS

The expected market penetration of DSM technologies and programs is a key uncertainty in identifying and forecasting the availability of energy-efficiency resources. This report reduces uncertainty about program-participation rates in utility DSM programs by: (1) investigating concepts and definitions of market penetration; (2) reviewing data which characterize the typical patterns of variation (including ranges, averages, and maximum levels) in the participation rates achieved by programs of several types; (3) identifying the factors that affect participation; and (4) reviewing the structure and data requirements of models that can be used to project market penetration. Findings on each of these issues are summarized below.

NEED FOR STANDARD DEFINITIONS

There are several possible definitions of program participation rates. Important distinctions relate to annual versus cumulative rates, and rates for retrofit versus replacement markets. Data bases on program participation define rates as the number of participating units divided by the number of eligible units. Clear and complete explanations of how the number of participating and eligible units are determined and of how membership in the eligible population changes over time are generally absent. The time period covered is often unspecified and issues of naturally-occurring versus program-induced participation are nearly always ignored. As a result, it is difficult to know how comparable information from various sources on participation rates may be. The use of standard definitions and the provision of complete explanations of the composition of the eligible population are essential steps for improving the usefulness of data on participation rates. The NORDAX data base provides a clear and comprehensive classification system for information on DSM programs which should contribute to progress in the standardization of definitions (Section 2, Table 6).

MAXIMUM VERSUS AVERAGE PARTICIPATION RATES

Conservation advocates, including organizations such as the Conservation Law Foundation, the Natural Resources Defense Council, and the Rocky Mountain Institute, suggest that it is possible to obtain very high levels of DSM program participation (85% to 100%). Several residential new construction programs have achieved nearly 100% participation. In these cases, because of competition among builders and builder education and persuasion by program managers, a market transformation occurred which made a high-efficiency rating a standard feature for

new homes. A few time-of-use rate and direct load control programs also achieved 100% participation, although some of these were mandatory programs.

Only one residential retrofit program achieved penetration higher than 85%. It was an experimental effort, which was very heavily marketed and resource intensive, that was implemented in a small town (Hood River, Oregon) in a semi-rural location. The level of effort devoted to the Hood River experiment was surely atypical. In addition, programs implemented in rural settings often achieve more participation than those implemented in large urban locations because trust in sponsors is not an issue and word-of-mouth recommendations are more effective. Thus, Hood River results probably are not generalizable to residential retrofit programs implemented by major utilities in large, urban service territories. For programs implemented under these conditions, cumulative rates of 50% to 60% seem to be the highest to date.

The highest rates ever obtained for full-scale commercial retrofit programs also seem to be in the range of 50% to 60%. Thus, except for Hood River (which has no commercial sector equivalent), there is not much difference in the maximum rates achieved by full-scale residential and commercial retrofit programs in representative situations. Average participation rates for commercial programs are, however, generally lower. Perhaps these lower average rates are due to the more recent origin of commercial programs. Alternatively, it may be that the barriers to participation are more formidable in the commercial sector and the means to overcome them are more difficult to implement.

In any case, for the vast majority of retrofit programs, penetration rates of a few percent (or less) per year are typical. Participation rates above 50% tend to occur only when all factors are favorable to producing them. That is, they are most likely to occur in highly convenient programs, offering free services and direct installation, which are not supply-constrained, and which are marketed by trusted sponsors through direct personal contact with customers. In addition, the programs with high participation rates tend to be targeted to customers or communities with above average receptivity. Rural communities and large commercial customers are more likely to accept program offerings than urban communities and small commercial customers. The programs with the highest participation rates tend to target these more receptive groups.

In everyday, business-as-usual situations, cumulative rates of program participation below 30% are typical (Section 3). Nevertheless, much of the data on average program-participation rates is not very relevant to the planning question of how much penetration could be achieved under ideal conditions. The amount of participation is usually constrained more by the supply of services (i.e., the resources committed to programs) than by the demand for them. Thus, the

maximum rates observed may be more relevant to choosing planning assumptions than the average rates. When there is strong enough motivation (and a sufficient commitment of resources) to acquire energy-efficiency resources, participation levels above 50% can probably be obtained for most program types and for most customer groups and communities.

When supply constraints are not an issue, however, some adjustment may still be necessary to account for differences in the demand for program services. It may be that maximum achievable rates will differ significantly by customer and community characteristics. In addition, factors such as fuel prices and shortages, and political and social forces favoring conservation, can significantly impact customer levels of response. If such broad societal influences change, demand for past programs may not predict future demand well.

For all of the reasons discussed above, market-penetration rates above 80% will not be achieved with a business-as-usual approach or with the level of resources typically devoted to programs. Free, direct installation programs that are heavily marketed may sometimes achieve this level of market penetration. Most utilities do not, however, offer such aggressive and expensive programs. It is beyond the scope of this paper to resolve the policy issue of how intensive an effort or how many resources should be devoted to promoting energy efficiency. A realistic view of the evidence suggests, however, that penetration rates above 80% will not occur without dramatic changes in typical approaches to the promotion of energy-efficiency programs. Such dramatic changes will not occur without policy changes which affect the motivation and reward structure of the utilities that supply energy-efficiency programs. In addition, favorable conditions affecting the demand for services may be necessary to achieve rates above 80%. Some customer groups or types of communities are unlikely to respond at such high levels. In times of declining electricity prices or surpluses, high levels of participation may be difficult to obtain. Conversely, when economic, political, and social forces favor conservation, high program participation levels will be easier to achieve. In short, both supply and demand conditions must be nearly ideal to achieve rates above 80%. Under typical conditions rates of less then 50% should be expected.

IMPORTANCE OF NONFINANCIAL PROGRAM ELEMENTS

Because it is difficult to quantify nonfinancial elements of program design, they are generally ignored in formal models. More attention should be given to factors such as program sponsorship, marketing, trust, and convenience. Efforts to quantify their effects can rely on market research techniques, such as conjoint analysis, and field experiments which simultaneously vary both financial and nonfinancial program features. Particular attention should be given to the

interactions and trade-offs among incentive, marketing, and administrative costs so that the most cost-effective combinations of program features can be identified for specific market segments. Models of market penetration which vary only the level of financial incentives and which rely only on a lifecycle cost-minimization principle to explain behavior, will often miss the mark. In addition, program planning, design and implementation efforts which systematically study the probable effects of nonfinancial program features may discover low-cost and highly effective strategies for increasing market penetration. Thus, developing a broader perspective on how and why participation decisions are made will improve both program performance and one's ability to predict that performance.

FORECASTING TOOLS

At present the best approach to forecasting market penetration is a problem-oriented analysis in which concepts of cognitive psychology, theories of social influence, communication, diffusion of innovations, marketing research techniques and models, and traditional microeconomic theories all play a role.

For integrated utility planning purposes, cost-minimization models are currently the only available tool for many technologies and program types. These formal microeconomic models offer little guidance for designing programs which obtain the highest possible penetration rates. Models based on marketing-research approaches are more useful for this purpose. A number of observational and experimental studies suggest a variety of strategies that will increase market penetration rates for DSM programs. As a new conservation technology, policy or program moves toward implementation, market surveys and small-scale experiments are useful for refining the design in ways that increase acceptance. Program evaluation results also can offer valuable guidance for improving program penetration. Formal cost-minimization model predictions should be adjusted judgmentally (based on experience with similar programs and market research information) whenever possible. Empirical research that uses focus groups, market surveys, field experiments, and program evaluations can clarify issues related to the expected market penetration of specific energy-efficiency technologies and programs.

Six PC-based models designed to meet the specific needs of DSM program planners were reviewed in Section 5. None of the currently available models integrates all of the relevant approaches to forecasting customer acceptance of DSM options. Most assume customer behavior follows a life-cycle cost-minimization principle and ignore noneconomic influences. The most useful models have a flexible structure which can be tailored to specific applications. Efforts to calibrate diffusion curves with actual DSM program experience and appropriate historical analogies, which are still underway, seem likely to advance the state-of-the-art.

Efforts to test model predictions by comparing them to the results of field experiments and evaluation studies are needed. Studies of this type do not seem to be available. Predictions about market penetration developed from microeconomic models, from marketing models, and from problem-oriented approaches should be tested empirically. Results of such tests should be used to improve the accuracy of predictive tools.

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