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RCS Program Evaluation Plan Options

T. K. Stovall
C. K. Bayne

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T. K. Stovall C. K. Bayne

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RCS PROGRAM EVALUATION PLAN OPTIONS

T. K. Stovall C. K. Bayne

ABSTRACT

The Residential Conservation Service (RCS) Program evaluation plan is designed to provide an ongoing evaluation during the RCS Program's active period as well as a measurement of the RCS Program's cumulative effect after the program's termination.

The study options described include utility case studies, random survey sampling, directed survey sampling, and remote data collection. Survey techniques are described and appropriate questions are suggested. Several sample selection criteria are included as background for a DOE policy decision on this issue.

Present and anticipated data sources are listed and discussed. Statistical data analysis plans include a preliminary determination of required sample sizes.

1. INTRODUCTION

The Residential Conservation Service (RCS) Program, as mandated by Congress, requires all large utilities to offer home energy audits to their residential customers. This five-year program is intended to stimulate energy conservation in the residential sector.

The RCS Program evaluation plan must consider measurements of program cost and savings as well as energy demand patterns. Intermediate results comparing various utility programs and state plans will be useful for midprogram adjustments to ensure the best possible program results.

This evaluation plan must then address two distinct yet often overlapping tasks. The first is to provide a constant index of the program's progress. The second is to prepare for and complete a five-year summary of the RCS Program's overall impact on the nation.

This evaluation option plan is broken into four major topics. Each topic is discussed in a separate section of this report. Section 2 addresses residential consumption studies, dealing with both energy usage and cost, from a national standpoint and from a more localized, consumer-oriented view.

Section 3 addresses the comparison of utility programs and state plans. These evaluations will be particularly useful for the periodic progress reports required.

Section 4 includes a list of existing and anticipated data sources. These provide a starting point and may be revised during the course of the evaluation.

Section 5 proposes statistical analysis methods which are judged applicable to this type of task. They are, of course, subject to revision should the data received vary significantly from the anticipated form and content.

The options presented in this report can be used by DOE to choose the evaluation plan best suited to its information requirements and budget restraints.

2. CONSUMPTION STUDIES

2.1 NATIONAL INDICATORS

Variables measured on a national scale should indicate the effectiveness of the RCS Program but are also subject to many other influences. With proper recognition of these external influences, these nationally measured indicators can, however, contribute relevant data to the RCS Program evaluation effort. Five figures available on a national scale are (1) total national energy use, (2) energy pricing information, (3) total governmental dollars spent on the RCS Program, (4) total consumer dollars spent on conservation (and renewable resource measures), and (5) the Gross National Product (GNP).

The U.S. Bureau of Mines publishes energy use data broken down by consuming sector (commercial, residential, etc.) as well as by energy source (e.g., electricity, oil, and gas). Other groups likely to collect this information are the Edison Electric Institute and the Energy Information Administration (EIA). After the energy consumption in the residential sector is separated out, the data must be examined with consideration given to the energy pricing pattern and the economic background situation (perhaps as reflected by the GNP). An analysis of the historical interactions between these factors could be used to determine what portion of any change in energy consumption is due to the cost of energy or to the state of the economy. These analyses will necessarily be qualitative in nature, given the fact that the effects of the RCS Program will be difficult to identify on a national scale.

National energy pricing information is available from both the DOE and the EIA.

The total governmental dollars spent on the RCS Program will require a compilation of costs from the annual reports required from each state as well as from DOE budget figures, available from the Office of Management and Budget.

The consumer dollars spent on conservation measures must be obtained from various manufacturers. Quantities of material purchased (e.g., pounds of fiberglass insulation or number of storm windows) may be identified at the same time. Organizations representing groups of these manufacturers

should be checked, as they may already be collecting the data. Manufacturers of solar systems are presently creating such a data source which may prove useful. The EIA is also compiling this information (*Solar Collector Manufacturing Activity, July 1978-June 1979*, DOE/EIA-0174, February 1979). These data will also include those purchases made without any influence from the RCS Program. Local survey studies that could be used to identify the proportion of purchases related to the RCS Program are discussed in Sect. 4.2.

2.2 LOCALIZED CONSUMER STUDIES

The goal of reducing residential energy demand will be realized if the RCS Program can convince homeowners to implement energy conservation measures and practices. The localized consumer studies portion of the evaluation plan deals with measuring consumer interactions with the RCS Program. These studies will also be used in evaluating various utility and state plans, as discussed in Sect. 3.1.

2.2.1 Energy Conservation Measures

To conserve energy, the RCS Program recommends appropriate conservation measures to residential customers. Collection of data on the extent to which these measures are accepted and implemented by customers and on the resulting energy savings is therefore of prime concern.

Surveys appear to be the best approach to this data collection task. Utilities should provide access to the audit and fuel use information but would be an indirect data source for follow-up factors such as cost of measures and required maintenance. It should be recognized that if utilities are used to collect this follow-up information they will be performing these functions, and should therefore be funded, in the same manner as any other independent contractor.

After the selection of a survey sample, or base, as discussed in Sect. 4.2.1, the following issues should be addressed:

- (1) customer interaction with RCS Program (i.e., none, information, audit, arranging),
- (2) measure(s) undertaken,

- (3) customer motivation,
- (4) savings (dollars and energy) predicted by auditor,
- (5) savings (dollars and energy) experienced by customer,
- (6) cost of measure(s),
- (7) consumer satisfaction,
- (8) installation experience,
- (9) maintenance schedule and/or record, and
- (10) reliability/safety history of measure(s).

Those conservation measures identified in the survey as having been adopted by consumers should be compared with the DOE list of suggested measures. Based on this comparison, the DOE may choose to revise its list of suggested measures for selected geographic zones.

Limited information of a general nature about energy conservation measures will be available in the annual reports required from each state if the survey approach is identified as being too costly. This information would include the number of audits and arrangement of transactions, thus identifying the rates of response but not the corresponding energy savings.

Nonusers of the RCS Program will form some percentage of the random population samples chosen. Parametric studies can be used to discover any commonalities among the nonusers that might account for their lack of interest.

2.2.2 Energy Conservation Practices

An important part of the RCS Program is to recommend energy conservation practices. This part of the program is most likely to be carried out by the homeowner without much assistance from the utilities. Many homeowners will have knowledge of some or all of the practices before coming in contact with RCS Program, and therefore an evaluation of the practices that result directly from the RCS Program will be difficult. In addition, the energy saved from implementing energy conservation practices is very likely to be indistinguishable from the energy saved from implementing energy conservation measures such as insulating the attic, adding storm windows, etc. Evaluation of the conservation practices is important to the RCS program to allow an assessment to be made as to the worth of this part of the program.

Also, an evaluation can assist future development of the program by identifying those who use energy conservation practices and those who do not. An increased effort may be worthwhile to convey more information to certain population segments.

Since any evaluation of the energy conservation practices will require information on a homeowner's behavioral habits, strict guarantees must be given to the homeowner that this information will be kept confidential. Most of the information will have to be gathered by survey sampling, primarily on those homeowners who requested audits but did not take any further actions with the utility company. This set of homeowners is more likely to implement the energy conservation practices and not the energy conservation measures. This sample should be able to characterize the type of homeowner who uses the energy conservation practices and the influence of the RCS Program on energy consumption habits. If permission from these homeowners to study their power usage is granted, the effect of energy conservation practices can be evaluated. Information can also be obtained from homeowners if they will volunteer to fill out a form at the time of the audit on their energy consumption habits. Although little information about homeowners' energy conservation practices will be gathered by the utilities, some information can be obtained by keeping track of special requests for energy conservation practices and of customer complaints involving energy conservation practices. A sample of homeowners in nonparticipating utilities can be used to estimate the percentage of homeowners who have learned about energy conservation practices from sources other than the RCS Program. Comparing data from participating and nonparticipating districts will permit the effectiveness of the RCS Program in disseminating information on energy conservation practices to be studied.

Some of the questions that need to be answered for the evaluation of the energy conservation practices are:

- (1) What percentage of the population in the utility district uses each of the energy conservation practices?
- (2) What are the sources of information motivating energy conservation practices and what proportion of actions is attributable to each source?

- (3) Do homeowners feel that energy conservation practices save energy?
- (4) What are the characteristics of someone who uses energy conservation practices (load usage; low, middle, or high income; urban, suburban, rural geography; electric, gas, fuel oil, mixed energy type)? What are the characteristics of a nonuser?

2.2.3 Renewable Resource Measures

Among those conservation measures available to homeowners are renewable resource measures (e.g., solar and wind power). Due to the small expected consumer response to renewable resource measures, special-purpose surveys should be the most applicable form of study. The geographic areas chosen for this study should include several climatic regions but should place an emphasis on those regions most appropriate for solar technologies.

If the utilities are required to keep retrievable lists of those consumers to whom these measures have been recommended, the survey team may use this list as the basis for the survey sample. Otherwise, the sample may be identified by local contractors and/or solar and wind system retailers.

The survey should address several issues including, but not limited to, the following:

- (1) RCS Program interactions (i.e., none, information, audit, arranging),
- (2) measure(s) undertaken,
- (3) customer motivation,
- (4) savings (dollars and energy) predicted by auditor,
- (5) savings (dollars and energy) experienced by customer,
- (6) cost of measure(s),
- (7) consumer satisfaction,
- (8) installation experience,
- (9) maintenance schedule and/or record, and
- (10) reliability/safety history of the measure(s).

The survey team should also attempt to define reasons for nonuse of renewable resource measures. One possible approach to this task would be a "next-door neighbor" survey. Assuming that neighbors enjoy the same weather conditions, those persons living near a renewable resource user could be given the same survey questions.

The surveys could be managed in several different fashions. Methods could include personal interviews, telephone contacts, and mailed communications, as discussed in Sect. 4.

3. STATE AND UTILITY PLANS

Utility programs and their corresponding results must be evaluated during the course of the RCS Program to identify beneficial modifications to the less successful utility programs. State plans will be evaluated only insofar as they hinder or help a utility program under study. The final success or failure of the RCS Program will be decided in part by these local utility programs.

A case study on selected utilities is recommended for the utility plan evaluations. The selection method is discussed in Sect. 4.2.1. These case studies, while costly, will allow for a detailed review and provide valuable insights and recommendations. Another possible study method would be to use the data from the state annual reports. This approach would save money and produce results of a general, less detailed, nature.

Selecting features from both approaches would entail the use of consumer data from state reports, with case studies covering only details of utility programs. This combination of methods would provide necessary information on the utility program but lacks the quality of consumer data available with a complete case study.

The utility plan evaluation should address several aspects of a utility program. The utilities' response rate, i.e., the number of consumer requests and services rendered, will be a direct measure of RCS activity within the utility. The communications network used by the utility to promote the RCS Program is an important tool to be measured. The program's management hierarchy, financial arrangements, available manpower, and training procedures will all affect the program's success.

Internal utility changes caused by the RCS Program should be considered. These would include changes to the rate structure, load factor, and loading curves, among others.

3.1 RESPONSE RECORD

The rate of consumer response to state and utility RCS plans will be one measure of success of the RCS Program. A preliminary evaluation of the response rates can be obtained from the required annual reports from

each state. Not all of the 197 electric utilities and 149 gas utilities covered by the National Energy Conservation Policy Act (NECPA) Title II can be studied in depth, and a representative sample stratified on factors in Sect. 4.2.1 can be used for a comparison of response rates. This comparison would determine those features in the different state and local utility plans necessary to run a successful RCS program.

Response rates can be indicated by several variables: number of audit and postaudit requests, number of installation arrangements, number and type of financing arrangements, and number of complaints and redresses. These responses must be adjusted to certain population characteristics. For example, the bureau of Census 1975 Annual Housing Survey showed that 78% of single-family houses in Chicago, Illinois, had storm windows, storm doors, and insulation in the attic, while only 38% of single-family houses in Nashville, Tennessee, had this equipment. Therefore, the response in Nashville to RCS plan may be greater simply because the percentage of potential customers is greater. The number of residences already using conservation measures and practices may be determined by analyzing nearby utilities without RCS programs.

Different features of state and utility plans can be evaluated using the percentage of responses adjusted to the baseline data. These adjusted percentages can be used as an indicator of the features in the different state and utility plans that promote or hinder the RCS program. This evaluation may be used to identify beneficial modifications to ongoing programs during their five-year life.

3.2 COMMUNICATIONS

The area of communications addresses all information exchanges between a utility and its consumers. All advertising in newspapers or on television or radio should be considered. Bill stuffers, direct mailings, and the program announcement must be evaluated for form, content, and impact, if possible. There may exist standard marketing tools for this type of evaluation which could be used.

The utility marketing budget and state plan rules in this area must be considered, as they will affect the form of the communications.

If the utility receives an abundance of requests, a backlog of audits may be created. The utility's response to this situation may have an important impact on the public perception of the RCS Program. The mechanisms developed by utilities to handle this backlog should be recorded and evaluated.

3.3 MANAGEMENT HIERARCHY

There are many management alternatives available to a utility implementing the RCS Program. The level of ultimate responsibility, i.e., the first point on the ladder where a solitary person receives all the information and directs the program, is a good indicator of the importance attached to the program by the utility's overall management group. If this responsibility is assigned to lower level employees, they may not have the necessary authority to properly implement the program. Conflicts of interest may be created if, for instance, the director of the RCS Program is also the vice-president in charge of new generation construction projects. These situations should be checked for their impact on the total RCS Program.

The levels of intermediate management and their areas of responsibility should also be identified. If a utility is failing in a particular area, that portion of the management hierarchy should be examined for deficiencies. If a utility is highly successful in a certain area, the management setup should be identified and recorded as a model for less successful utilities.

3.4 FINANCIAL ARRANGEMENTS

The financial arrangements discussed here cover several areas: (1) total utility costs for operating the RCS Program, (2) method of utility cost recovery chosen in state plan, and (3) financial arrangements made for consumers.

The total utility costs should be broken down into cost accounts for direct customer service (audits), advertising and other communications, data processing, support personnel, management, and other overhead. Costs

should also be considered for any utility providing installation or financing services under the grandfather clause of the RCS rules.

The cost recovery method chosen by the state regulatory body will have a direct effect on the audit response rate. It has been shown that placing any charge on an audit drastically reduces the demand for the audits. This factor must be considered in any utility plan evaluation.

The nature of the financial arrangements performed by the utility for the consumers should be identified.

3.5 MANNING AND TRAINING

The manpower devoted to the RCS Program by utilities will vary with the size of the utility and the scope of its program. The manning should be normalized on a per-eligible-customer basis and recorded. Also of interest is the personnel distribution. The percentages of people assigned to auditing, data processing, billing, management, etc., should be identified.

The training and assignment requirements — particularly of auditors — should be studied. Were the auditors chosen for their sales abilities, their technical proficiency, or some other criterion? What additional training did they receive after their job assignments? Were new people hired or did the utility shift responsibilities around among existing employees? If new jobs were created, what is the number and expected assignment duration?

These questions should be answered and the answers correlated with the utility program's progress.

3.6 INTERNAL EFFECTS

The RCS Program, if successful, should have a definite effect on each utility's forecasted generation or supply requirements. This in turn will affect the rate structure, capital requirements, construction plans, etc., of each utility. This evaluation should examine any difficulties caused by these changes within the utility. Any substantial peak shift or peak reduction should be evaluated to determine if the RCS program is a contributing factor, and if so, to what degree.

4. DATA SOURCES AND ACCESS ALTERNATIVES

4.1 PREEXISTING DATA SOURCES

Preexisting data sources are herein defined as those sources not created or funded by the RCS Program. These sources include EIA surveys, census data, manufacturer's annual reports, and National Oceanic and Atmospheric Administration (NOAA) weather data, among others. The use of these data in the RCS Program evaluation should be at most a gathering and data reduction function. Some data validation may be required. Some of these data can be enhanced through program-directed activities, as discussed in Sect. 4.2.

4.1.1 EIA Data

The EIA is presently conducting a Residential Energy Consumption Survey which could be of value to this evaluation. Since this survey is taking place before the RCS Program starts, it will provide good baseline data for a before-and-after comparison.

The EIA may also submit questions to the Bureau of the Census for inclusion in the Bureau's quarterly housing survey. This has already been done to produce EIA's Quarterly Tracking System [*Quarterly Tracking System Energy Using and Conservation Equipment in Homes*, DOE/EIA-0067/1(78), July 1978]. The addition of a few pertinent questions to the present survey could be a great help in the RCS Program evaluation. Discussions with personnel in both the Census Bureau and the EIA suggest that this is a feasible alternative.

4.1.2 Manufacturers' Organizations

Manufacturers' organizations and trade magazines keep track of marketing activity in their areas. Groups such as the National Home Improvement Council or the National Insulation Contractors Association could provide data on the amount and kind of insulation and storm windows/doors sold and installed. Solar trade associations and publications such as the Solar Science and Technology Magazine report solar manufacturing activity

on a regular basis. The EIA also collects and distributes this sort of information.

4.1.3 Existing Utility Programs

Several pre-RCS utility conservation programs have collected relevant data and some have conducted in-house evaluations. The Tennessee Valley Authority (TVA) has, for example, performed over 100,000 home energy audits and placed a portion of the data on computer tape. Such data sources, properly collected and validated, could form an effective data base for the RCS Program evaluation. A preliminary identification of these programs may be made by referencing *Survey of Load Management and Energy Conservation Projects*, ORNL/Sub-77/13509/4.

4.1.4 List of Data Sources

Following is a list of the preexisting data sources mentioned in this plan. This list will be expanded during the course of the evaluation.

- Edison Electric Institute
- Energy Information Administration (EIA)
- National Home Improvement Council
- National Insulation Contractors Association
- National Oceanic and Atmospheric Administration (NOAA)
- Oak Ridge National Laboratory
- Office of Management and Budget
- Solar Science and Technology Magazine
- Tennessee Valley Authority
- U.S. Bureau of the Census
- U.S. Bureau of Mines

4.2 PROGRAM-DIRECTED DATA SOURCES

Program-directed data sources are those sources created or funded by the RCS Program. This would include all surveys and case studies done for the purpose of this evaluation. Available funding for these program-directed activities must be identified before an appropriate scope of work can be chosen.

4.2.1 Selection of Samples

Samples must be chosen for each survey and case study. The sample choice is an important decision. Should the samples represent some kind of weighted national cross section, or should they be used as examples? The national cross section is desirable but may not be possible, since the nature of this evaluation is not that of a controlled experiment. This cross section could, however, be approximated.

The example approach would be less costly and more specific. The generalities available with a national cross section could not be made from the results of this type of study. The examples could, however, cover a wide range of utility-customer situations.

Sample sizing is discussed in Sect. 5. It is suggested that all surveys be conducted within the framework of the utility case studies. This would involve two separate sample identification tasks, (1) utility selection and (2) customer selection.

The utilities could be chosen based on any or all of these factors: geography, climate, fuel type and prices, service provided (gas, electricity, fuel oil, or combinations), size, ownership (public versus private), local price index.

The customer sample selection could consider any or all of these factors: location (urban/rural), family income, structure type, energy consumption, owner/tenant, education.

There will be many factors that affect the results from sample surveys, and the confounding of various factors will make interpretation of some of the results difficult. For example, if a homeowner implements both an energy conservation measure — insulating his attic — and an energy conservation practice — turning down his thermostat to 68°F — the proportion of the resulting energy savings due to the energy conservation measure or the energy conservation practice cannot be determined. In some cases, the residences in a survey sample may be matched according to all but one or two factors, such as family income or home structure type. The difference in the results of the matched residences can then be attributed to the unmatched factors. Matching may also be done with the survey of nonparticipating homeowners mentioned in Sect. 2.2.2.

4.2.2 Case Studies

Case studies would involve collecting detailed information from the chosen sample utilities. This information should include the topic areas discussed in Sect. 3. The consumer response surveys within each sample utility will be a subtask of the case study and may be performed by the same contractor if desired.

4.2.3 Surveys

Surveys may be accomplished in person, by telephone, or by mail. An in-person survey is the most expensive due to travel time and expenses but allows the most complex questions. Quality control may be a problem and is directly related to the integrity of the surveyor.

A telephone survey allows semicomplex questions and is less expensive than an in-person survey. A telephone surveyor may be able to key survey information directly into a data processing system, thereby eliminating a costly middle step. Quality control is less of a problem, as telephone surveyors may be kept under supervision at all times and are easily spot-checked.

A mail survey is the least expensive of the three options, but the questions asked must be extremely simple. There may also be a bias in the answers due to the self-selected nature of the sample; that is, an entire class of people may choose not to reply to the survey.

The data collected with any of the three options must be validated. This could be done by resurveying a small proportion of the sample or by using a computerized cross-check of the entire sample.

Besides those consumer surveys done as a part of a case study, special-purpose surveys may prove useful. As mentioned in Sect. 2.1, such a survey could be used to determine the proportion of insulation sales attributable to the RCS program.

Since those surveys used to study renewable resource measures have a relatively small target population, extra data collection efforts may be required. Toward this end, renewable resource manufacturers could be asked to include a questionnaire with their product's information packet, or contractors could be used to distribute questionnaires at the time of

installation. Using the manufacturers or the contractors would identify those actions taken that were uninfluenced by the RCS Program.

Questionnaires left by an auditor or mailed by a utility could provide useful information but would not be focused on renewable resource measures. They would require a lot of sifting for the purpose of a study of renewable resource measures. This method would be more cost-effective if the evaluation of renewable resource measures were combined with the evaluation of all measures.

4.2.4 Utility Record Keeping

It is inappropriate to require every utility to keep extensive data on every customer receiving service under the RCS Program. The amount of data collected with such a shotgun approach would be staggering, and only a small portion would ever be evaluated. This approach also places the financial burden of a DOE evaluation on the utilities and their ratepayers. It is suggested that the DOE provide funds for those utilities chosen for case studies to keep records on a sample of their customers. This method collects only those data that will be used and places the cost burden (now much reduced by the smaller volume of data) on DOE, rather than on the utilities and their ratepayers. The data collected and retained (for five years) by the chosen utilities on the sample population should include (1) name and address of each eligible customer who requests an energy audit, (2) audit data collected and savings estimates reported to the customer, (3) a list of those customers requesting furnace audits, (4) names and addresses of those customers requesting arranging services, and (5) the amount and cost of fuel purchased each billing period by each customer.

It may be necessary to obtain some sort of information waiver from those customers included in the study sample. It will also be necessary to correlate the information for each customer serviced by multiple utilities. As a last resort, it may be possible to ask these customers to keep track of their fuel bills for alternate utilities and for DOE to collect this data from them at regular intervals.

5. STATISTICAL ANALYSIS METHODS

Any results from the statistical analysis of the RCS data will be compromised by the fact that all the behavioral factors and environmental factors relating to conservation of energy cannot be controlled. Therefore, the effects attributed to any one of the factors will be confounded by one or more other factors (Sect. 4.2.1). For this reason, any comparisons among utilities or geographical areas must be made with caution.

The results of any analysis will represent the conditions and effects due to selected state and utility plans and will not necessarily represent generalized results. The determination of a successful or an unsuccessful RCS plan may not be clear cut, but part of each plan could be judged an overwhelming success while other parts may be judged unsatisfactory. For those cases that are judged unsatisfactory, the causes of the poor performance should be investigated to see if they can be changed.

5.1 COLLECTED DATA AND SAMPLE SIZE

The majority of data collected from the RCS program will be count data (number of audits, number of requests for insulation, etc.) or percentage data (percentage of houses with storm windows, percentage of houses with clock thermostats, etc.). Some data will be continuous data, such as energy usage and energy savings versus time. The count data can be analyzed to determine high and low response rates to different factors of each RCS program, while the continuous data can be used to judge the effectiveness of different utility RCS plans.

Both count data and continuous data will be collected from baseline data (Sect. 4.1.4), case studies, and survey samples. The established data bases contain information that can be used to estimate population parameters to determine what factors are most important in the selection of case studies (Sect. 4.2.1) and the size of survey samples. The size of survey samples¹ will depend on four factors (1) the desired limits of error on the results, (2) the type of sampling used, (3) estimates of certain unknown properties of the population, and (4) the resources available to take the sample.

The statement of the error limit may be interpreted as the amount of error that we are willing to tolerate: "I would like to know the proportion of the population within $\pm 5\%$ who set their thermostats at 68°F ." In many cases the error limit will come as a result of weighting the sample sizes for different desired precision and considering the consequences of errors of different sizes to decisions that must be made from the survey results. In addition to the precision, sample size will also depend on the chance of drawing an "unlucky sample" that will give erroneous results. Most calculations of sample size are usually based on a 1:20 or 1:10 chance of getting an unlucky sample.

For example, suppose we wish to estimate the proportion, P , of the population within $\pm d\%$ who set their thermostats at 68°F . The sample size n_0 for a simple random sample is

$$n_0 = \frac{t^2 P(1 - P)}{d^2} ,$$

where $t = 1.96$ for a 1:20 chance of an unlucky sample and $t = 1.65$ for a 1:10 chance of an unlucky sample. The sample size formula depends on the proportion, P , which is the unknown quantity. A first approximation of P can be obtained from baseline data, pilot surveys, or guesswork about the structure of the population. In any case, the largest value of n_0 occurs when $P = 0.50$. For the example, if $P = 0.50$, $t = 1.96$, and $d = 0.05$, then

$$\begin{aligned} n_0 &= \frac{(1.96)^2 (0.50)(0.50)}{(0.05)^2} \\ &= 384 . \end{aligned}$$

Therefore, a maximum of 384 samples would be needed to get an estimate of P with a 5% error limit with a 1:20 chance of drawing an unlucky sample. Here the size of the true population, N , is assumed to be large ($>8,000$); for smaller populations, n_0 would be adjusted by dividing by $(1 + n_0/N)$.

For estimating continuous data, the variance (S^2) of the observations must first be approximated, rather than the proportion, for the sample size formula:

$$n_0 = \frac{t^2 S^2}{d^2} .$$

For example, suppose the cost of one square foot of R-11 insulation is approximately \$0.25 based on baseline data with a standard deviation of \$0.05, and we wish to determine the average cost in 150 stores with a 5% error limit. With simple random sampling, how many stores would have to be surveyed to estimate the average cost within 5%, apart from a 1:10 chance of an unlucky sample? In this example $t = 1.65$, $S^2 = (0.05)^2$, and $d = 5\% \times \$0.25$:

$$n_o = \frac{(1.65)^2(0.05)^2}{(5\% \times 0.25)^2}$$

$$= 43.56 \approx 44 .$$

Since the population is small, $N = 150$, n_o is adjusted by

$$n_o = \frac{44}{1 + 44/150} = 34 .$$

When the sample sizes are determined, the cost of the survey will be estimated and compared with the available resources. Adjustments can then be made on the error limits, types of information desired, types of sampling used, etc.

The types of problems in determining sample sizes have been illustrated with simple random sampling. These types of problems will also occur when stratified sampling or cluster sampling is used. These methods will be dealt with in a similar manner using baseline data, pilot surveys, and guesswork about the structure of the population.

5.2 DATA ANALYSIS

Procedures suggested here for analyzing count data, percentage data, and continuous data range from data presentation to multiple regression and represent the minimal data analysis to more sophisticated data analysis. These methods are not to be considered as the final word on the analysis and may have to be tailored to each case study or data set collected.

5.2.1 Count Data and Percentage Data

Two useful methods for displaying count data and percentage data are histograms and box plots.² Histograms display the frequency of count and percentage data versus a population parameter, while box plots display six statistics (maximum, minimum, upper quartile, lower quartile, median, and mean) of count and percentage data for each population parameter. Examples of the types of population parameters that can be used for histograms and box plots are illustrated with count data for the number of audits:

- number of audits vs month;
- number of audits vs location;
- number of audits vs low, middle, and high load demand;
- number of audits vs cost/kWh;
- number of audits vs amount of advertisement;
- number of audits vs low, middle, and high income.

Another useful way to display count data and test for relations among factors in different RCS programs is by using contingency tables.³ Since each count of an attribute represents a positive response or a negative response, a $2 \times c$ table can be formed for c factors and these factors can be tested by a chi-square test to see if the effects on the response are equal. If O_{1i} represents the observed number of negative responses for the i th factor and O_{2i} represents the number of positive responses with $N_i = O_{1i} + O_{2i}$ being the total number of people surveyed, then the following $2 \times c$ contingency table can be formed:

Response	Factor					Total
	1	2	3	...	c	
Negative	O_{11}	O_{12}	O_{13}	...	O_{1c}	F
Positive	O_{21}	O_{22}	O_{23}	...	O_{2c}	S
Total	N_1	N_2	N_3	...	N_c	N

To test if all the factors have the same effect on the response, the chi-square test statistic with $(2 - 1)(c - 1) = c - 1$ degrees of freedom,

$$\chi^2(c-1) = \sum_{i=1}^2 \sum_{j=1}^c \frac{(O_{ij} - E_{ij})^2}{E_{ij}},$$

where

$$E_{1j} = \frac{FN_j}{N} \text{ and } E_{2j} = \frac{SN_j}{N} \text{ for } j = 1, 2, \dots, c,$$

is compared to a tabulated $100\alpha\%$ critical value $\chi^2(c-1)$ of the chi-square distribution.⁴ If $\chi^2(c-1) > \chi_{\alpha}^2(c-1)$, then the effects of each factor are not equal at $100\alpha\%$ significance level and if $\chi^2(c-1) \leq \chi_{\alpha}^2$, then the responses do not indicate any differences among the effects of the different factors.

For example, suppose we wish to know if the number of audits is the same for low, medium, and high yearly peak load demands, and we collected the following data on customers with essentially the same population parameters except for different yearly peak load demands.

Response	Yearly peak load demand (kWh)			
	<1500	1500-3000	>3000	Total
Did not request audit	20	24	18	62
Did request audit	980	576	207	1763
Total	1000	600	225	1825

The chi-square statistic with $c-1 = 2$ degrees of freedom is:

$$\begin{aligned} \chi^2(2) &= \frac{(20 - 33.97)^2}{33.97} + \frac{(24 - 20.38)^2}{20.38} + \frac{(18 - 7.64)^2}{7.64} \\ &\quad + \frac{(980 - 966.03)^2}{966.03} + \frac{(576 - 579.62)^2}{579.62} + \frac{(207 - 217.36)^2}{217.36} \\ &= 5.75 + 0.64 + 14.05 + 0.20 + 0.02 + 0.49 \\ &= 21.15. \end{aligned}$$

Since the test statistic is larger than the chi-square value [$\chi^2_{0.01}(2) = 9.21$] at the 1 percentile point, the hypothesis that the requests for audits are equal for customers with different yearly peak demand would be rejected at the 1% significance level.

An extension of the $2 \times c$ contingency table is the $2 \times r \times c$ contingency table in which each observation can be classified as either a positive or a negative response in $r \times c$ categories. In general, Table 1 represents a $2 \times r \times c$ contingency table. With the $2 \times r \times c$ contingency table, the equality of the effects of factors classified in $r \times c$ categories can be tested with the chi-square statistic with $(r - 1)(c - 1)$ degrees of freedom:

$$\chi^2[(r - 1)(c - 1)] = \sum_{i=1}^r \sum_{j=1}^c \frac{(O_{Fij} - E_{Fij})^2}{E_{Fij}} + \sum_{i=1}^r \sum_{j=1}^c \frac{(O_{Sij} - E_{Sij})^2}{E_{Sij}},$$

where

$$E_{Fij} = F \frac{r_i}{N} \frac{c_j}{N} \text{ and } E_{Sij} = S \frac{r_i}{N} \frac{c_j}{N} \text{ for } i = 1, 2, \dots, r$$

and $j = 1, 2, \dots, C$.

Table 1. $2 \times r \times c$ contingency table

Row	Negative response				Row total	Positive response				Row total
	Column					Column				
	1	2	...	c		1	2	...	c	
1	O _{F11}	O _{F12}	...	O _{F1c}	r _{F1}	O _{S11}	O _{S12}	...	O _{S1c}	r _{S1}
2	O _{F21}	O _{F22}	...	O _{F2c}	r _{F2}	O _{S21}	O _{S22}	...	O _{S2c}	r _{S2}
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
r	O _{Fr1}	O _{Fr2}	...	O _{Fr c}	r _{Fr}	O _{Sr1}	O _{Sr2}	...	O _{Sr c}	r _{Sr}
Total	c _{F1}	c _{F2}	...	c _{Fc}	F	c _{S1}	c _{S2}	...	c _{Sc}	S

Row total for i th row: $r_i = r_{Fi} + r_{Si}$.

Column total for j th column: $c_j = c_{Fj} + c_{Sj}$.

Total: $N = F + S$.

This chi-square test statistic can then be compared with the α -critical value for the chi-square distribution. If the test statistic is larger than the critical value, we conclude that the effects of the $r \times c$ factors are not equal at the $100\alpha\%$ significance level; otherwise, we conclude that the data do not indicate a difference in the effects of the $r \times c$ factors on the response.

For example, we would like to know if the number of audits is the same for urban and rural customers with small, medium, and large housing area with all other population parameters being essentially the same. The audit data and the chi-square statistic are presented in Table 2. The 0.05 chi-square critical value with two degrees of freedom is $\chi^2_{0.05}(2) = 5.99$ at the 5% significance level. Thus, we would reject the hypothesis that the same numbers of audits are requested by rural and urban customers.

Table 2. Example of a $2 \times 3 \times 2$ contingency table

Housing area (ft ²)	Did not re- quest audits		Row total	Did request audits		Row total
	Location			Location		
	Urban	Rural		Urban	Rural	
<1200	24	22	46	980	380	1360
1200-2000	18	14	32	420	230	650
>2000	17	16	33	230	180	410
Total	59	52	111	1630	790	2420

$$r_1 = 1406, r_2 = 682, r_3 = 443, c_1 = 1689, c_2 = 842; \\ N = 2531.$$

$$\chi^2(2) = \frac{(24 - 41.2)^2}{41.2} + \dots + \frac{(180 - 140.9)^2}{140.9}$$

$$= 63.11.$$

Count data will be used not only to test significant factors, but also to estimate percentages. To gain confidence in the different estimated percentages, upper and lower confidence limits on the expected value

of the estimated percentages can be calculated. If the true value of the percentage of positive responses is P , then the expected value of the estimate $\hat{P}$ is P . To compute an upper and lower boundary for P at the 95% confidence limit, the binomial distribution can be used and is tabulated in tables.^{5,6} If the confidence limits cannot be found in the tables or the tables are not available, approximate methods for computing upper and lower bounds can be used based on other probability distributions.⁷ Let X_0 = sum of the positive responses from N samples (i.e., $\hat{P} = X_0/N$). For a large sample, a good approximation of the 95% confidence limits is:

$$\begin{array}{l} \text{upper limit} \\ \text{lower limit} \end{array} = \frac{(X_0 + 1.92 \pm 0.5) \pm 1.96 \sqrt{\frac{1}{N}(X_0 \pm 0.5)(N - X_0 \mp 0.5) + 0.96}}{N + 3.84}$$

To illustrate the 95% confidence limit, the upper and lower boundary on the percentage of audit request from customers who have a yearly peak load of more than 4000 kWh will be calculated. Suppose a utility has 2000 residential customers with yearly peak loads of more than 4000 kWh and 140 of these customers have requested audits. What is the 95% confidence limit on the audit response rate? The percentage estimate is:

$$\hat{P} \times 100\% = \frac{140}{2000} \times 100\% = 7\%$$

The 95% confidence limit is computed as follows:

$$\begin{array}{l} \text{upper limit} \\ \text{lower limit} \end{array} = \frac{(140 + 1.92 \pm 0.5) \pm 1.96 \sqrt{\frac{1}{2000}(140 \pm 0.5)(2000 - 140 \mp 0.5) + 0.96}}{2000 + 3.84}$$

$$\begin{array}{l} \text{upper limit} \\ \text{lower limit} \end{array} = \begin{array}{l} 0.0823 \\ 0.0594 \end{array}$$

Therefore, the 95% confidence limit of the true value of the response rate for customers with yearly peak loads of more than 4000 kWh is between 5.94% and 8.23%.

To identify the factors that influence percentages, the general technique of cluster analysis can also be used. The aim of cluster analysis is to group "good" conditions and "bad" conditions that may cause low and

high percentages of responses. For example, suppose a number "c" is chosen. If $P_i > c$, we have good conditions for the percentage of responses; if $P_i < c$, we have bad conditions for the percentage of responses. A function^{8,9} of the factors in the different utility RCS plans can be found which will classify good and bad conditions in terms of the factors of different utility RCS plans. With cluster analysis techniques as well as visual inspection, a general understanding of the effects of the factors of different utility RCS plans can be inferred. These inferences will help to determine the parameters which cause the worst response rate.

5.2.2 Continuous Data

Energy consumption data and energy savings data will be collected as an indicator of the effectiveness of the RCS program. These data can be displayed in graphical form with energy consumption (savings) plotted on the ordinate axis versus degree day or average daily temperature on the abscissa axis for various population parameters (housing square feet, number of occupants, etc.).

These data can be analyzed using linear regression analysis.^{10,11} For this analysis the response data are assumed to depend on a linear function of the degree days and population parameters. There is an abundance of books which explain how to analyze linear regression models. Several problems explained in the references which may concern the investigator are:

- (1) correlation of population parameters,
- (2) data scaling,
- (3) correlated errors of time series models,
- (4) transformation of the response data to achieve normally distributed values, and
- (5) weighted analysis to correct for unequal number of responses on different degree days.

The regression analysis should indicate how different factors of RCS plans influence the energy consumption (savings).

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