Performance Measurement: Establishing Energy Impacts of Commercial New Construction Programs

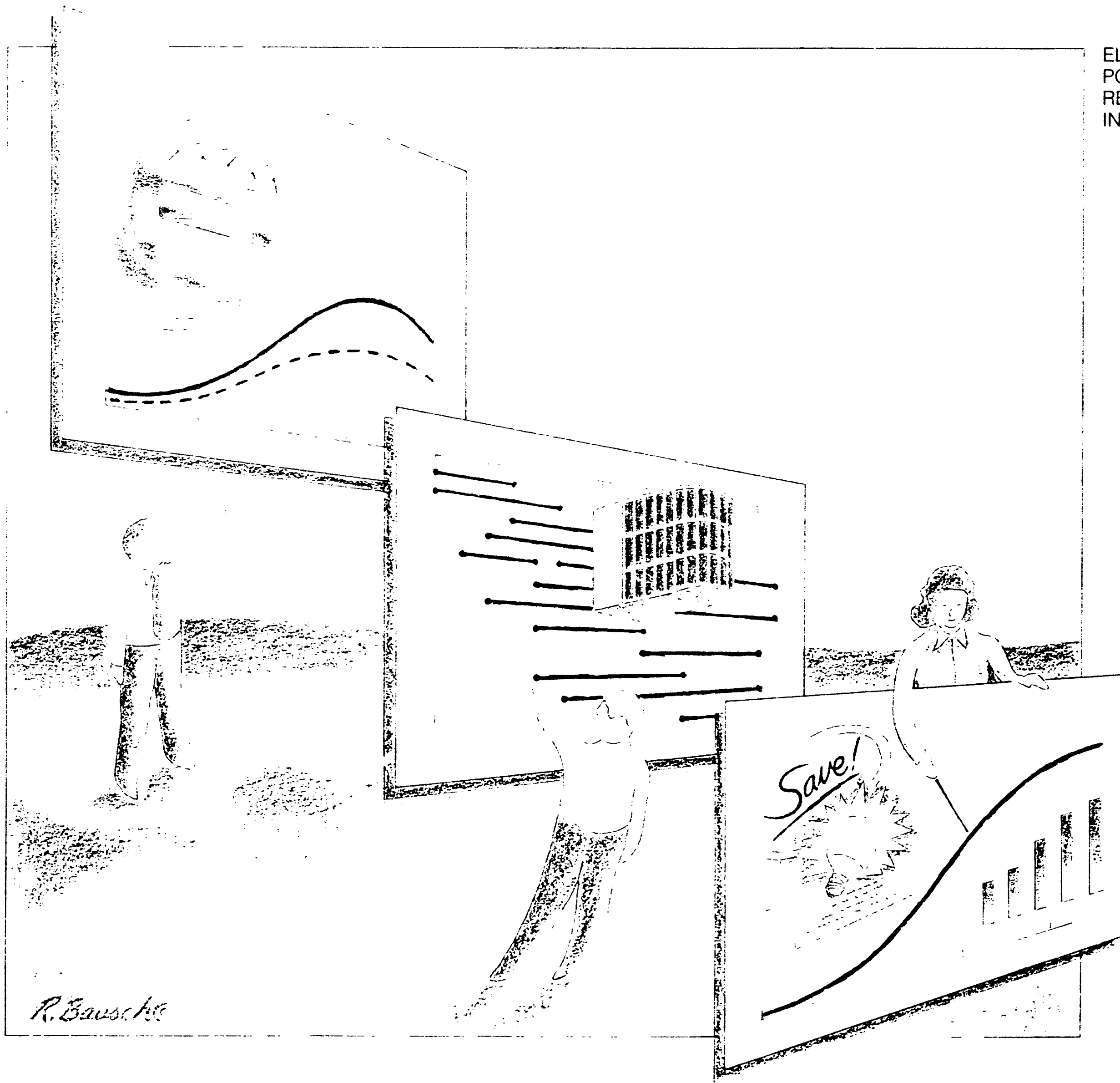
EPRI

A Pacific Northwest Study

Prepared by
XENERGY Inc.
Oakland, California

Regional Economic Research, Inc.
San Diego, California

Architectural Engineering Corp.
Boulder, Colorado



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REPORT SUMMARY

Performance Measurement: Establishing Energy Impacts of Commercial New Construction Programs

A Pacific Northwest Study

In an increasingly competitive energy industry, the commercial new construction market will be an excellent target for bundled energy services. This report describes a method to evaluate the effect of bundled energy efficiency services on energy consumption. The method integrates on-site surveys with engineering analysis statistically calibrated to billing data and employs efficiency choice modeling to assess the impacts from new construction marketing programs. Such capabilities will provide utilities with the information they need to improve their new construction marketing programs.

INTEREST CATEGORIES

Market research
Marketing
Strategic market assessment
Marketing program evaluation

KEYWORDS

Engineering
Marketing
Demand-side management
Conservation
Load Management
Statistical analysis

BACKGROUND Evaluating the performance of energy-related new construction marketing programs presents a difficult measurement problem. It is important that the evaluation method cost-effectively and reliably assess program impacts on the energy usage of new commercial buildings. The method must also provide information on the potential of the program to change customer behavior and be sufficiently flexible to address a wide range of performance issues.

OBJECTIVES

- To develop and demonstrate a prototype method for evaluating the performance impacts of new construction programs.
- To estimate the achievements of two Pacific Northwest new construction programs in regard to electricity impacts and market penetration.

APPROACH Investigators developed a hybrid approach to performance evaluation, involving the use of 1) on-site surveys and engineering analysis to produce initial estimates of energy use and savings; 2) billing data and statistical regression analysis to calibrate the engineering estimates to actual consumption data; 3) choice models to help determine how the program influences building practices; and 4) a research design that facilitates estimation of program penetration. The method was applied to variations of two efficiency programs, Energy Smart Design (ESD) and Design Excellence Award Program (DEAP), which were offered to the construction market by utilities in the Pacific Northwest, including Bonneville Power Administration, Idaho Power, Puget Power, Seattle City Light, and Tacoma Public Utilities. EPRI cosponsored this project with the above utilities.

RESULTS This report describes a method for assessing the energy performance impacts of a commercial new construction efficiency marketing program. In a field demonstration of the method, the on-site surveys and engineering analyses were valuable in assessing the comprehensive energy efficiency levels of each building. Comparison of the efficiency levels across buildings using choice models proved a viable means of determining net program impacts. In addition, the development of energy use estimates under as-built and reference conditions provided an approach for calculating an efficiency index for each building and end use. The overall method had the added benefit of determining spillover and rebound effects.

In this demonstration, the use of bill comparisons or billing analysis was not effective for assessing the performance impacts of new construction programs. Controlling for building size and type fell short of the many factors that must be accounted for in a billing comparison. Billing data was, however, very useful in calibrating engineering models.

EPRI PERSPECTIVE The ability to get involved at early phases of commercial construction and influence building construction practices has been a strategic asset for utilities. Performance measurement of new construction marketing programs provides valuable feedback on the results of such involvement, especially in a competitive business environment. While this study was conducted for demand-side management (DSM) programs, issues related to program effectiveness remain the same. Evaluation of utility programs—whether they are related to energy services, competitive positioning, or regulatory-driven DSM—will continue to be an important activity for making sound management decisions.

Related EPRI research includes *Performance Impacts for Commercial Retrofit* (TR-106923), *Performance Impacts: Evaluation Methods for the Nonresidential Sector* (TR-105845), *Impact Evaluation of Demand-Side Management Programs* (CU-7179, volumes 1–2), and *Engineering Methods for Estimating the Impacts of Demand-Side Management Programs* (TR-100984, volumes 1–3).

PROJECT
WO3539-01
EPRI Project Manager: Rich Gillman
Retail Market Tools & Services
Customer Systems Group
Contractors: XENERGY Inc., Regional Economic Research, Inc., Architectural Engineering Corp.

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A Pacific Northwest Study

TR-106924
WO3539-01

Final Report, September 1996

Prepared by
XENERGY INC.
492 9th Street, Suite 220
Oakland, California 94607

REGIONAL ECONOMIC RESEARCH, INC.
12520 High Bluff Drive, Suite 220
San Diego, California 92130-2062

ARCHITECTURAL ENGINEERING CORP.
2540 Frontier Avenue
Boulder, Colorado 80301

Principal Investigators
R. Barnes
F. Sebold
P. Jacobs

Prepared for
Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, California 94304

Bonneville Power Administration
905 Northeast 11th
Portland, Oregon 97232

Idaho Power Company
1221 West Idaho Street
Boise, Idaho 83702

Puget Power Company
P.O. Box 97034
Bellevue, Washington 98009-9734

Seattle City Light
700 Fifth Avenue, KT-3254
Seattle, Washington 98104

Tacoma Public Utilities
3628 South 35th Street
Tacoma, Washington 98409

EPRI Project Manager
R. Gillman

Retail Market Tools & Services
Customer Systems Group

ORGANIZATION(S) THAT PREPARED THIS REPORT
XENERGY INC.
REGIONAL ECONOMIC RESEARCH, INC.
ARCHITECTURAL ENGINEERING CORP.

ORDERING INFORMATION

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ABSTRACT

The commercial new construction market provides considerable opportunities for utility marketing initiatives. One objective of many marketing initiatives is to influence the efficiency level and thus the energy consumption of various market segments. In an increasingly competitive energy industry, the commercial new construction market will be an excellent target for bundled energy services. Measuring the performance of commercial new construction programs, however, presents many unique challenges. This report describes a method to evaluate the effect of bundled services on energy consumption. The method integrates on-site surveys with engineering analysis statistically calibrated to billing data and employs efficiency choice modeling to assess the impacts from new construction marketing programs. Such capabilities will provide utilities with the information they need to improve their new construction marketing programs and thereby enhance their competitive advantage.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the support of Electric Power Research Institute and their project managers, Rich Gillman and Ilene Obstfeld. This study would not have been possible without the cooperation of the sponsoring clients and their representatives, including Bruce Cody of Bonneville Power Administration; David Lerman and Joe Taffe of Tacoma Public Utilities; Brian Coates and Dennis Pearson of Seattle City Light; Eric Brateng, Bill Hopkins, and Tim Newcomb of Puget Power; and Claude Davis of Idaho Power. In addition, this study benefited greatly from the input of our Technical Advisory Team, including Ken Keating of Bonneville Power Administration, Vince Schuler of the Washington State Energy Office, and Jeff Harris of the Northwest Power Planning Council.

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EXECUTIVE SUMMARY

Introduction

This report presents the results of a multi-year evaluation project for new construction demand-side management (DSM) programs in the Pacific Northwest. While this is a DSM project, the insight it offers into new construction practices and how a utility can influence those practices can be applied in today's utility business environment. Specifically, insights can be gained into the impacts of alternative technologies on energy use, methods for determining those impacts, and analysis of those impacts in terms of business decision making. For readers who do not have a background in DSM, a glossary of terms can be found in Appendix D.

Background

The ability to get involved at early phases of commercial construction and influence building construction practices has been a strategic asset for utilities. In a competitive electricity industry, utilities and energy services companies will continue to develop marketing initiatives that relate to the energy decisions of the building industry. Performance measurement of new construction marketing programs has provided and will continue to provide valuable feedback on their success.

Evaluating the performance of energy-related new construction marketing programs presents a difficult measurement problem. It is important that the evaluation method cost-effectively and reliably assess program impacts on the energy usage of new commercial buildings. The method must also provide information on the potential of the program to change customer behavior and be sufficiently flexible to address a wide range of performance issues.

This report demonstrates a method to assess the performance impact of a commercial new construction marketing initiative. The method integrates calibrated engineering analysis and experimental design to assess how behavior was changed in the building industry and the resulting change in efficiency level and energy usage. The method was applied to variations of two efficiency programs, Energy Smart Design (ESD) and Design Excellence Award Program (DEAP), which were offered to the construction market by utilities in the Pacific Northwest, including Bonneville Power Administration, Idaho Power, Puget Power, Seattle City Light and Tacoma Public Utilities.

Approach

The difficulty of estimating performance impacts was divided into two separate problems. The first involved estimating the energy impacts associated with the installation of various combinations of equipment and the adoption of energy efficiency measures. The second problem consisted of assessing how the program influenced decisions to adopt such measures.

An approach that combines on-site surveys and engineering analysis with various applications of statistical analysis was developed to estimate performance impacts. The primary features of the approach include:

- On-site surveys and engineering analysis
- Calibration of the engineering results to actual consumption data
- Models to assess the program influences on building practices

The energy impacts resulting from the adoption of energy efficiency measures were estimated by deriving and comparing two sets of end-use energy usage estimates for each building. The first set of usage estimates reflected the as-built conditions of each building. The second set of usage estimates reflected what the buildings would have used if they were built to "reference" conditions. An efficiency level index for each building and end use was produced by calculating the ratio of the as-built usage estimates to the "reference" case usage estimates.

It is expected that the average efficiency level index for program participant buildings would be different from the average index of control buildings. The difference between these two average indices is due to the different types of equipment belonging to the two groups of customers. The difference in equipment stocks may be partly due to the program and partly due to other differences between the two groups that have nothing to do with the program.

The impacts attributed to the program are determined by comparing the efficiency level indices of participants to nonparticipants while controlling for differences that may exist between these two groups. A rigorous means of controlling for differences between participants and nonparticipants must be used if program savings are to be estimated in an unbiased way. This entails specifying a model of behavior covering decisions for both efficiency levels and program participation.

The result of the efficiency models is an estimate of the efficiency level of participants if no program was offered. The estimate is referred to as the participation baseline. The net savings can be developed by comparing the as-built energy use to the baseline energy use for the entire sample of participants.

Findings

Two types of findings were obtained from this project:

1. Evaluation of the methodology: Given the demonstration nature of this project, key findings consist of the successes and shortcomings of the performance impact measurement method used.
2. Measurement results: The performance impacts themselves are of interest to the new construction program design and implementation teams in the Pacific Northwest and elsewhere.

Evaluation of the Methodology

The approach was effective in identifying net impacts from the programs and producing an estimate of program penetration. The on-site surveys and engineering analyses were valuable in assessing the comprehensive efficiency levels of each building. The use of the realization rate model was critical for ensuring that the engineering estimates were consistent with the billing data. The efficiency level models were successful at producing estimates of what the efficiency levels of the participating buildings would have been in absence of the program.

In this project, it was demonstrated that the use of bill comparisons or billing analysis is not effective for assessing the performance impacts of new construction programs. Controlling for building size and type falls short of the many factors that must be accounted for in a billing comparison. Billing data is very useful, however, when used to calibrate engineering models.

The development of energy use estimates under two conditions, as-built and reference, provided a means to calculate an efficiency index for each building and end use. Comparing the efficiency levels across buildings using choice models provided a valuable means to determine the net program impacts.

The approach also has the added benefit of assessing some aspects of spillover and rebound effects. The approach does not simply focus on the measures for which incentives and recommendations were provided; all equipment and characteristics are considered in producing the efficiency level indices.

The success of the approach does not imply that all aspects went smoothly. Several lessons were learned and sharing them may be of value to future performance impacts of new construction programs. Following are several key lessons:

- *New Construction Market Tracking*: The lack of a new construction market tracking system for the Pacific Northwest limited the ability to accurately measure program penetration. Tracking the new construction market will prove useful in designing market programs and measuring performance.

- *Grouping Multiple Meters at a Building*: Few utilities have effectively addressed the problem of grouping meters. Without a meter grouping system, it is very difficult to assess performance impacts. Meter grouping is essential to track the energy consumption of entire buildings, an ability that will increase in importance as the industry becomes more competitive.
- *Ensuring Quality On-site Survey Data*: The use of experienced energy surveyors is important for commercial site data collection, but is not sufficient to ensure high quality data. Other valuable features of a successful commercial data collection effort include: maintaining high levels of structure and consistency with regard to filling out survey forms, simplifying the data collection process by collecting less data, and conducting a technical review of surveys on a real-time basis.
- *Assessing Impacts of Variable Speed Drivers (VSDs) and Control Measures*: Using simulation modeling to assess control measures does not tend to address the key determinants of the impact. The assessment effort for these types of measures may need to focus more on direct measurements of behavior and load profiles.

Measurement Results

The various utilities in the Pacific Northwest that offered either ESD or DEAP for new commercial buildings had estimated an annual energy reduction of 53 GWh. Using the method presented in this report, a measurement of nearly 27 GWh per year was derived. The difference between these estimates was primarily due to assumptions regarding free ridership and engineering parameters of certain HVAC measures. Detailed impact findings by end use and estimates of cost effectiveness are provided in Section 3 of this report.

The experience gained from conducting performance measurements of commercial new construction programs has led to three conclusions that can help utilities to design more effective new construction programs.

1. Utilities can reduce the risks associated with obtaining impacts by pursuing efficient lighting and HVAC equipment and avoiding control-related measures such as energy management systems, VSDs, and lighting sensors.
2. Free ridership can be reduced by using comprehensive performance programs rather than measure-based programs and gathering information on building practices on a regular basis. A program design that reduces free ridership may not be the most cost-effective option, however. It is unrealistic to assume that an incentive program or an information program can be designed to have no free riders. The likely existence of free riders should be considered in estimating the potential cost-effectiveness of a program.
3. New construction programs can be more effective if they are coupled with commissioning activities. The positive impacts of new construction programs must be maintained and reinforced over time. Many building operators have no involvement in the original design process and can benefit from a review of operations and monitoring activities as well as additional training.

1

INTRODUCTION

This report presents the results of the Performance Impact Measurement study for Commercial New Construction programs in the Pacific Northwest. The project involves assessing the performance impact of two commercial new construction programs offered by several utilities throughout the region. The project was funded through an EPRI-tailored Collaborative consisting of five utilities: Bonneville Power Association, Idaho Power Company, Puget Power, Seattle City Light, and Tacoma Public Utilities.

A team of four consulting companies was selected to perform this project. XENERGY Inc. was the primary contractor and was responsible for project management, data collection, and research design. Regional Economic Research (RER) was responsible for designing and estimating the various statistical models used in this project. Architectural Engineering Corporation had the lead role of developing the engineering estimates of end-use energy usage from survey data. Portland Energy Conservation Inc. (PECI) assisted in the coordination of the on-site surveys.

A project coordination committee was formed with representatives from EPRI and each of the sponsoring utilities. The role of the committee was to review the approach and results at various stages of the project. The committee met with the project team several times a year and provided substantial input to the methods and interpretation of the results. The committee members also served as a primary contact point for transferring data from the utilities to the project team.

This report is intended to serve various informational needs. Readers interested in the program impacts should focus their attention on Section 3. Detailed impact results are also provided given in Sections 5 through 9. For those interested in performance impact methods, an overview is provided in Section 2 and detailed descriptions of the methodology are provided in Sections 5 through 8. Additional methodological issues are discussed in Section 4. A glossary of commonly used terms is provided in Appendix D.

Background

This project was conceived by a group of utility staff who faced similar issues in evaluating a commercial new construction program. BPA had created the Energy Smart Design (ESD) Program to encourage new buildings to increase the overall efficiency of the electric end uses. Several utilities throughout the Northwest region offered this program or a similar variation of it to their customers. BPA as well as several utilities wanted to know the impact of this program for both planning purposes and regulatory review.

It was apparent to many ESD utilities that simple evaluation methods were not well suited for new construction programs. It was generally felt that engineering analysis on its own was insufficient for determining program impacts. Engineering analysis tends to rely on assumptions and does not always reflect the actual energy use of buildings. The use of billing comparison methods was believed to be ineffective in assessing new construction programs. The ability to create an appropriate comparison is an overwhelming task even with the use of complex statistical models.

It was understood by the ESD utilities that a successful new construction program performance impact required an integrated approach that combined measurement and engineering modeling and statistical analysis. Many of the utilities were faced with the situation in which a small number of participants did not justify the design and use of a state-of-the-art new construction performance impact approach. By pooling data and resources across utilities, however, it was possible to proceed with a regional evaluation of the ESD program. The concept of pooling data and resources led to the creation of the collaborative study.

Idaho Power Company (IPC) joined the collaborative shortly after the start of the performance impact study. IPC offered a program to its customers known as the Design Excellence Award Program (DEAP). The adding of IPC to the collaborative benefited both IPC and the existing members. All parties benefited through increased sample sizes and project funding. In addition, the DEAP program did not offer incentives and Idaho did not have any building codes in effect. This provided an opportunity to better assess the impacts of offering incentives under the ESD program and to get an indication of the effects of building codes.

This performance impact project had two overriding objectives:

1. To develop and demonstrate a prototype method for the performance impact of new construction programs and
2. To estimate the program accomplishments regarding electricity impacts and market penetration.

The project sought to demonstrate an approach that went beyond simple engineering analysis and billing comparisons. The approach needed to reflect the actual behavior of customers. There was a preference, however, not to rely heavily on end-use metering in order to keep the costs reasonable.

The sponsoring utilities were interested in obtaining an approach that could be used in future performance impact studies. They wanted to see what aspects of the approach worked and what areas needed improvement. They wanted to compare the results to billing comparison results to assess the usefulness of that approach. They wanted data and results that would provide a foundation for future performance impact and planning studies.

Although demonstration of the approach was an important objective, this was still a performance impact project. As with most performance impact projects, there was an objective to estimate the energy savings from the program. Specifically, estimates were required on: net program kWh impacts, gross kWh impacts, program penetration, and cost-effectiveness of the program.

Program penetration was an issue because BPA set program penetration goals of reaching 15 percent of the new construction market. Net program impacts, gross impacts, and cost-effectiveness results were important for justifying the program or identifying areas of the program that needed improvement or revision.

Description of Approach

The project team developed a hybrid approach that combined on-site surveys and engineering analysis with various applications of statistical analysis. The primary features of the approach include:

- The use of on-site surveys and engineering analysis to produce initial estimates of energy use and energy savings;
- The use of billing data and statistical regression analysis to calibrate the engineering estimates to actual consumption data;
- The use of state-of-the-art choice models that allow the estimation of how the program influences the building practices of participants; and
- A research design that allows for the estimation of program penetration.

The problem of estimating net program impacts was divided into two separate problems. The first problem involved estimating the energy savings associated with the installation of various combinations of equipment and measures. The second problem consisted of assessing how the program influenced the decision to adoption DSM measures.

The energy savings resulting from the adoption of DSM measures were conducted in a three-step process: data collection, engineering analysis, and calibration.

More than 200 program participants and 150 nonparticipants were selected and surveyed. The surveys were conducted on-site and collected detailed information on equipment characteristics, building shell, and operation schedules. For example, a complete lighting inventory was taken so that lighting densities could be estimated. The building shell data was collected to estimate the overall U-value of the building and to estimate the solar gains. Thermostat, ventilation, and lighting schedules were collected for each piece of equipment.

Two sets of end-use electricity estimates were produced for each building. One set reflected the conditions and operations of the building at the time it was surveyed. The second set was an estimate of electricity use for the building if it had been built using "reference case" equipment and characteristics.

In developing the reference case for each building, the equipment and certain building shell characteristics were changed to reflect the reference case equipment and characteristics. The reference case equipment and characteristics were initially based on the applicable energy codes of Washington. Some further refinements of the reference case definitions were done, however. Detailed definitions of the reference case characteristics and equipment are provided in Appendix B.

The use of the "reference case" is an innovative feature of this project. Comparing the energy use per square foot across buildings does not provide much insight given the differences from one building to another. An efficiency level index can be developed, however, as the ratio of as-built usage divided by the reference case usage. The efficiency index can be compared across sites in a more meaningful manner.

Once the engineering estimates were produced, they were calibrated using billing data. A statistical regression technique known as a realization rate model was used to perform the calibration. The realization rate model can be used to calibrate both the reference case and as-built energy use. The model relies on the variations in energy use, reference case usage, and as-built usage to identify whether systematic errors and differences between the engineering estimates and billing data exist. The model produces adjustment parameters that correct for any systematic differences. The adjustment parameters are applied to the initial engineering estimates to produce calibrated estimates of energy use.

The result of the three previous steps are calibrated estimates of reference case energy use, as-built energy use, and the efficiency level index for each building and end use. By itself, comparing as-built energy use to the reference case use is not a good indicator of the program impacts. It is uncertain whether the participant would have built to the reference case in absence of the program.

The net program impacts are determined by comparing the efficiency level indices of participants to nonparticipants while controlling for differences that may exist among these two groups. A rigorous means of mitigating self-selection bias and controlling for other differences between participants and nonparticipants must be used if net program savings are to be estimated in an unbiased way. This entails the specification of a model of behavior covering both efficiency level decisions and participation decisions.

The result of the efficiency models is an estimate of the efficiency level of participants if no program was offered. The estimate is referred to as the participation baseline. The net savings can be developed by comparing the as-built energy use to the baseline energy use for the entire sample of participants.

Program Background

The New Construction Performance Impact Project covered two distinct types of programs: variations of the Energy Smart Design Program designed by BPA and offered by Puget Power, Seattle City Light, Tacoma Public Utilities, and other utilities in BPA's service territory; and the Design Excellence Award Program offered by Idaho Power.

Energy Smart Design (ESD) Program

The Energy Smart Design Program offered cash incentives for installing program measures. Various types of design assistance also were provided. More than half the buildings received incentives for measures affecting a single end use. Lighting and HVAC measures each accounted for about 50 percent of the expected program impacts. A total of 331 customers participated in 1991 and 1992.

The Energy Smart Design (ESD) was developed jointly by Bonneville and the Region's electric utilities as a long-term program to acquire cost-effective conservation resources from new and existing commercial buildings. ESD benefits Bonneville by helping it meet load growth with resources that are competitively priced, environmentally responsible, and preferred under the Regional Council's plan.

ESD benefits the utilities ("Contractors") who contract to implement it in at least four ways:

- They are able to provide substantial economic benefits to their customers;
- They are provided with an "off-the-shelf" work plan or the criteria and format for designing their own work plan to pursue cost-effective conservation in the commercial sector;
- They are reimbursed by Bonneville for a substantial portion of their administrative costs for implementing ESD to acquire conservation resources; and
- They reduce the risk of having their rates for power from Bonneville surcharged pursuant to the Northwest Power Act, because ESD meets the 1987 Model Conservation Standards recommended by the Regional Council.

Program Objectives. ESD was designed to:

- Promote the installation of efficient equipment to achieve electrical efficiency improvement and load reduction in new and existing commercial buildings;
- Provide technical and design assistance and resource acquisition payments and related services, through Contractors or their designated agents, to owners, developers, and designers of new and existing commercial buildings to achieve energy savings;
- Effect changes in the Region's energy codes by demonstrating the economic benefits of energy efficiency improvements;

- Educate designers, developers, professional educators, financial institution, property managers, building operators, and others regarding the benefits of including energy efficiency measures in commercial buildings;
- Support the use of energy efficient electric products as a means of promoting conservation and prudent load growth in the commercial sector;
- Bring ESD's analytical criteria and installation standards to new commercial buildings and those considered for major remodeling or equipment replacements at the most opportune time to capture resources and thus minimize "lost opportunities" by coordinating the efforts of owners, designers, developers, property managers, and energy service companies; and
- Contribute substantially to the acquisition of at least 206 MW of energy savings from the Region's commercial sector by the year 2003 through the development of specific targets for individual utilities.

Program Principals. ESD was created to provide needed incentives to acquire cost-effective conservation beyond that which can be achieved by code, such as the 1987 Model Conservation Standards adopted by the Regional Power Planning Council or equivalent building codes adopted by states in the region.

Bonneville provides incentives to acquire resources, in the form of conservation, from new and existing commercial buildings. ESD has the same duration as Contractors' firm requirements contracts with Bonneville: until 2001. All commitments made by Contractors to third parties will be honored by Bonneville until satisfied. ESD is a resource acquisition investment for Bonneville and the Region.

Contractors are accountable for implementing ESD in accordance with program requirements. Contractors build quality assurance into all aspects of their implementation plans evidenced in work plans that meet ESD criteria. Contractors are accountable for performing in accordance with their work plans.

Bonneville performs compliance reviews and both process evaluation and performance impact projects of ESD, and Contractors cooperate by keeping and making available necessary information on both participating and nonparticipating commercial customers.

ESD was designed and is implemented jointly between Bonneville and Contractors. Bonneville and Contractors share in the responsibility for acquiring reliable conservation resources. Changes to the program and contract are made through consultations with Contractors and Region-wide negotiations, as appropriate. Maximum authority and accountability is placed at the implementation level—in the hands of Contractors and Bonneville's area and district offices. ESD complies with National Environmental Policy Act (NEPA) requirements, based on mutual desire of Bonneville and Contractors, to acquire conservation in an environmentally responsible as well as cost-effective manner.

The Design Excellence Award Program (DEAP)

DEAP provided design assistance to builders but did not offer incentives for installing measures. DEAP had 158 participants in 1991 and 1992. The participants were expected to save approximately 6 GWh per year.

The general objective of DEAP is to improve the energy efficiency of new commercial buildings, making them at least as efficient as would be required by the Northwest Power Planning Council's Model Conservation Standards (MCS). In DEAP, an alternate specification providing equivalent savings is used. The approach taken is the provision of building energy simulation services and conservation information to the commercial building design community.

Assistance on small commercial buildings represents the bulk of the effort for Idaho Power Company. For very simple buildings, design assistance consists of advice and information on energy conservation. Other buildings are modeled using the BESA program and the energy savings and economic benefits of recommended conservation options are calculated for the project. For more complex buildings, Idaho Power provides financial assistance to outside design professionals for modeling and analysis.

Idaho Power Company offers this program to all its commercial customers regardless of proposed building fuel use. The Idaho Power Company Design Excellence Award Program has as its scope and objectives the following:

1. To provide energy efficient, economical, and comfortable buildings for their customers' satisfaction.
2. To increase the use of energy modeling in the design community.
3. To increase the technical capabilities of Energy Management Commercial Representatives.
4. To learn more about the potential for energy efficient improvements in commercial buildings.
5. To provide a method for Idaho Power to acquire conservation energy resources that would otherwise be lost.
6. To promote the requirements of Bonneville Power Administration's commercial Model Conservation Standards (MCS).
7. To satisfy IPUC's Conservation Order No. 22299 requiring substantial research.

2

METHODOLOGY OVERVIEW

This section presents an overview of the methodology used to estimate the gross and net impacts of the ESD program and DEAP. The four main components of the performance impact methodology are discussed in this section: data collection and sample design, the engineering analysis, the realization rate model, and the efficiency level model.

Several terms are used throughout this report that may be unfamiliar to the reader. A glossary of selected terms is provided in Appendix D.

Background

The general goal of performance impact is to quantify and document the effect of DSM programs on the characteristics of buildings, equipment, and energy use patterns. The performance impact task can be broken into two main branches:

- Measuring what has happened with programs and
- Estimating what would have happened without them.

Both branches are complicated in the commercial sector because of building, equipment, and customer diversity. As two decades of market research and engineering studies have shown, it is both difficult and costly to estimate end-use consumption and technology impacts in commercial buildings with great precision.

The challenge is greatest in new construction. Performance impact efforts for existing buildings focus on changes in equipment and shell efficiency, and estimation approaches rely strongly on comparisons of energy use before and after actions are taken. With new construction, there is no "before," placing a much greater burden on engineering analysis and cross-section comparisons to establish a baseline.

To further complicate matters, actual energy use in new construction can be erratic over the "start-up" period for the building. The full level of savings may not be realized until the building is fully commissioned and steady-state operating levels are reached, introducing severe analysis lags and uncertainties.

In developing the approach for this performance impact, several design principles were specified. Discussion of these principles is provided below.

Principle 1: Split the Performance Impact Problem into Two Separate Problems

It is conceptually convenient to decompose a new construction performance impact into two steps: (a) assess the program impacts on DSM technology adoption and (b) estimate the realized savings from the adoption of DSM technologies.

DSM programs such as ESD and DEAP encourage customers to install DSM measures. The goal of Step A is to estimate what the adoption levels of program participants would have been in absence of programs and compare this to the observed adoption rate of participants. Issues of free ridership and self-selection bias are covered in this analysis.

The installed DSM measures will likely result in energy savings. The goal of Step B is to estimate the change in energy use resulting from the measures being installed. Issues for this step involve addressing engineering model bias, rebound effects, and end-use interaction effects.

Principle 2: Use Efficiency Levels Index Rather Than Assessing Adoption Rates of Individual Measures

For most end uses, analyzing the adoption of specific measures is not appropriate. The feasibility of individual measures vary from site to site. Customers have a choice of several competing measures to achieve energy savings for each end use. Customers can choose from a continuous range of the amount of a measure to install (i.e., R-value of insulation, SEER of cooling system).

In these types of complex situations, it is more appropriate to assess measure adoption on a continuous basis rather than on a binary basis. This concept is especially useful when evaluating customized or performance-based programs. With this approach, an efficiency index is defined and used to reflect the extent that energy efficient systems have been installed.

The efficiency index is developed for each building and end use by comparing the estimated electric use of a building to the estimated use of the building if it had been built with "reference case" equipment and characteristics. The use of the reference case provides a means to compare the efficiency level across very different types of buildings in a meaningful manner. The definition of the reference case will directly effect the estimates of gross savings but will not have an impact on the estimate of net savings.

Principle 3: Use Structured Adoption Modeling Approach

The questions associated with the analysis of net adoption caused by a program are inherently modeling questions. The goal is to estimate an unobservable outcome—what participants would have done in the absence of a program. Without an experimental design that allows construction of an unbiased comparison group, modeling approaches are the only acceptable way to adjust differences between participant and nonparticipant outcomes for differences in the basic characteristics of these two groups.

Also, modeling approaches can take full advantage of the cross-sectional variation available in a multi-utility study. This variation is an important source for identifying the role of incentive levels and retail rates on DSM adoption behavior. In turn, estimated models provide a method for adjusting performance impact results from this study, such as free-rider ratios, to apply to individual utilities and to apply to future performance impacts of programs with different incentive levels.

Principle 4: Use an Engineering-based Approach Rather Than a Pure Statistical Comparison Approach

A wide variety of researchers have concluded that customer diversity in the commercial sector severely limits the usefulness of pure statistical approaches. In new construction, the further limitations imposed by small sample sizes and absence of pre-participation bills place severe strains on statistical models. As a result, engineering models and combined estimation approaches are an indispensable component of DSM evaluation in this sector.

The translation of non-HVAC technology data into engineering estimates of energy use requires basic assumptions about operating schedules and operating loads. For estimating direct and indirect impacts on HVAC systems and plant, more complex algorithms are required. As part of this project, a standardized engineering framework and set of estimating rules should be developed and documented, allowing verification and refinement over time.

Principle 5: On-site Data are Required for New Construction Performance Impacts

To support DSM technology penetration modeling, it is necessary to know the level of DSM technology adoption and other site characteristics for a group of program participants and nonparticipants. It was judged that this would require on-site data collection to support model estimation. These same data will provide a consistent basis for development of engineering estimates of energy use and energy savings associated with DSM adoption.

Principle 6: Use Billing Data and Regression Analysis to Calibrate Engineering Results

Engineering estimates produced from on-site survey data and complex algorithms are likely to suffer from systematic error. Assumptions are required to produce engineering estimates of usages and savings regardless of the amount of data collection that is done.

Engineering estimates of usage can be compared to billing data if estimates for all end uses are developed. Regression analysis of billing data on the engineering estimates can be used to test and correct for systematic errors associated with different customer characteristics, behavior, or efficiency levels.

Overview of Method

The design principles above guided the development of the approach used in this project. Simple engineering analysis and statistical comparison approaches used in other performance impact studies do not address the issues outlined in these principles.

The performance impact process used in this project is depicted in Figure 2-1. The remainder of this section provides a brief discussion of the various components. The methodology is described in greater detail in later sections. Section 5 details the sample design and data collection activities. Section 6 presents the engineering analysis. Section 7 describes how the engineering analysis was calibrated to billing data using a "Realization Rate Model." Section 8 shows how the net impacts were derived using efficiency choice models.

The process begins with sample selection of program participants and nonparticipants. The participant and nonparticipant buildings provide variation in installed efficiency levels and the ability to assess the impact of the program.

Building data is collected for each sampled building through an on-site visit. The survey data is used in an engineering analysis to produce estimates of electricity use for each end use. In addition to estimating the as-built electricity use of each end use in the building, the engineering task also produces an estimate of electricity use for the building as if it had been built to reference case conditions. More information on reference case conditions is provided in Section 6 of this report.

The engineering estimates of electricity use are calibrated to actual billing data using a "realization rate model." This model results in engineering estimates that have been adjusted to reflect actual usage. The gross impact then is equal to the difference between the adjusted as-built electricity use and the adjusted reference case electricity use.

The net program impacts are derived by estimating the efficiency level that the participant would have installed had there not been a program. The estimate of the baseline for the participant is developed through a set of efficiency choice models.

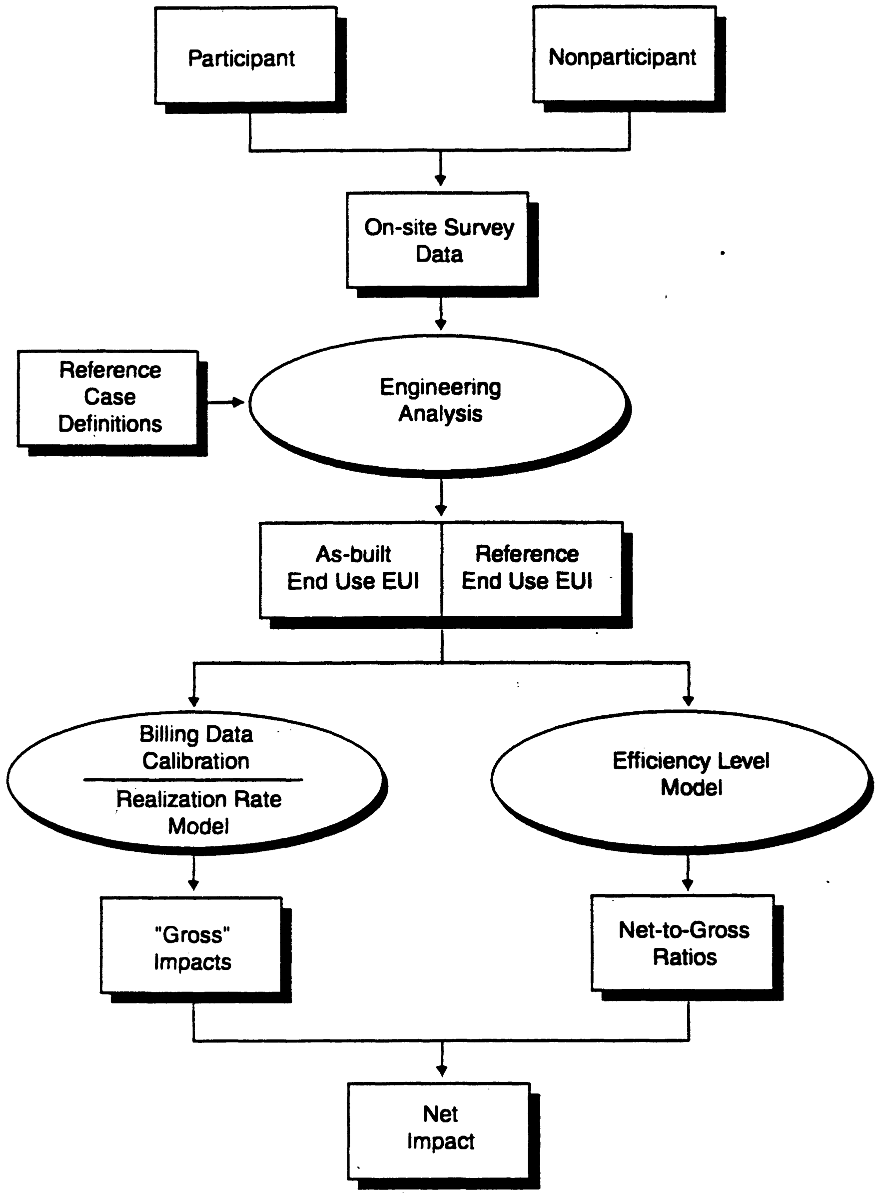

Figure 2-1
New Construction Performance Impact Process

Sample Design and Data Collection

Two samples were drawn for the performance impact, a new construction market sample consisting of 183 sites and a participant sample of 190 sites. A stratified sample design was used to select the samples. The sample frames were developed from a variety of sources.

Participants were defined as buildings that received an ESD incentive or a DEAP plaque. Idaho Power customers were given a DEAP plaque if the estimated savings from installed measure equaled or exceeded the estimated savings from the measures that were recommendation as part of the design assistance process.

In addition to assessing the net impact of the programs, it was also a goal of this project to measure program penetration. This goal influenced the type of samples that was selected in this project. Program penetration can be assessed by selecting a sample from all new commercial buildings and determining which buildings participated in the program. The new construction market sample was developed for this purpose.

The new construction market sample was drawn from the population of buildings built in 1991 and 1992. This sample was used to estimate program penetration and to provide both nonparticipant sites (154) and participant sites (29) for the impact analysis.

There was a downside to the market sample approach. The population of nonparticipants tend to be very different than the population of participants. Selecting a sample to represent all buildings restricted the selection of a sample of nonparticipants that was similar to the participants. There is no guarantee, however, that a nonparticipant sample that was similar to participants could have been selected, even if attempted.

On-site surveys were performed on all sampled sites. The on-site surveys required, on average, approximately eight hours of surveyor time to complete. The eight hours included recruitment time, time to review program records, travel, time on-site, and time to complete the survey form.

The surveys collected detailed data on: building shell characteristics, equipment characteristics, operation behavior, occupancy, and equipment change history. Surveyors provided notes on the survey form to clarify and supplement responses.

Engineering Analysis

The engineering analysis was used to develop estimates of site usage for both participating and nonparticipating sites under two alternative scenarios with respect to the construction of the site:

- First, for the site as actually built, and
- Second, for the site had it been constructed to minimally comply with either building codes or other reference criteria.

Both sets of estimates were developed under specific assumptions about the actual operation of the site (e.g., operating hours, lighting schedules, etc.). For participants, the difference in energy usage between these two scenarios constitutes a preliminary engineering estimate of the gross savings associated with measures adopted by participants.

Engineering algorithms were developed to produce EUI estimates from survey data. Short-term monitoring of 12 sites was used to aid in the development of the HVAC algorithms. The HVAC algorithms were developed using regression analysis on results of 3,600 parametric DOE-2 runs. Default values were developed when key survey elements were not obtainable.

Realization Rate Model

The realization rate model was used to calibrate the engineering estimates to billing data. The model relies on two types of engineering estimates: 1) estimates of end-use consumption under the "reference case" scenario, and 2) estimates of the difference between the estimated "as-built" electric usage and the estimated reference case usage. The model also makes use of information on site characteristics (e.g., square footage), weather conditions, and occupancy characteristics that might affect the realization of the engineering estimates of baseline usage and DSM-related savings.

The second engineering estimate described above is sometimes referred to as the engineering estimate of gross savings. Please keep in mind that the definition of gross savings for this performance impact is the difference between reference case and as-built estimated usage. Thus, gross savings in this project are not an estimate of the savings due directly to the measures that were installed as part of the program. Both participants and nonparticipants will have some level of gross savings (perhaps negative in some cases).

The realization rate model produces a set of adjustment coefficients (or adjustment functions) that translate the engineering estimates into estimates consistent with observed energy usage and savings. These coefficients are called realization rates. The realization rates on savings reflect the proportion of engineering-based savings estimates actually realized in the form of reduced site usage.

The model is an extension of a standard SAE model and produces various types of adjustments for: varying occupancy levels over time; systematic over- or underestimation of a given EUI; systematic over- or underestimation of the impact associated with varying efficiency levels; and a systematic error in estimating the impact of a particular measure.

The types of adjustments that can be made through the use of the realization rate model are portrayed below in Figure 2-2.

The standard SAE model is capable of adjusting energy use upward or downward if a systematic error is found. This type of adjustment is reflected in the top right graph. The realization rate model used in this project can also adjust for errors associated with different efficiency levels. The middle right and lower right graphs demonstrate additional types of adjustments that can be made by the realization rate model.

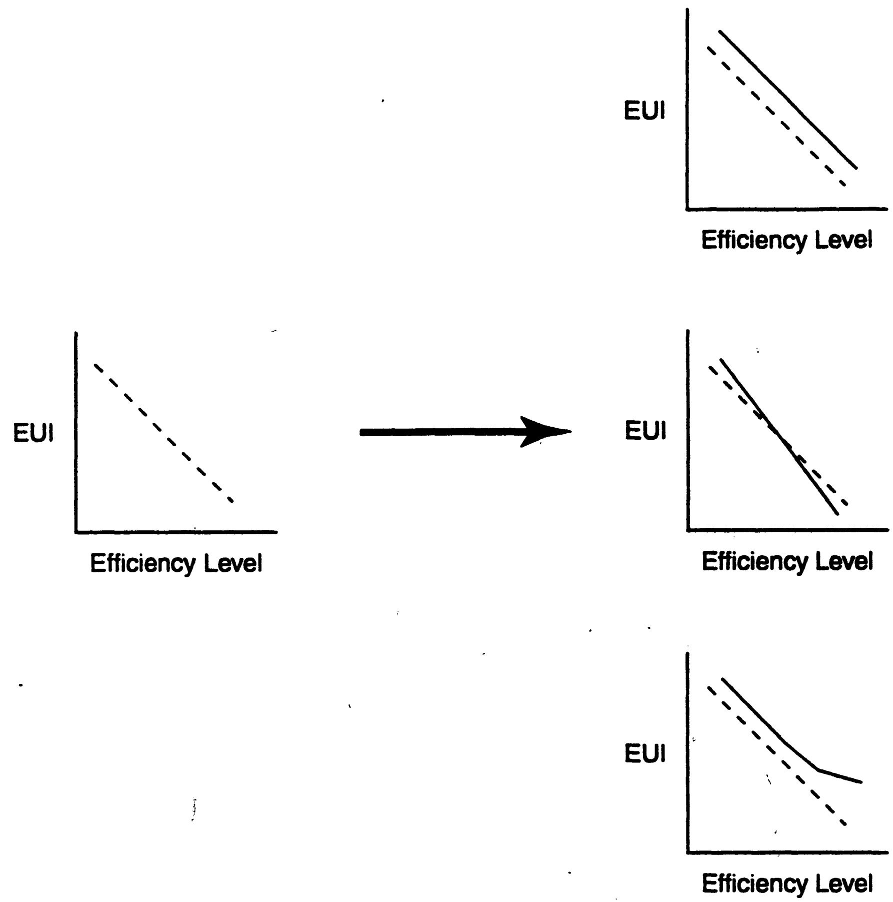

Figure 2-2
Realization Rate Model Adjustments

Efficiency Choice Model

The goal of the efficiency choice analysis is to estimate the *net* level of DSM adoptions actually attributable to the programs under study (i.e., net of the free-rider effect). Conceptually, this entails comparing observed adoptions by program participants to the levels that would have occurred for these same participants without the program. Insofar as the latter levels of adoptions are not directly observable, they are typically estimated in one of two ways:

- Through the use of nonparticipant adoptions as a proxy for what participants would have done had they not participated in the program, or
- Through the use of statistical models of customer efficiency choice behavior to predict what participants would have done had no program been available.

For this performance impact, efficiency level models were estimated for each end use to determine the efficiency level that participants would have installed if there were no program. The efficiency level of nonparticipants served as a major determinant of the "baseline" for participants. Because participants and nonparticipants tend to be different, however, a model is needed to account and adjust for these differences.

As Figure 2-3 exhibits, the efficiency model that was used also takes into consideration the fact that participation and efficiency level decisions are interrelated.

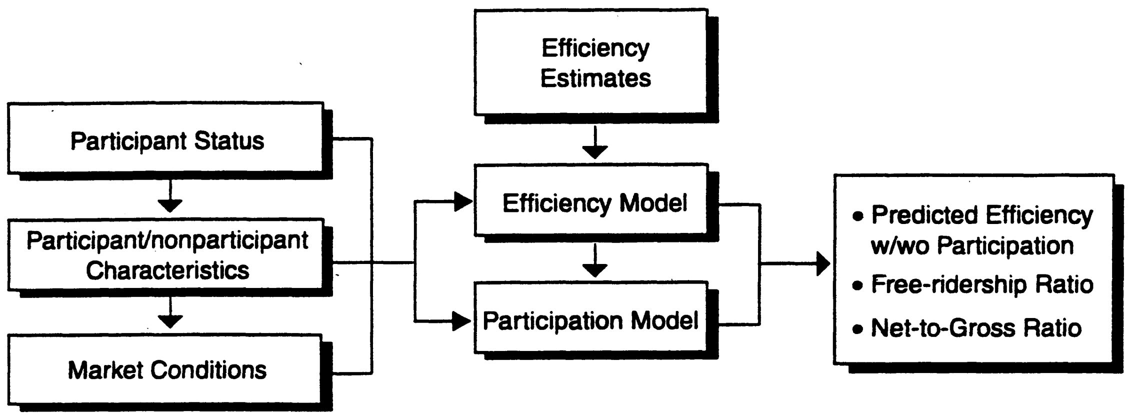

Figure 2-3
Efficiency Choice Model

The efficiency choice analysis leads to three related figures: a predicted efficiency with and without participation; a free-ridership ratio; and the ratio of net attributable adoptions to gross participant adoptions, known as the net-to-gross ratio. The analysis conducted as part of this performance impact was designed to estimate a net-to-gross ratio for each of the end uses affected by program measures.

Cost Effectiveness

Using the net savings results of the performance impact and the program tracking data on measure costs, incentives, and expected measure lives, levelized costs of conserved energy were developed for the programs (on a Mills-per-kWh basis). The analysis used the methodology and assumptions provided by BPA.

For the analysis, the present value of all costs and savings were calculated using a three percent real discount rate. Present-value costs then were divided by present-value kWh savings. Levelized costs were calculated from a regional program perspective (using paid incentives as the measure cost indicator for ESD and modeling costs as the indicator for DEAP) and from a total regional perspective (using total incremental measure costs). The following equations were used:

Levelized regional program costs =

$$\frac{PV(Incentives/Modeling\_Costs + Fixed\_Program\_Costs)}{PV(kWh\_Savings)}$$

Levelized total regional costs =

$$\frac{PV(Incremental\_Costs + Fixed\_Program\_Costs)}{PV(kWh\_Savings)}$$

Adjustments to tracking system costs were required for the total regional cost calculation because the program tracking systems contained *total* measure costs rather than *incremental* measure costs. Based on discussions with ESD utility staff about the program-imposed relationship between incremental costs and incentive levels, incremental costs were set to the minimum of the total measure cost, or 2.5 times the paid incentive. For DEAP, incremental costs were adjusted to average $0.21 per kWh, based on discussions with DEAP utility staff. In addition, a net-to-gross ratio was applied to the incremental measure costs to net out measure costs paid by free riders. (The net-to-gross ratios were based on the comparison between the estimate of net impacts and the estimated realized tracking system savings. The realized tracking system estimates were calculated by applying the realization rates obtained from the realization rate model to the original tracking system estimates.)

Fixed program costs in the analysis include: the utility component of performance impact costs, utility administration costs, BPA administration costs, marketing costs, and training costs. Costs for the *Electric Ideas Clearinghouse*, and the *Lighting Design Lab* were not included in the calculations. All included costs were assumed to be financed at BPA's treasury borrowing rate of 8.35 percent for 20 years (which incorporates an assumed inflation rate of four percent).

3

OVERVIEW OF FINDINGS

This section presents the findings on the energy impacts, cost effectiveness, and market penetration of the ESD Program and DEAP. The utilities that offered either ESD and DEAP to new commercial buildings had initially estimated an annual energy reduction of 53 GWH. Through this study, an estimated impact of 27 GWH was derived implying a realization of 50 percent of the expected savings. The difference between the estimated net impact and initial program tracking estimates is primarily due to free ridership and inaccurate HVAC engineering assumptions used to develop the initial estimates.

The concept of free ridership does not reflect some sort of negative behavior by the customer or program staff. Free ridership reflects that some portion of the savings attributable to the program measures would have occurred if there was no program. Free riders are often viewed as participants who would have installed the measures even if the program was not offered. From another perspective, the amount of free ridership reflects the amount of error in estimating the baseline conditions used to derive the tracking system savings.

Tracking system estimates have built-in "baseline" assumptions regarding what the participant would have installed without the program. If the baseline assumptions are accurate, there is no free ridership. An accurate baseline assumption must account for the fact that participants would have installed a range of efficiency levels in absence of the program. The baseline assumptions that reflect the least efficient option will almost always result in free ridership.

Nearly all incentive programs will have some free ridership. The best way to reduce free ridership is to better estimate the baseline conditions. Assuming that the least efficient option would have been installed in all cases will only provide an illusion of what the true net program savings are. Understanding the distribution of baseline practices will also avoid the offering of measures that have a relatively high likelihood of being installed on their own.

In addition to energy impacts, the cost-effectiveness of the programs were also assessed. Regional program costs were estimated to be 59.3 mills per kWh for ESD and 11.0 mills per kWh for DEAP. Total regional costs were estimated to be 47.0 mills per kWh for ESD and 26.6 mills per kWh for

DEAP. The levelized total regional cost goal for the ESD program was 43 mills per kWh. Further discussion on the cost-effectiveness measurements are provided later in this section.

With regard to program penetration, approximately 10 percent of new buildings participated in one of these programs during 1991 and 1992. The 478 participating buildings accounted for 34 percent of the total floor space built during these two years. The penetration of the DEAP program was 12 percent of the new buildings and 44 percent of the newly constructed floor space. The penetration of the ESD program was nine percent of the buildings and 33 percent of the floor space. The program goal for ESD was to obtain participation from 30 percent of the new buildings.

Implications of Results

The results of this performance study as well as other new construction studies have produced several insights for designing new construction marketing programs. Design issues such as focusing on certain end uses and measures, minimizing free ridership, and ensuring savings over time are briefly discussed below.

Reliable Impacts

It is commonly found in performance impact studies that engineering estimates of savings are often more accurate for certain types of measures. It is also believed that achieving the estimated savings from certain types of measures is a much riskier situation. It is likely that future efficiency programs will need to be more risk-adverse and pursue those measures that provide reliable, measurable impacts.

Obtaining savings from efficient lighting and HVAC equipment tends to be a lot less risky than control-related measures such as EMS systems, VSDs, and lighting sensors. The savings for control-related measures are less reliable because they largely depend on behavioral issues that vary significantly across sites. Even given that the savings from control measures are present, it is much more costly to "observe" control-related savings in a new construction performance impact.

Free Ridership

Free ridership was the major reason for the net impacts to be about 20 percent of the tracking system savings. Many program designers want to better understand free riders and design programs with low free ridership.

Free ridership tends to be high in many new construction programs that provide incentives (or recommendations) for a prescriptive set of measures. It is nearly impossible, however, to classify potential participants as free riders. Free ridership occurs when incentives are offered to install measures that have some chance (perhaps small) of being installed on their own. Free ridership also occurs when participants make trade-offs between program measures and other actions that could result in higher efficiency levels.

The key to reducing free ridership is knowing what the building industry will install on its own (the baseline) and providing incentives for going beyond the baseline. This concept sounds good but is nearly impossible to design and implement. There is a wide range of what customers would do in absence of the program.

By design, most programs will have a market transformation effect. The market transformation effect creates a situation in which free ridership increases as time goes on unless the qualifying measures are regularly updated.

Potential program design features that result in lower free ridership tend to include:

- Using comprehensive performance-based incentives rather than measure-based incentives; and
- Regular gathering of information on standard building practices to update qualifying measures and adjust reference cases for performance models.

Both features above come at a cost. It may be more cost effective to develop a low cost program with a high portion of free riders than a high cost program that has few free riders and probably few participants.

Finally, it is unrealistic to assume that an incentive program or an information program can be designed to have no free riders. The likely existence of free riders should be considered in estimating the potential cost effectiveness of the program. If an assumption of little or no free ridership is necessary to make a program cost-effective, it is likely that the program will not be cost effective.

Commissioning

The installation of efficient measures in new buildings provides energy savings but often provides fewer savings than were expected. In new buildings, the people who decide to install a measure and the people responsible for building operations several years later are usually different. The incorrect operation of the building can result in portions of the savings being lost.

New construction programs can be more effective if they are coupled with commissioning activities. Many building operators can benefit from a review of operations, monitoring, and additional training. Commissioning studies should be conducted shortly after the building is occupied and then every two to five years afterward. The best candidates for commissioning are buildings that have been installed with control-related measures or HVAC measures.

Performance Impact Findings

A summary of impact results by end use is presented below, using a series of line graphs (Figures 3-1 through 3-7). The axis of the graph measures both the relative efficiency levels and the relative energy use index (EUI). For a given operation schedule, a 10 percent increase in overall efficiency level will produce a 10 percent decrease in the EUI.

Four points are plotted on each line graph. One point reflects average electricity use under reference case conditions. The other three points show the energy use of participants and nonparticipants relative to the reference point. The result for interior lighting from the ESD program is shown below in Figure 3-1.

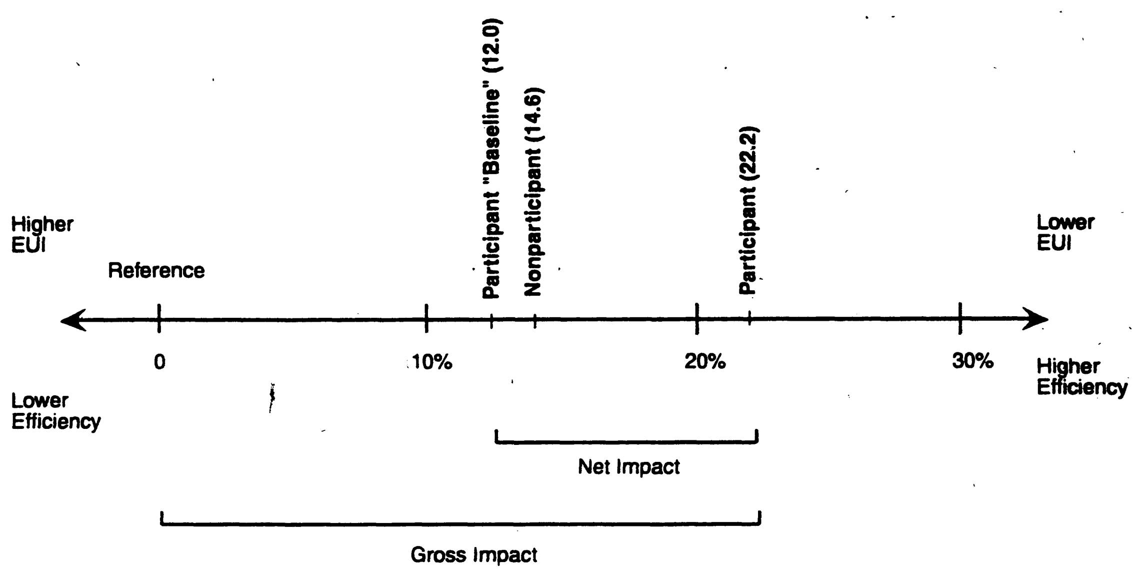

Figure 3-1
ESD: Interior Lighting

The line graph demonstrates the gross and net impact as a percentage of the reference case usage. The participants are about 22 percent more efficient than the reference case. The program was estimated to be responsible for savings that equal 10 percent of the reference case usage. This implies that the remaining 12 percent was caused by market factors other than the 1991–1992 ESD program, including both economic forces and previous program activity. The line graph also shows that nonparticipants were 15 percent more efficient than reference case conditions.

The gross impact is defined as the difference between the as-built electric usage and what the electric usage would have been if the building were built with "reference case" equipment and building shell characteristics. The gross savings include the impact of all measures and efficient equipment regardless of whether an incentive was paid.

The net impact is the difference between the as-built electric usage and what the usage would have been in the absence of the program. As the line graphs show, the absolute estimates of net savings do not depend on how the reference point or case has been defined.

The reference point could be set to reflect the baseline conditions used in calculating the tracking system estimates. The tracking system estimates, however, were not constructed using a consistent baseline assumption. In addition, baseline conditions should be set for all end uses so that potential spillover effects could be captured. The reference case for this project was set to reflect the minimum efficiency levels permitted for equipment and buildings in Washington and Oregon.

The participant and nonparticipant as-built data points are derived from the engineering estimates and the billing data calibration (realization rate model). The participant "baseline" is the estimate of what the relative efficiency level for participants would have been if there were no 1991–1992 ESD program. This "baseline" value is derived from the engineering estimates and the efficiency choice models.

The estimated baseline for participants was developed from a set of efficiency choice models that were estimated using both participants and nonparticipants. The participant baseline efficiency level (which is unobservable) is derived, in part, from the estimated efficiency level of the nonparticipants (which is observable). The participant baseline is statistically estimated to account for differences between the participants and nonparticipant samples such as larger buildings sizes, increased glass area, and increased propensity toward single tenancy and owner occupation of the building.

A similar line graph is shown below in Figure 3-2 for HVAC measures of the ESD program.

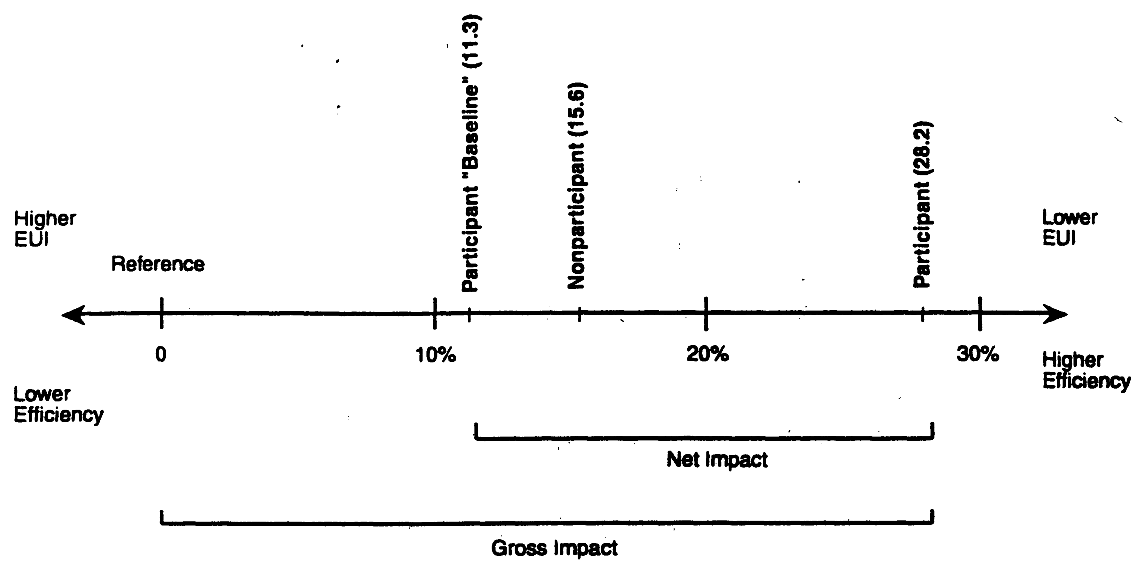

Figure 3-2
ESD: HVAC

The participants were 28 percent more efficient than the reference case conditions. The program was responsible for a reduction of 17 percent from the reference case.

The exterior lighting results for the ESD program are shown in Figure 3-3.

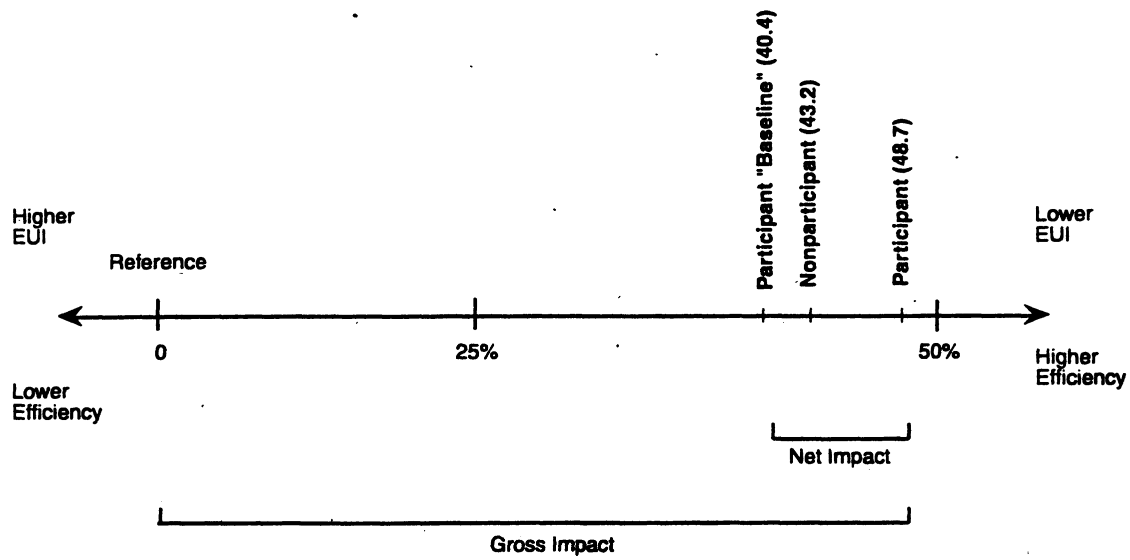

Figure 3-3
ESD: Exterior Lighting

The lighting results are impacted by the fact that mercury vapor lamps were used as the reference case condition for all HID fixtures. Both participants and nonparticipants are much more efficient than the reference case. The program was responsible for saving nine percent of the reference case usage. If another reference case such as metal halide were used, the gross savings would decrease but the percentage net savings would increase as the reference usage goes down. The resulting net savings would be the same regardless of where the reference point is set.

The overall ESD program impact for all affected end uses combined is shown in Figure 3-4.

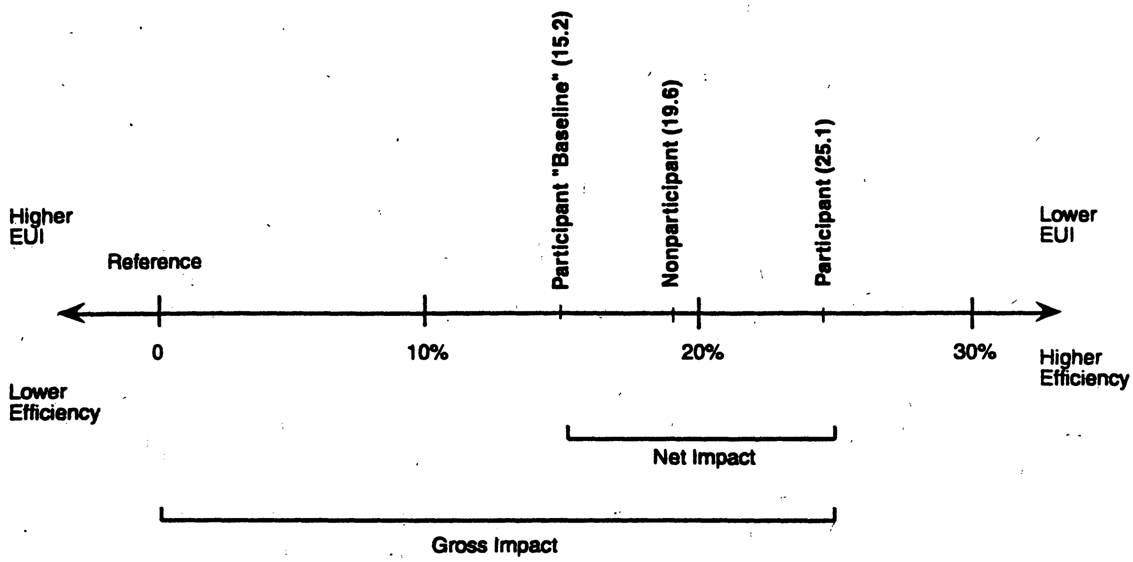

Figure 3-4
ESD: All Affected End Uses

Overall, participants were 25 percent more efficient than the reference case and about seven percent more efficient than the nonparticipants. Nearly 40 percent of the difference between the reference case efficiency and the participant as-built efficiency is due to the program.

Similar graphs are shown for DEAP. Figure 3-5 shows the program impact on interior lighting.

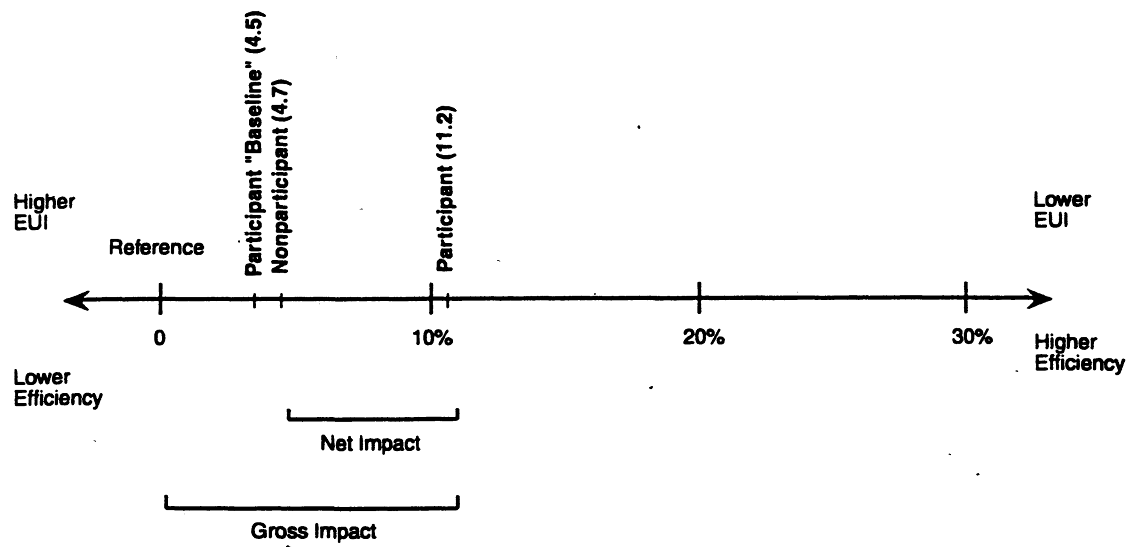

Figure 3-5
DEAP: Interior Lighting

The DEAP participants are about 11 percent more efficient than the reference case. DEAP is responsible for reducing participant electric use for lighting about six percent from the reference case usage.

Figure 3-6 presents the relative efficiencies for HVAC in the DEAP area.

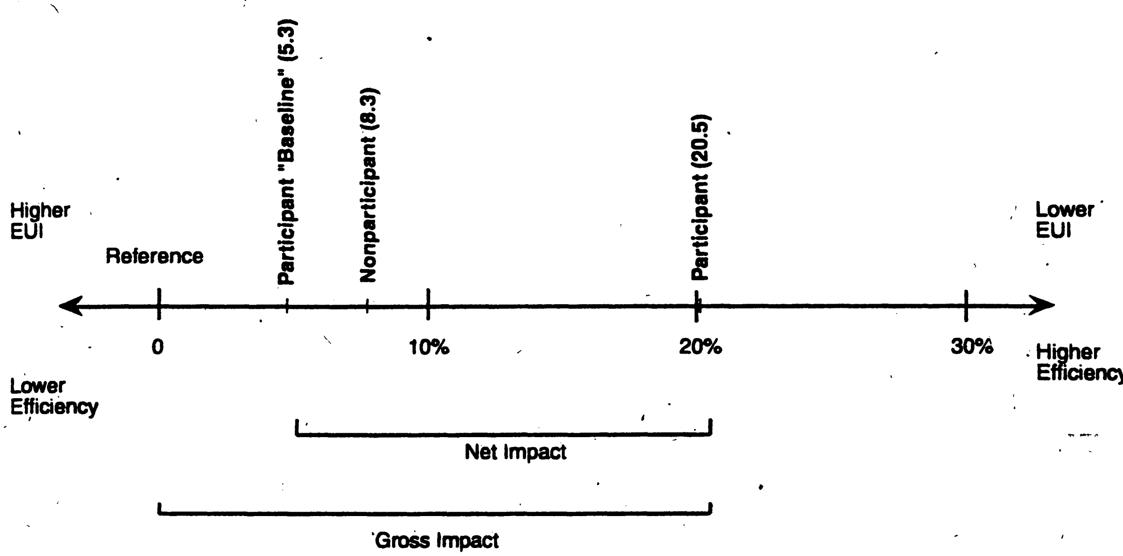

Figure 3-6
DEAP: HVAC

The DEAP participants were about 20 percent more efficient than the reference case efficiency level. DEAP was responsible for about a 15 percent reduction while non-program factors accounted for the other five percent.

The last line graph, Figure 3-7, shows the overall results for DEAP.

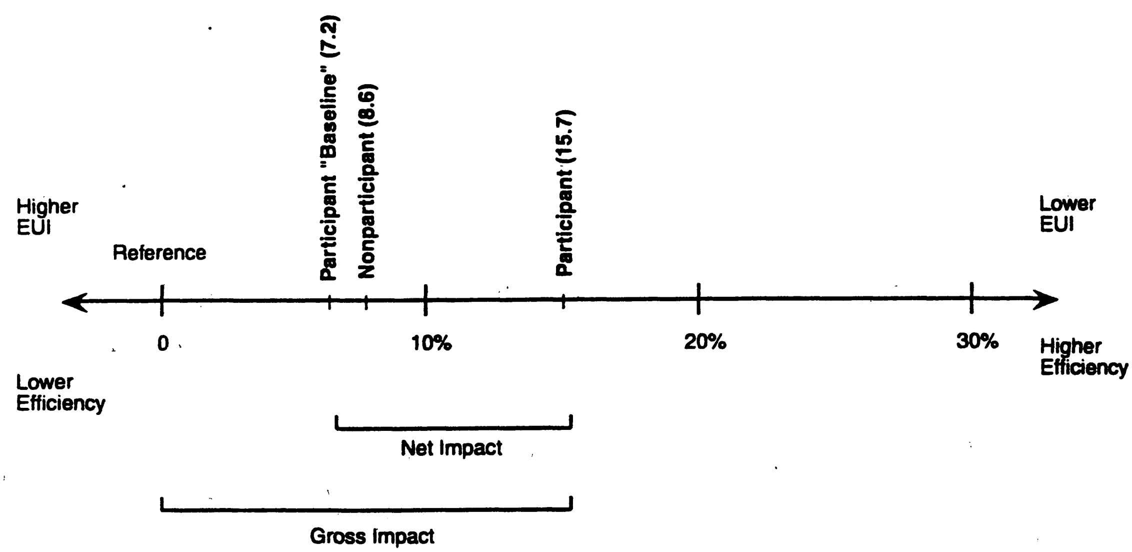

Figure 3-7
DEAP: All Affected End Uses

Overall, DEAP was responsible about one half of the difference between the reference case efficiency and the as-built efficiency.

Table 3-1 below summarizes the program impacts on a percentage basis.

Table 3-1
New Construction Results

Program	Participant As-built Relative Efficiency (Gross Impact)	Participant Baseline Relative Efficiency	Net Impact % of Reference Case Usage	Net Impact % of Baseline Usage
ESD	25.1%	15.2%	9.9%	11.3%
DEAP	15.7%	7.2%	8.5%	10.1%

The existence of building code is primarily responsible for the higher baseline efficiency levels of the ESD participants compared to the DEAP participants. The DEAP program achieved similar percentage savings as the ESD program without the use of incentives. The lack of building code in the DEAP area provided more potential savings for the DEAP participants, however. The DEAP participants had an as-built efficiency level that was about the same as where the ESD participants would have been if there was no ESD program.

Providing the results on a relative percentage basis is useful but does not tell the whole story. As stated above, the relative reference case efficiency level and various impact estimates can be expressed in terms of EUIs. Provided in Table 3-2 are various EUI estimates for ESD participants. The overall net program impacts for ESD are about 2.0 kWh per sq. ft.

Table 3-2
ESD Participant Average EUIs

End Use	Reference Case EUI	As-built EUI	Gross EUI Savings	Base Line EUI	Net EUI Savings
Interior Lighting	9.6	7.5	2.1	8.5	1.0
Exterior Lighting	3.2	1.6	1.6	1.9	0.3
HVAC	3.9	2.8	1.1	3.5	0.7
DHW	1.1	1.1	0.0	1.1	0.0
Refrigeration	7.6	6.2	1.4	6.7	0.5
Total Affected	20.5	15.3	5.1	17.4	2.0

Table 3-3 provides similar EUI estimates for the DEAP participants. The DEAP program was responsible for a 1.2 kWh reduction per sq. ft.

Table 3-3
DEAP Participant Average EUI

End Use	Reference Case EUI	As-built EUI	Gross EUI Savings	Base Line EUI	Net EUI Savings
Interior Lighting	8.7	7.8	1.0	8.3	0.6
Exterior Lighting	1.3	0.7	0.6	0.8	0.1
HVAC	3.8	3.1	0.8	3.6	0.6
DHW	1.1	1.1	0.0	1.1	0.0
Refrigeration	0.5	0.4	0.0	0.4	0.0
Total Affected	14.5	12.2	2.3	13.4	1.2

The total net EUI savings is less than the sum of the end use EUI savings because not all buildings have all of the end uses.

The DEAP net impacts are lower than the ESD impacts primarily due to base EUI values that were lower to begin with. The percentage savings of the DEAP are only slightly lower than the percentage savings of ESD. ESD was responsible for an 11 percent reduction in energy use for affected end uses while DEAP was responsible for a 10 percent reduction in energy use.

The fact that DEAP and ESD had similar percentage savings may be surprising on the surface. The ESD offered customers incentives to install measures. DEAP only provided recommendations and did not provide incentives.

The lack of building codes in Idaho also played a part in affecting the net impacts of the program, however. Due primarily to the lack of code, the buildings in Idaho tended to be about 10 percent less efficient than buildings in Washington and Oregon. The fact that buildings are less efficient in Idaho provides more opportunities for savings.

The fact that the EUIs tend to be lower for the DEAP participants do not reflect that DEAP participants are more efficient. The lower EUIs are primarily due to differences in building types and operation hours. The reference case was defined with identical assumptions for DEAP and ESD buildings. The fact that ESD participants are nearly 25 percent below their reference case EUI compared to about 16 percent for DEAP participants reflect that ESD buildings are more efficient.

Table 3-4 compares the total GWH gross and net impacts of ESD and DEAP to the tracking system estimates of gross impacts.

Table 3-4
Estimates of Program Impacts

End Use	Tracking Savings (MWh)	Gross Savings (MWh)	Net Savings (MWh)
Lighting w/incentive	19,973	37,523	13,170 65%
HVAC w/incentive	26,849	19,498	9,728 36%
DEAP	6,012	6,952	3,735 63%
Total	52,836	63,974	26,635 50%

The net savings for ESD lighting is 65 percent of the tracking system estimates, primarily due to free ridership. The net savings for DEAP are also lower than the tracking system estimates primarily because of free riders.

The net savings for ESD HVAC measures is about one-third of the tracking estimate. Although free ridership plays a small role in the discrepancy, it is not the primary cause for the difference. The discrepancy is primarily caused by different assumptions regarding the operation of the equipment. The cooling EUIs obtained from this study appear to be much lower than the EUIs assumed in the tracking estimates. Tracking system estimates of impacts from variable speed drives (VSD) were much higher than the estimates that were derived in the engineering analysis.

The estimated gross impacts obtained from this study can be misleading. The gross impacts are equal to the difference between the reference case energy usage and the as-built energy use. They did not reflect an engineering analysis of the specific measures where either incentives were given or recommendations were made. The gross impacts are a measure of all savings beyond what is assumed in the reference case regardless of whether it is a program measure or not.

In reviewing the gross impacts, it is important to note that: 1) these impacts depend on how the reference case is defined, and 2) nonparticipants had significant levels of gross savings also. The comparison of efficiency levels across participants and nonparticipants is critical in determining the impacts from the program. The result of comparing participants to nonparticipants using the efficiency choice models is that more than half of the total gross impacts in Table 3-4 would have been realized if the program had not been offered. This accounts for the total net impacts of 27 GWH, compared to the total gross impacts of 64 GWH.

The gross savings are expected to be higher than the tracking savings estimates because they should contain both program measures and non-program measures. The fact that the gross savings for HVAC is lower than the tracking system estimates reflects that the engineering estimates of savings for the HVAC measures are considerably lower than what was assumed in the tracking estimates.

The Effect of Building Codes. Assessing the impact from building codes was not major objective of this project. Comparing the relative efficiencies across the DEAP and ESD areas does shed some insights on the effect of code, however, as building code existed in the ESD areas and did not exist in the DEAP area. The effect of building code can be estimated by comparing the relative efficiency of the nonparticipants and the baseline efficiency of the participants across the two areas. This comparison is shown in Table 3-5 for lighting, HVAC and the total of all affected end uses.

Table 3-5
Estimated Building Code Impacts

Area	End Use	Nonparticipant As-built Relative Efficiency	Participant Baseline Relative Efficiency	Average Relative Efficiency without Programs	Impact from Building Code
WA, OR	Lighting	14.6%	12.0%	13.8%	
Idaho	Lighting	4.7%	4.5%	4.6%	9.2%
WA, OR	HVAC	15.6%	11.3%	14.3%	
Idaho	HVAC	8.3%	5.3%	7.0%	7.3%
WA, OR	All affected	19.6%	15.2%	18.2%	
Idaho	All affected	8.6%	7.2%	8.0%	10.2%

From the preceding table, it is estimated that building code is responsible for about a nine-percent reduction in lighting energy use. Code is responsible for about a seven-percent reduction in HVAC usage. Overall, building code reduces the overall EUI of the affected end uses by 10 percent.

The effect of building code can also be inferred using the estimated parameters of the efficiency level models. The results from the efficiency models were somewhat different from what was found using the simple comparisons presented in Table 3-5. For example, a six-percent reduction was estimated for lighting in the Idaho sites if building code, similar to those in the ESD areas, was implemented. A 16 percent reduction in HVAC usage was estimated for the Idaho sites using the efficiency model.

In theory, the efficiency level model should provide a "better" estimate of the effect of building code than simply comparing the relative efficiency levels across the two areas. The estimates from the efficiency model are not, however, statistically different from those produced using the simple comparisons in Table 3-5. Given that the estimates from both sources are subject to bias from omitted variables, it is felt that the simple comparison approach is sufficient for determining the likely impact from code.

Cost-effectiveness Results

Levelized costs estimates are presented in Table 3-6. The regional program costs include all program costs paid by BPA or the utilities to achieve the energy savings. Program costs include incentives, marketing, evaluation, and administrative activities. The total region costs include the incremental cost of the measure and program costs other than incentives paid by BPA and the utilities.

Two sets of cost estimates are provided in Table 3-6. The first set is derived using tracking system estimates of savings and costs. The second set of levelized cost estimates was developed using the results from the performance impact.

Table 3-6
Levelized Costs (Mills per kWh)

	Tracking System Results		Net Performance Impact Results	
End Use	**Regional Program Costs[1]**	**Total Regional Costs[2]**	**Regional Program Costs[1]**	**Total Regional Costs[2]**
ESD Lighting	25.4	31.0	54.3	47.3
ESD Other	34.2	40.3	64.2	46.7
ESD Total	29.5	35.3	59.3	47.0
DEAP	7.7	22.6	11.0	26.6
Total	27.6	34.2	53.5	44.6

1 Cost includes all program costs paid by utilities and BPA.
2 Cost includes incremental measure costs and program costs other than incentives.

The levelized cost using the performance impact results are higher than those using the tracking system information. The primary cause of the difference is free ridership. Low realization rates for HVAC measures are also a small contributor to the higher levelized cost estimates.

Free ridership tends to affect the regional program cost much more than the total regional cost. In determining the total regional costs, the measure costs for free riders are not considered. Thus, free ridership will reduce both the cost and kWh savings for determining the total regional cost. In determining the regional program costs, however all incentive costs are considered regardless of to whom they were paid. Thus, free ridership reduces the amount of savings but does not have any affect on the program costs.

Incremental measure costs were estimated using information provided in the tracking system. Adjustments to tracking system measure costs were required because the program tracking systems sometimes contained *total* measure costs rather than *incremental* measure costs. Based on discussions with ESD utility staff about the program-imposed relationship between incremental costs and incentive levels, incremental cost limits were set to the minimum of the total measure cost, or a maximum of 2.5 times the paid incentive. For DEAP, incremental costs were set to an average to $0.21 per kWh, based on discussions with DEAP utility staff.

For ESD, lighting savings are more cost effective than savings from other measures from a regional program perspective, while lighting and nonlighting costs are similar from a total regional perspective. Levelized costs are lowest for DEAP. Costs are disaggregated by cost element in Table 3-7.

Table 3-7
Levelized Cost Disaggregation (Mills per kWh)

	ESD		DEAP	
Cost Element	**Regional Program Costs**[1]	**Total Regional Costs**[2]	**Regional Program Costs**[1]	**Total Regional Costs**[2]
Site cost per kWh saved	37.7	25.5	6.2	21.5
Utility fixed program cost1	7.3	7.3	4.9	4.9
BPA fixed program cost	14.2	14.2	–	–
Total	59.3	47.0	11.0	26.6

1 Cost includes all program costs paid by utilities and BPA.
2 Cost includes incremental measure costs and program costs other than incentives.

As the table indicates, DEAP costs are lower for several reasons:

- DEAP does not pay incentives—only energy modeling assistance is provided, thus site-based costs are lower;
- Fixed program costs are lower for DEAP; and
- There are no energy codes for new buildings in the DEAP area, thus much of the low cost savings often attributed to codes can be captured by DEAP.

Program Penetration Statistics

This subsection describes the program penetration. Program penetration statistics are presented on a building basis and a floor space basis in Table 3-8.

Table 3-8
Program Penetration: by Building

Area	Total Buildings	Participant Buildings	Program Penetration
ESD	3518	320	9%
DEAP	1357	158	12%
Total	4875	478	10%

As Table 3-8 documents, participation on a building basis was nine percent in the ESD area and 12 percent for DEAP. In total, 478 buildings were involved in the programs out of a total of 4,875 buildings in all program areas. The nine percent building participation rate for ESD compares to the goal of 15 percent set by BPA for the ESD program.

Table 3-9
Program Penetration: by Floor Space

Area	Total Floor Space (million sq. ft.)	Participant Floor Space (million sq. ft.)	Program Penetration Rate
ESD	32.1	10.6	33%
DEAP	8.0	3.5	44%
Total	42.1	14.1	34%

Program penetration by floor space paints a different picture, however (Table 3-9). On a floor space basis, the participation rate is 34 percent, with 44 percent in Idaho Power's area. The penetration rate on the floor space basis is much higher than on a building basis because the largest buildings were much more likely to participate.

4

DISCUSSION OF METHODOLOGY APPROACH

A primary objective of this project was to develop and demonstrate a method of measuring the performance impacts of commercial new construction programs. This section provides discussion on several methodological issues. This section is designed to provide insights for those who conduct performance measurements on commercial new construction programs.

This approach was effective in identifying net impacts from the program and producing an estimate of program penetrations. The on-site surveys and engineering analyses were valuable in assessing the comprehensive efficiency levels of each building. The use of the realization rate model was critical for ensuring that the engineering estimates where consistent with the billing data. The efficiency level models were successful at producing estimates of what the efficiency levels of the participating buildings would have been in absence of the program.

In this project, it was demonstrated that the use of bill comparisons or billing analysis is not effective for assessing the impacts of new construction programs. Controlling for building size and building type falls short of the many factors that must be accounted for in a billing comparison. Billing data does serve an important role in the approach, however, through the calibration of engineering estimates of energy use.

The approach involved the development of energy use estimates for all buildings under two conditions: 1) as-built and 2) reference. This approach allowed for accounting for differences between participant and nonparticipant buildings in a straightforward manner. The percentage difference between the reference case energy use and the as-built energy use provides a measure of the efficiency level that was installed. Comparing average efficiency levels across participants and nonparticipants provided a better indication of the program impacts than simply comparing energy use per square foot across these two groups.

This approach also has the added benefit of picking up some aspects of spillover and rebound effects. This approach does not simply focus on the measures for which incentives and recommendations were provided. All equipment and characteristics are considered in producing the efficiency level indexes. Therefore if a participant installs additional measures outside of the program, the effect of these measures will be accounted for. Short-term rebound effects are accounted for by the realization rate model that permits the calibration to be a function of the installed efficiency level.

Market transformation is an ever increasing issue in evaluating programs. The goal of a new construction program is to change the behavior of the building industry. It is possible that the program can have an impact on all builders whether they directly participate or not.

The method potentially suffers from the assumption that market transformation effects of ESD and DEAP are negligible. Because 1991 and 1992 were the first two years of these programs, however, the likelihood of significant free drivership was thus reduced. It is possible that a few free drivers were created by making recommendations to builders who did not choose to participate.

It is important to differentiate between market transformation effects from previous programs and building code and the market transformation effects of ESD and DEAP. All programs and standards are likely to effect market behavior. Previous programs such as Energy Edge and building codes have significantly transformed the market.

The approach is designed to measure the incremental impacts of ESD and DEAP above and beyond the transformation effects of previous activities. Only those market transformation effects that are due directly to the offering of ESD and DEAP will potentially bias the impact results from this study. The effect of free drivers for ESD and DEAP was concluded to be not significant, given the short time frame in which these programs have been offered.

Although the overall approach was found to be effective at determining net impacts, several aspects of the project provided significant challenges. Discussion of issues involving the sample frames, billing data, data collection, and the engineering analysis are provided in the remainder of this section.

Sample Frame for Market Penetration Assessment

Considerable time was spent on this project exploring appropriate methods to estimate the market penetration of the programs. Several issues needed to be addressed before a market penetration estimate could be produced. It was determined that a trade-off was required between a comprehensive definition of market penetration and the ability to develop a sample frame that could be used to measure market penetration.

Two conclusions were reached through the experiences. First, the lack of a new construction market tracking system for the region limited the ability to accurately measure program penetration. Although the costs of tracking the new construction market can be high, the benefits over and above the ability to measure penetration is likely to outweigh the costs.

Second, developing a comprehensive and accurate definition of program penetration that can be measured in a cost-effective manner probably is not feasible. One must settle for a measure of penetration, which is an indicator of penetration. The reasons behind this limitation involve the scope of the programs as well as the lack of a market tracking system.

Fortunately, a comprehensive and accurate definition of program penetration is probably not needed. Program penetration is simply an indicator of the success of the program. Knowing the exact program penetration is not significantly more useful than knowing an approximate level of penetration. It appears that the best estimate of market-penetration is one that can be obtained for a relatively low cost.

In addition to measuring program penetration, tracking the new construction market can be beneficial for several reasons. A new construction database allows for the development of a sample frame that can be used to research baseline construction practices. Knowledge of the baseline is valuable for the planning of DSM and other marketing activities. A tracking database provides information that can be used to market programs such as ESD. Information on new buildings will be very valuable in a more competitive industry as energy service providers explore new products and services that can be offered to the new construction market. Finally, it is likely that many companies and organizations outside the energy industry would be willing to pay for information on the new construction market.

BPA has explored possible data sources for developing a commercial population database. This database also could serve as a new construction tracking system. New construction data from Dodge or tax assessor data from Metroscan are both possible sources for building such a tracking system.

Market penetration is usually defined as a ratio. Given the interest in measuring program penetration, the numerator of the ratio would be defined as the size of the market that participated in the program. The denominator of the ratio could be the size of the market that was eligible for the program. Size could be defined as the number of buildings or the amount of floor space. A comprehensive definition of program penetration would include all participants in the numerator of the ratio and all "eligible" buildings in the denominator of the penetration ratio.

The ESD new construction program was not just targeted at new buildings. For many utilities, older buildings undergoing a major remodel also were eligible for ESD. In addition, buildings that had been built before the program years of interest but were being "built-out" during the program years might also be participants of the ESD.

It is not a simple matter to determine the amount of floor space or buildings that participated in the program. The program tracking systems provided by the utilities contain records for each participant. A participant, however, can reflect a building, several buildings, a portion of a building, or just the exterior areas of a building. It was found that one building could have two or more participant records that reflect different phases of construction of different measures.

Determining the size of the entire eligible market for these programs is a very expensive task. A survey could be done on a sample of all buildings to determine whether the building fell into one of the groups eligible for the program. This assumes, however, that a sample frame of all commercial buildings could be developed.

Given the high cost of estimating the size of the entire eligible market, it might be better to focus simply on estimating penetration for the new building market. If the remodel and build-out buildings are not included in the denominator of the penetration ratio, a choice must be made whether to include remodel and build-out participants in the numerator. Removing these participants from the penetration analysis could result in a reasonable estimate of market penetration for new buildings. The removal of these participants could only be done after surveying the buildings, however, because most tracking systems did not provide information to classify the buildings into one of the three eligible groups.

For this project, market penetration was defined in a simple yet imperfect manner. Market penetration of buildings was defined as the number of all participants divided by the estimated number of new buildings that were constructed during 1991 and 1992. The market penetration of floor space was defined as the total floor space of all participating buildings divided by the total floor space of new buildings.

The number of participants was taken from the program tracking systems obtained from the various utilities. The floor space of participants were obtained through the on-site surveys. The floor space of the entire building was considered regardless of the scope of the measures that were installed. Sample expansion weights were used to estimate the total participating floor space from the floor space of the sampled sites.

The estimates of the total new construction market was developed from a combination of sources. For SCL, a list of new buildings along with their floor space was obtained from the City's Land Use Department. Idaho Power developed and provided a new construction database which also contained floor space amounts. TPU provided a database of new buildings with floor space amounts constructed from Metroscan data and billing data. Puget Power provided an extract of their billing system, which contained approximately 3,000 accounts that were coded as new buildings. The Puget data did not contain floor space estimates. Because this data reflects electric meters and not buildings, account grouping of meters to buildings was required. The estimate of new construction floor space for Puget was obtained by surveying a sample of the new buildings.

The attempt to locate a list of new buildings for the other ESD areas that were not in SCL, TPU, or Puget's service areas was not successful. Estimates of total commercial floor space by year was obtained from Dodge on a county basis. An estimate of the total floor space additions for the "other" ESD areas was developed by assuming a one percent building decay rate and by selecting the building stock of appropriate counties. Care was taken to ensure that the areas served by SCL, TPU, and Puget were not double counted.

The most cost-effective solution for estimating program penetration of new construction programs involves developing a new construction market tracking system. This database should track all new buildings and include the date of initial occupancy as well as the total floor space.

The participant tracking system should be set up on a building basis, if possible. In addition to the standard measures, savings estimates, and cost data, affected floor space estimates would also be useful. If only the exterior of the building is affected by the program, the total floor space of the building should be noted along with an exterior only indicator. Each building should be denoted as either a new building, build-out, or remodel. Ideally, there should be linkage between the new participant buildings and the buildings in the new construction tracking system.

One further issue involving the definition of buildings and participants is determining the date that the building was constructed. Several cases were found in which one source stated that the building was built in 1992 and another source stated that the building was completed in 1993. Nearly 20 buildings built in 1992 were initially defined as nonparticipants that were later found to be in the 1993 participants tracking system. If this error went undiscovered, the estimates of non-program induced efficiency would have been biased upward, therefore biasing the net program impacts downward.

It is probably wishful thinking to hope that the dates could be defined in a consistent manner. Therefore, it may be necessary to examine the time frame for participants and new buildings extending at least one year before and one year after the time period of interest. This must be done to ensure that buildings are not mis-coded as nonparticipants simply because of inconsistent completion dates across data sources.

Grouping Multiple Meters at a Building

Few utilities have effectively addressed the problem of grouping accounts. Most utilities tend to track meters in the billing system and have not been concerned about grouping meters together that serve the same building or customer.

There are several benefits to grouping meters into buildings, customers, or both. Although the concept of meters is sufficient for billing purposes, market and research activities are often done at a customer or building basis. In a competitive industry, one is better off understanding the entire load of a customer rather than the load of one of the customer's meters.

The impacts of DSM programs do not often show up on one meter. In this project, the goal was to calibrate survey and engineering estimates for a building to the billing data. If the accounts were not all gathered, then the calibration would produce biased results.

Although considerable effort was spent in identifying all meters at each building, there is still some doubt for several buildings. All electric meters were meant to be identified during the on-site survey, but in many situations, the meters were not accessible. The staff at the utilities had limited success in identifying additional meters when the engineering estimates were very different than the billing data that was received.

The optimal solution is for utilities to become proactive and address this issue on an ongoing basis. Considerable effort and money has been spent over the last 10 years on finding ways to get around the problem for research and evaluation applications. Perhaps the possibility of retail competition will provide utilities with the justification to invest in developing and maintaining a building-/customer-based information system where meters are grouped together.

On-site Surveys: Ensuring Quality Data

The primary goal of the on-site surveys was to provide site-specific data that would be used in engineering algorithms to produce site-specific end-use estimates of electricity use. Experienced energy surveyors were hired to collect a large amount of detailed data on the building, equipment, and operation of the equipment.

Several quality control activities were established to supplement the experience of the surveyors. These activities included initial clerical review of the surveys before keypunching, a technical review of the data by the engineering staff after keypunching, and comparison of engineering estimates of energy use to billing data.

Although the quality control process eventually resulted in high quality data, several iterations were required before this was achieved. The process relied on experienced surveyors and computer review of the data and results. A number of aspects involved in the data collection process could have been improved, based on experience. Several activities for this project were not implemented early enough in the project. Too much emphasis was placed on simplifying the data collection process. Hence, the later stages of the project were too much relied on to ensure consistency and fix problems. Below, a number of suggested improvements are discussed.

First, the survey was designed by project survey staff and engineering staff. The survey was designed to be a flexible, easy-to-use instrument. Not enough attention was directed to creating an instrument that was easy to keypunch into a database, however.

Surveyors were given several options for recording data, such as operation schedules and assigning equipment inventories to various spaces in the building. This flexibility was provided to reduce the time spent by surveyors filling out the forms. The time savings were more than offset, however, by the added time needed for editing surveys, keypunching, and the analysis portions of the project. In hindsight, too much flexibility was given to the surveyors in filling out forms.

Technical review of the surveys was performed after the surveys were edited and keypunched. Once again, in hindsight, the engineering staff should have been reviewing the surveys within a day or two after they were completed. This process would have provided a means to provide feedback to the surveyors and would have allowed for a more effective design of the survey editing and analysis tasks.

It is likely that too much detailed data was attempted to be collected for each site. Too much of the data collection budget was directed toward the surveyor being on-site and not enough was spent conducting technical reviews and ensuring data consistency. Although reducing the amount of data collected would appear to reduce the accuracy of the site-specific engineering estimates, it is not clear whether more data means greater accuracy. In future projects, less detailed information would probably be collected. This would mean that more assumptions would be required for the engineering analysis, but it would also free some of the budget to ensure that the data that was collected is of maximum usefulness.

Aligning Data Collection and Engineering Methods

One goal of the project was to develop a low-cost approach to developing site-specific engineering estimates of electricity use. The approach was to collect site-specific data but avoid the cost of performing site-specific analyses of energy use. A set of simple algorithms was developed to turn the detailed survey data into energy use estimates.

The simplified engineering analysis did not proceed as smoothly as was hoped. The approach initially was designed to require survey data being in perfect condition with all fields completed. The flexible aspects of the data collection project are more consistent with a site-specific analysis process.

For example, the surveyors provided clarifying notes on the survey form when they thought that additional information would be useful for the engineering analysis. The clarifying notes were not easily incorporated into the databases nor into the structured engineering algorithms. The notes were reviewed if and only if the engineering estimates were inconsistent with the billing information or program tracking system data.

In addition, there were many cases in which information was not accessible or feasible to collect. The surveyors had a limited amount of time on-site and they needed to use their judgment on how to best spend their time on-site.

It is still believed that a simplified engineering approach can be used to produce reliable estimates of energy use. Some modifications to the process would have likely reduced the number of revisions required to be made, however. These modifications would include:

1. Performing technical review of all surveys before developing algorithms;
2. Developing default values and algorithms if survey data is missing;
3. Identifying sites for which simple algorithms will not be effective and applying a site-specific approach; and

4. Spending more effort on up-front and intermediate data quality assessment rather than back-end review of engineering estimates.

Comprehensive Efficiency vs. Measure-based Impacts

Performance impacts that rely on engineering analysis can be addressed from two different perspectives: a measure substitution perspective or an overall efficiency level perspective. In a measure substitution perspective, energy use is estimated with and without a specific measure installed as part of a program. In an overall efficiency perspective, the efficiency of an entire end-use system is compared to what the overall efficiency would have been if no program had existed.

It was thought, going into this project, that a measure-based approach was not appropriate to assess a new construction program. Usually, a customer can use several competing methods to achieve energy savings. For example, a customer can achieve lighting savings by operation controls, efficient ballast and lamps, or by installing a more efficient light source. HVAC savings can be achieved through shell improvements, system efficiency, or control measures.

Customers may make trade-offs in which they install certain measures so that they do not have to install other measures. It is also possible that a spill-over effect occurs in which customers who install program measures also install other non-program equipment that improves their overall system efficiency.

The approach for the project was to assess the overall efficiency of systems rather than the impacts of given measures. The efficiency level of each end use and building was estimated relative to a reference case situation that was also building-specific. Models that provided estimates of how the program impacted the overall efficiency levels that were installed were developed.

The advantage of the efficiency level approach is that it effectively deals with the issues of competing measures and spillover in determining net energy savings from the program. The disadvantage of this approach is that it does not provide measure-specific estimates of gross savings that can be compared to initial tracking system estimates on a measure-by-measure basis.

The advantages of the overall efficiency approach are believed to outweigh its disadvantages. Measure-specific studies could still be performed for certain measures if this information were required. The measure substitution method creates the potential for biased estimates or at least significantly complicates the modeling process.

Impacts of VSD and Control Measures

The approach tended to work very well in assessing the impacts of measures that involved simple efficiency improvements. The approach was less successful, however, in measuring the impacts of control measures and variable speed drives.

The VSD impacts were obtained primarily from prototypical DOE-2 simulations. Site information generally was used to scale the percentage savings of VSDs obtained from the DOE-2 results.

For control measures, average assumptions regarding the percentage reduction in full load hours that would occur from various controls were typically used. The site information again was used to determine the energy use to which the percentage was applied.

The savings from VSD and control measures can vary greatly across sites. Using average assumptions and prototypical models is a low-cost approach, but it may not reflect the specific application very well.

The engineering savings for VSDs were about half of what was assumed in the tracking system. The savings for VSDs were further reduced through the realization model which found that the engineering estimates for cooling and ventilation tended to be high across all levels of system efficiencies. There were no major systematic differences between the engineering estimates of savings from control measures and those that were identified in the tracking system.

Although the estimates of VSD impacts are reasonable, the discrepancies between the tracking system estimates and the final estimates do raise some concerns. Given that the simple approach potentially does have some shortfalls in assessing VSDs, further, more detailed analysis may be warranted. The more detailed analysis could involve site-specific simulation modeling or some monitoring of the affected motor loads.

5

DATA COLLECTION

This section provides details regarding the sample design and data collection activities. A good portion of the effort in this performance impact was directed toward these two tasks. Developing sample frames for the new construction market was challenging. On-site surveys of new commercial buildings were used to obtain most of the building data for this performance impact.

The sample design for this project needed to address several research objectives. The sample design that best serves one research objective often will not best serve a second objective. Given this situation, a design was developed to address all of the research objectives well, but not to address any single objective in an optimal manner.

In this discussion of sample design, population and sample summary statistics are presented. Each of the sample frame sources that were considered are reviewed and the rationale behind the selected sample design is provided.

Data collection presented typical challenges. The data collected needed to support the estimation of electricity use by building and end use. The data collection needed to provide information to determine the "efficiency level" of each building end use. The survey data needed to collect various types of information regarding the operations within the buildings.

The data collection section focuses on the survey design issues and data quality issues. An outline of the protocols used for site recruitment and data collection is provided. This section explores the trade-off between allowing surveyors flexibility to save surveying time and having them follow strict protocols to potentially save time in the analysis downstream.

One project objective was to produce estimates of the penetration of the program in the new construction market. Estimates of program penetration are provided on a per-building and per-floor-space basis. A discussion of issues regarding the selection of the market penetration approach and potential biases is also provided.

The availability of lighting loggers from BPA allowed the research team to collect information to assess the error associated with the collection of lighting operation schedules. For all buildings, lighting operation schedules were estimated by the surveyor for each "group" of lighting fixtures. The lighting loggers results provide a means to assess if certain surveyors systematically under- or overestimated run-time hours. The lighting logger data gives an indication of the accuracy of run-time estimates from surveys.

Sample Design

The sample design for this project was driven by the research needs and by the availability of market information. The sample design needed to support the assessment of both net impacts and program penetration. The lack of a regional tracking system for newly constructed buildings caused the piecing together of a sampling strategy for the new building market.

A common sample design for new construction performance impacts involves a "choice-based" design in which a sample of participants and a sample of "similar" nonparticipants are selected. These two samples provide a means to assess the program impact on the overall efficiency level of the installed equipment and building shell characteristics. The two samples also provide the variation in overall installed efficiency level that can be used to determine the energy use associated with differences in the installed level of efficiency.

The above sample design does not provide a means to measure the overall market penetration of the various programs. To assess program penetration, it is necessary to estimate the total size of the new construction market. Determining program penetration can be straightforward if a database that contains all newly constructed buildings and clearly identifies the participants is available. Idaho power was able to provide a new construction database covering the areas where DEAP was offered. A new construction database for the ESD region did not exist.

Two options were considered for the sample design. One option involved selecting three samples: 1) participants, 2) similar nonparticipants, and 3) the overall new construction market. In the second options, only two samples are selected: 1) participants, and 2) the overall new construction market. The second option was selected for this study.

The second option, with only two samples, is a lower cost approach than the first option. The second option provides a sample of nonparticipants as a subset of the overall new construction sample. The nonparticipants in the second option, however, are not selected in a manner to be similar to the participants.

The two-sample design was selected because of budget constraints and because it was believed that the differences between the participants and nonparticipants could be controlled for using statistical modeling. Even if the nonparticipants were selected to be similar to participants, some "controlling" for differences would still be required.

Stratification of the participant and whole market samples were performed to reduce sampling error and to ensure that certain segments were represented sufficiently. For the ESD participants, sample stratification was based on the utility, affected end use, expected amount of savings, and completion date. For DEAP participants, space heating fuel, location, and building size were used to stratify the population into six segments. For the whole market sample, either square footage or electricity consumption were used to stratify the buildings by "size."

Stratification by size of the building or the amount of expected energy savings is useful in reducing sampling error. Because the expected savings are likely to be highly correlated with actual savings, stratification by expected savings will likely result in a lower sampling error for the purpose of estimating savings. Because of the interest in estimating penetration on a floor space basis, stratification by floor space also will result in lower sampling error when assessing program penetration.

For the ESD program, the participants were also stratified into two groups based on whether the building was built before or after July 1, 1992. It was suggested that the buildings built after July 1, 1992, may not have a sufficient series of billing data for use in the calibration process. It was decided to concentrate the sample on sites built before July 1, 1992, to avoid this potential problem as much as possible.

In the other BPA areas, several modifications were needed to the above sample design. A few local utilities did not want their customers surveyed and were excluded from the study. Also, a sufficient sample frame could not be developed for the whole market in these areas. An approach for these areas in which a sample of nonparticipants were gathered through leads from local utility contacts was used.

Sample Frames and Population Statistics

Based on the utility tracking systems, there were 331 commercial participants of the ESD program and 158 participants in DEAP during 1991 and 1992. Program records were obtained from each of the five sponsoring utilities. BPA provided an extract from their tracking database for the entire region. Seattle City Light, Tacoma Public Utilities, and Puget Power records were removed from this BPA database.

As discussed above, a stratified sample design was chosen to select the participants. The ESD participants were stratified by:

- Four sponsoring utilities;
- Four affected end-use segments;
- Two expected savings segments; and
- Two completion data segments.

The ESD population counts by these segments are shown in Table 5-1.

Table 5-1
ESD Population Counts

Expected Savings	End Use	Completion Date	Number of Participants: Puget	SCL	TPU	Other Areas	Total ESD
Large	Lighting Only	Before 7/1/92	6	1	0	2	9
Large	Non-lighting	Before 7/1/92	14	0	0	1	15
Large	Lighting & Other	Before 7/1/92	11	1	1	7	20
Large	Prescriptive Path	Before 7/1/92	0	0	0	0	0
Large	Lighting Only	After 7/1/92	3	1	0	3	7
Large	Non-lighting	After 7/1/92	5	0	0	0	5
Large	Lighting & Other	After 7/1/92	13	2	2	4	21
Large	Prescriptive Path	After 7/1/92	0	0	0	1	1
Small	Lighting Only	Before 7/1/92	17	7	8	19	51
Small	Non-lighting	Before 7/1/92	31	1	1	7	40
Small	Lighting & Other	Before 7/1/92	4	0	3	10	17
Small	Prescriptive Path	Before 7/1/92	0	0	0	17	17
Small	Lighting Only	After 7/1/92	33	8	6	16	63
Small	Non-lighting	After 7/1/92	16	2	0	4	22
Small	Lighting & Other	After 7/1/92	7	0	6	12	25
Small	Prescriptive Path	After 7/1/92	0	0	0	11	11
Total			160	23	27	114	331

For the DEAP participants, end-use information was not available in the tracking system. Also, the expected program impacts for each site were based on varying assumptions regarding baseline conditions and were negative numbers in some cases. The DEAP tracking system did provide information on building size, location, and heating fuel. It was decided to use these three pieces of information to stratify this population. The segments and population sizes are shown below in Table 5-2.

Table 5-2
DEAP Segments and Population Counts

Segment	Number of Participants	Total Floor Space
Large floor space - Electric heat	10	713,000
Small floor space - Electric heat	17	107,000
Large floor space - Gas heat	13	1,388,000
Medium floor space - Gas heat	19	566,000
Small floor space - Gas heat - Western region	50	385,000
Small floor space - Gas heat - Eastern region	49	326,000
Total	158	3,485,000

The sample frame for the new construction market was created from a variety of sources. Idaho Power was able to provide a database of all buildings built in their service area. This database contained key information such as account numbers, square footage, building type, and location. IPC also provided a database of DEAP participants with account numbers. Thus the DEAP participants in the new construction database could not be identified.

For the ESD program, a single database of new construction activity for the entire region did not exist. In past performance impacts of new construction programs for single utilities, billing records were used to create a sample frame. More than 20 utilities were part of the Energy Smart Design (ESD) program, however, not to mention the many more utilities that did not participate in the region. Even if the non-sponsoring utilities would have provided their billing records, many did not track in their billing records when a building was built.

Puget Power provided an extract of their billing database. The observations in this extract reflected a single billing meter and building. The project team aggregated these meters into buildings using an iterative matching method that involved various fields in the database such as name and address. Floor space values for each building were not available for size stratification. Electric use was available for the previous year, however, and was used as a proxy for building size.

Tacoma Public Utilities provided a database of new buildings in their service area that they created from Metroscan and their billing records. The Metroscan data provided estimates of floor space for stratification.

Seattle City Light (SCL) went to another city department to obtain a database of new buildings. Seattle City Light staff matched these buildings with their billing records. This data also contained floor space values.

An interesting issue regarding Seattle City Light is that multifamily common areas were a significant portion of the new construction program activity. SCL treats this segment as a commercial building. The floor space value for a multifamily building is not always reflective of the common areas serving that building. It was decided to break out the multifamily common area "buildings" as its own sample segment.

The new building count for each utility and strata is provided in Table 5-3.

Table 5-3
New Building Count by Utility and Strata

Utility	Strata	Building Count	Total "Size" Covered
IPC	X-large	15	2.1 million sq. ft.
	Large	45	2.1 million sq. ft.
	Medium	140	2.2 million sq. ft.
	Small	300	1.4 million sq. ft.
	X-small	864	1.0 million sq. ft.
Puget	X-large	10	70 GWh
	Large	70	93 GWh
	Medium	220	66 GWh
	Small	700	45 GWh
	X-small	1393	13 GWh
SCL	Large	7	1.7 million sq. ft.
	Medium	22	1.1 million sq. ft.
	Small	41	0.4 million sq. ft.
	Multifamily	48	1.0 million sq. ft.
TPU	Large	8	1.2 million sq. ft.
	Medium	34	1.3 million sq. ft.
	Small	133	0.8 million sq. ft.

Sample Statistics

The budget for this project allowed between 350 and 400 sites to receive on-site surveys. A total of 368 sites were surveyed, 183 in the new market sample and 185 sites in the participant sample. Twenty-four of the market sample sites were participants. Thus, the final sample contained was 209 participants and 159 nonparticipants.

An initial sample design was developed to serve as a guideline for selecting sites. During the data collection process, some sites will refuse to be surveyed while other sites will simply prove not to be feasible to survey. Thus, it is likely that the initial sample allocation will not be followed exactly.

The initial sample allocation began with 200 of the 400 possible surveys to be allocated to the market sample. The remaining 200 surveys were allocated to the participant sample. The sample points then were allocated across the sponsoring utilities using the size of the market as a primary consideration. The points were further allocated across the various segments within each division to ensure that all end use segments were represented. The large sized strata tended to receive more data points relative to the number of cases in the population.

In general, the initial sample guidelines were followed. The final ESD participant sample distribution across the various sample strata is shown in Table 5-4 below.

Table 5-4
Final ESD Participant Sample Distribution

			Number of Surveyed Participants				
Expected Savings	**End Use**	**Completion Date**	**Puget**	**SCL**	**TPU**	**Other Areas**	**Total ESD**
Large	Lighting Only	Before 7/1/92	4	1	0	2	7
Large	Non-lighting	Before 7/1/92	11	0	0	1	12
Large	Lighting & Other	Before 7/1/92	10	1	1	4	16
Large	Prescriptive Path	Before 7/1/92	0	0	0	0	0
Large	Lighting Only	After 7/1/92	2	1	0	1	4
Large	Non-lighting	After 7/1/92	3	0	0	0	3
Large	Lighting & Other	After 7/1/92	8	1	1	2	12
Large	Prescriptive Path	After 7/1/92	0	0	0	1	1
Small	Lighting Only	Before 7/1/92	8	5	6	6	25
Small	Non-lighting	Before 7/1/92	14	1	0	0	15
Small	Lighting & Other	Before 7/1/92	2	0	5	4	11
Small	Prescriptive Path	Before 7/1/92	0	0	0	5	5
Small	Lighting Only	After 7/1/92	5	6	7	5	23
Small	Non-lighting	After 7/1/92	5	0	1	1	7
Small	Lighting & Other	After 7/1/92	5	0	3	5	13
Small	Prescriptive Path	After 7/1/92	0	0	0	4	4
Total			77	16	24	41	158

In a few cases, a site had two or more participant records. This occurs because sites are sometimes built in phases. The total number of ESD participant sites that were surveyed was 154.

The design for the DEAP participant sample was to evenly distribute the sample across the six strata. As shown in Table 5-5, the surveyed site were fairly evenly distributed. This design results in the favorable situation where nearly half of larger sites ended up in the sample, compared to about one-fourth of the smaller sites.

Table 5-5
Final DEAP Participant Sample Distribution

Segment	Number of Surveyed Participants
Large floor space - Electric heat	7
Small floor space - Electric heat	8
Large floor space - Gas heat	9
Medium floor space - Gas heat	10
Small floor space - Gas heat - Western region	10
Small floor space - Gas heat - Eastern region	12
Total	56

The market sites that were surveyed are provided by the sampling strata. The distribution of sampled sites across the strata is very similar to what was designed. Neyman Allocation was used to allocate sample points to the various strata within a utility. The use of Neyman Allocation results in a sample design that minimizes the sampling error of estimating the mean square footage for the overall new market within a utility area. Table 5-6 shows the final distribution of surveyed market sites.

Table 5-6
Final Distribution of Surveyed Market Sites

Utility	Strata	Number of Surveyed Market Sites
IPC	X-large	6
	Large	10
	Medium	10
	Small	8
	X-small	7
Puget	X-large	10
	Large	19
	Medium	12
	Small	12
	X-small	5
SCL	Large	5
	Medium	11
	Small	8
	Multifamily	8
TPU	Large	6
	Medium	13
	Small	6
Total		156

Of the 156 surveyed market sites, 24 were program participants. An additional 37 nonparticipants were surveyed from the "other BPA areas."

Sample Weights

After the surveys were completed, it was necessary to develop sample weights so that each data point would represent the appropriate number of sites. Sample weights are required because the probability of a site being selected is different across the various strata.

The weighting process is complicated by the fact that some participants were also in the market sample. The weighting process is further complicated by the fact that some participants were not in the new construction market sample frame for a variety of reasons. One primary reason was that some participants were not new buildings but were buildings that received extensive remodels. Also, because the participants and market sample frames came from different sources there was no guarantee that the project completion dates were consistent. In some cases, buildings in the 1992 market sample were later found to be in the 1993 participants database.

It was decided to compute one set of weights for the participants and one set for the market sample. From these two weights, an overall combined market weight was developed.

A participant weight was developed for each surveyed participant site. Weight cells were developed based on the utility, amount of expected savings, and completion date. The total expected savings for each weighting cell was calculated for the population and for the sampled sites. The weight for each cell was calculated as the ratio of the population total divided by the sample total. In the case of the DEAP program, floor space was used instead of expected savings. The weighting results for participants are shown in Table 5-7.

Table 5-7
Sample Weights for Participants

Utility	Strata	Sample Expected Savings	Sample Count	Pop Expected Savings	Pop Count	Weight
BPA	L A 6/92	1,146,556	4	4,788,584	8	4.18
BPA	L B 7/92	2,197,602	7	3,579,432	10	1.63
BPA	S A 6/92	394,083	15	1,259,834	46	3.20
BPA	S B 7/92	443,016	15	1,546,911	46	3.49
IPC	E-L	451,441	7	713,457	10	1.58
IPC	E-S	71,694	8	106,570	17	1.49
IPC	G-L	1,121,395	9	1,388,375	13	1.24
IPC	G-M	285,136	10	566,231	19	1.99
IPC	G-S-W	94,706	10	384,724	50	4.06
IPC	G-S-E	85,396	12	326,441	49	3.82
PUG	L A 6/92	8,638,149	13	10,589,016	21	1.23
PUG	L B 7/92	14,189,212	25	16,722,085	31	1.18
PUG	S A 6/92	552,053	15	1,911,500	56	3.46
PUG	S B 7/92	1,025,522	24	1,637,789	52	1.60
SCL	L A 6/92	471,855	2	1,772,809	3	3.76
SCL	L B 7/92	1,393,074	2	1,393,074	2	1.00
SCL	S A 6/92	193,850	6	392,158	10	2.02
SCL	S B 7/92	270,442	6	314,207	8	1.16
TPU	L A 6/92	662,826	1	917,075	2	1.38
TPU	L B 7/92	171,600	1	171,600	1	1.00
TPU	S A 6/92	299,251	11	305,707	12	1.02
TPU	S B 7/92	276,767	11	306,234	12	1.11

A market weight was developed for the market sites using a similar approach as the participants. The weighting cells were the same as the sample strata. For Puget Power, annual kWh was used to construct the weight. Floor space was used for SCL, TPU, and Idaho Power.

For the "other areas" of the ESD program, the nonparticipants needed to be weighted so that they represented that total population of nonparticipation in these areas. Information from the FW Dodge Building Stock Database was used to estimate the total amount of new construction activities in these areas. The participant data for these areas was used to estimate the total floor space that participated in the program. Subtracting the participating floor space from the total constructed floor space produced an estimate of the nonparticipant market size. The weight for the "other areas" nonparticipants was equal to the total floor space of nonparticipant market divided by the total floor space of the thirty-seven sampled sites.

A summary of the new market weights are provided in Table 5-8.

Table 5-8
New Market Weights

Utility	Strata	Market Sample Size	Market Sample Count	Market Pop Size	Market Pop Count	Weight
IPC	X-large	852,455	6	1,237,455	9	1.45
IPC	Large	522,420	10	2,090,421	44	4.00
IPC	Medium	184,119	10	2,202,704	140	11.96
IPC	Small	37,155	8	1,493,839	300	40.21
IPC	X-small	8,382	7	978,842	864	116.78
PUG	X-large	60,206,320	10	70,897,360	10	1.18
PUG	Large	30,359,991	19	93,380,020	70	3.08
PUG	Medium	5,938,952	12	66,330,470	220	11.17
PUG	Small	849,144	12	45,098,010	700	53.11
PUG	X-small	177,693	5	13,398,578	1,393	75.40
SCL	Large	1,081,333	5	1,747,206	7	1.62
SCL	Medium	543,253	11	1,053,532	22	1.94
SCL	Small	56,781	8	551,731	48	9.72
SCL	Multifamily	464,808	8	1,137,354	56	2.45
TPU	Large	954,991	6	1,208,121	8	1.27
TPU	Medium	509,516	13	1,265,579	34	2.48
TPU	Small	38,688	6	774,795	133	20.03
BPA	Nonparts	862,949	37	10,882,170	737	12.61

A combined weight was created for all market sample sites and for participants that were newly constructed buildings. The market weight was used for all nonparticipants, the participant weight was used for all participants. This combined weight was used to summarize the impact results.

Data Collection

The data collection activities for this project included the survey instrument design, site recruitment, on-site surveys, and data entry. The surveys were conducted by engineers with experience in assessing energy use of commercial buildings.

The first major step for the data collection process was the development of a survey. A team consisting of surveyors and engineering analysts was used to develop the survey instrument. The primary considerations for determining the elements to include in the survey were the importance of the element for predicting electricity usage and the likelihood of being able to collect the data in a reliable manner. A copy of the final survey instrument is shown in Appendix C.

The survey instrument focuses on several areas. The first section gathers various general building data such as overall size, number of floors, electric meter inventory, and an occupancy history. In the second section, the site is split into "space areas." Each space area is assigned to a space type (i.e. office, retail, common area). The size, occupancy schedules, and thermostat schedules for each space is also provided. The building shell data is provided in the Section 3. Sections 4 through 13 focus on the equipment and schedules and different end uses. The final section is used to verify that the program measures are present.

Sample lists of buildings were provided to the surveyors by strata. These lists contained up to two times the required number of sites. The sites were sorted in a random order. The surveyors would contact and recruit sites by starting at the top of the list and working down. The sites were recruited by the surveyors.

The surveyor would begin the data collection process by reviewing the program tracking data on sampled sites. The site visit would be performed using the following protocols:

1. **Customer Orientation:** Customer is briefed on the project purpose and the scope of activities.
2. **Initial Customer Interview:** Identify existence, location, and operation schedules of equipment.
3. **Physical Inspection:** Walk through the buildings to confirm equipment and gather additional details.
4. **Follow-up Customer Interview:** Review discrepancies and confirm schedules.
5. **Fill-in forms:** Surveyors often would use notepads to collect equipment information such as lighting fixtures as they walk from room to room. After leaving the site, the surveyor could

then combine the various fixtures into lighting fixture groups. The counts and average schedule for each fixture group would be entered into the survey form.

The average time spent by a surveyor per site was about seven hours. The time spent in Idaho was somewhat less due to Idaho Power staff assistance in recruiting the sites.

The data entry process of the project was quite involved due to the fact that the surveyors were allowed some flexibility in the way that they recorded schedules. Each survey was hand-edited to convert the surveyor responses to a consistent format. The data was entered to a Paradox database for which screens had been designed to follow the questionnaire layout.

The first phase of the quality control assessment involved a cross-reference examination of lighting inventory data and space data. It was checked to ensure that each lighting fixture group was assigned to a building space. In some cases, it was found that spaces were not assigned lighting equipment because they were unoccupied or were not accessible to the surveyor.

The connected load of each lighting fixture group was estimated using the number of each fixture type from the survey and estimated wattage by fixture type through a look-up table. The total connected load of an area could then be compared to each square footage of the area. If the lighting watts per square foot of a space did not fall within the norm, then both the square footage data or the lighting data could be checked for error.

Program Penetration Estimates

Estimating the market penetration of the program was one of the primary goals of this project. Throughout the initial phases of the project, considerable time was spent discussing how market penetration should be defined. It became clear that there was no perfect way to estimate penetration.

The participants for ESD and DEAP were not always new buildings. Buildings that are undergoing a major build-out or remodel could also qualify for these programs. The calculation of market penetration is complicated in that it is more difficult to estimate the size of the eligible market given the eligibility of build-outs and remodels to participate.

In estimating market penetration, two pieces of information are needed:

1. The size of the participating market; and
2. The size of the total market.

The important issue for market penetration is how the two markets are defined. The total market could be new constructed buildings, or it could include built-out or remodeled spaces. The participant market could be defined in a similar fashion. In general, it is preferable if the two markets are defined in the same way.

The limiting factor for assessing market penetration is identifying definitional concepts that can be measured in a cost-effective manner. It may be too costly to estimate market penetration using a preferred definition. The value of penetration estimates comes from comparing activity over time, however. It is probably more important to find a method that can produce penetration estimates in a consistent manner over time for a reasonable cost.

For this project, market penetration was defined in a simple yet imperfect manner. Market penetration of buildings was defined as the number of all participating buildings divided by the total number of new buildings. The market penetration of floor space was defined as the total floor space of all participating buildings divided by the total floor space of new buildings.

The market penetration estimates by sponsoring utility is shown in Tables 5-9 and 5-10.

Table 5-9
Program Penetration for Buildings

Area	Total Buildings	Participant Buildings	% Participants
Puget	2393	160	7%
SCL	133	23	17%
TPU	175	27	15%
ESD Other	847	110	13%
DEAP	1357	158	12%
Total	4905	478	10%

Table 5-10
Program Penetration for Floor Space

Area	Total MMSq. Ft.	Participant MMSq. Ft.	% Participant
Puget	11.6	4.8	41%
SCL	4.5	1.0	23%
TPU	3.3	0.8	25%
ESD Other	14.9	4.0	27%
DEAP	8.0	3.5	44%
Total	42.2	14.1	33%

The market penetration of floor space is much higher than that of buildings. This was caused by the situation in which the largest buildings tend to get more attention from utility staff and thus are more likely to participate. In fact, the 10 largest buildings in Puget's territory were all program participants. These 10 buildings account for more than 25 percent of the floor space but less than one percent of the buildings.

The number of participating buildings is equal to the number of records in the tracking databases. The square footage of participants is equal to the sum of the weighted square footage for the sampled participants.

The number of new buildings was obtained from the various sample frames of new buildings developed for the market sample. The tracking system estimates of square footage were used for the Idaho, SCL, and TPU buildings. The market sample survey data was used to estimate the total square footage for the Puget market. In the "other areas" of ESD, Dodge data was used to estimate the size of the total market.

Lighting Monitoring Results

As noted earlier, the availability of lighting loggers from BPA allowed the research team to collect information to assess the error associated with the collection of lighting operation schedules. For all buildings, lighting operation schedules were estimated by the surveyor for each group of lighting fixtures. The lighting loggers results allowed for the determination whether certain surveyors systematically under- or overestimated run-time hours.

As Figure 5-1 below portrays, on average, surveyors slightly underestimated the full-load hours for lighting. Surveyors estimated 11.4 hours per day compared to 11.9 hours per day obtained from the light loggers.

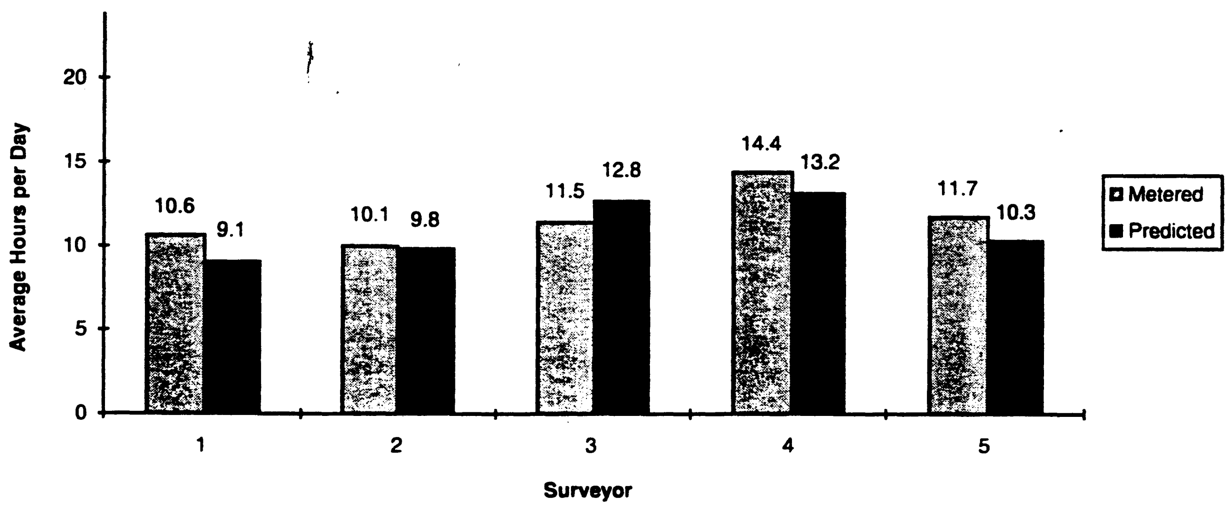

Figure 5-1
Lighting Monitoring Data

Figure 5-2 below shows a fair level of agreement between the metered data and surveyors' predicted values. Nearly 50 percent of the cases are predicted within two hours per day and about three-fourths of the cases were within four hours per day. Although the errors on a individual case basis can be large, the data does not show any signs of systematic error.

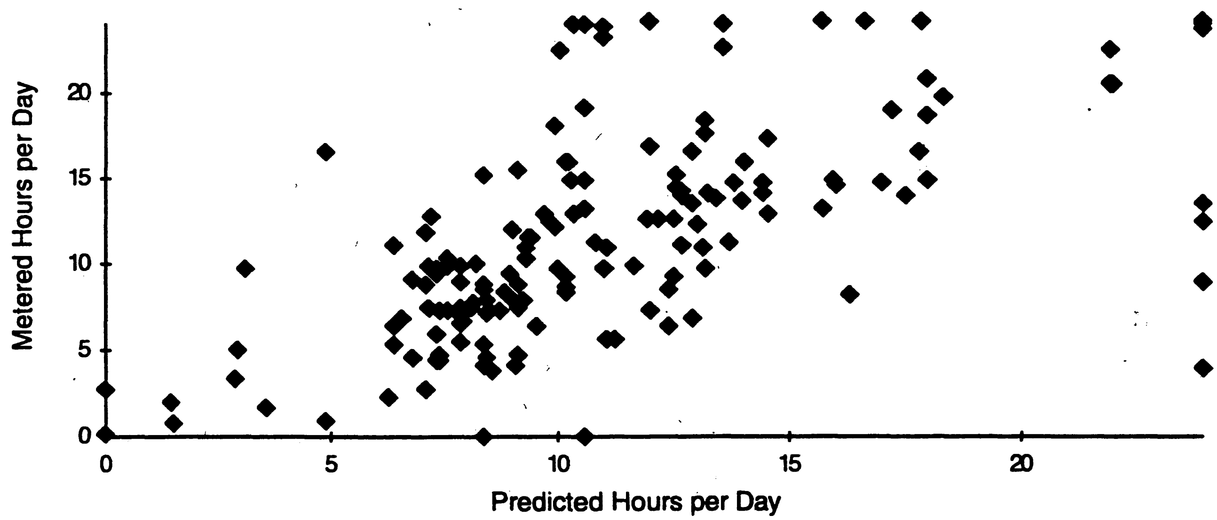

Figure 5-2
Lighting Monitoring Data

In summary, the results from the lighting monitoring is consistent with the results found in the realization rate model. Both approaches show signs of slight underestimation by the survey of operation hours for lighting. The monitoring results did not warrant that separate adjustments be applied to account for different surveyors with different biases.

6

ENGINEERING ANALYSIS

Introduction

Engineering calculations, calibrated to billing data, are a key component of the overall program evaluation methodology. The engineering calculations use the information about the buildings gathered during the on-site survey to calculate end-use energy consumption on a monthly basis. Estimates of monthly end-use energy consumption were calculated for all buildings in the study under two scenarios: as-built and reference. The monthly as-built energy consumption estimates were compared to monthly whole-building utility billing records for each site as a means of calibrating the engineering calculations. The reference case calculations were used to calculate gross energy savings relative to a fixed reference point for both program participant and nonparticipant buildings.

The objective of the engineering analysis was to provide estimates of monthly end-use energy consumption for all buildings in the study. The end uses defined for this project are as follows:

- **Lighting:** All interior and exterior lighting.
- **Equipment:** Electricity for miscellaneous plug and process loads, not including cooking, and refrigeration.
- **Heating:** Electricity used in space heating.
- **Cooling:** Electricity used by cooling system compressors and condensers (or cooling tower).
- **HVAC auxiliaries:** All electricity used for fans and pumps required for space heating, cooling, and ventilation, except condenser fans and pumps.
- **Water heating:** All electricity used for service hot water heating, excluding pool and spa heating. The calculation includes water heater and recirculation pump energy.
- **Cooking:** All electricity used for food preparation.
- **Refrigeration:** All electricity used for refrigeration.
- **Pools and spas:** All electricity used for pool and spa heating and pumping.

Because the objective of the analysis was to estimate end-use *electricity* consumption, only end-use equipment served by electricity was estimated. For example, if a food service establishment used both electric and gas cooking equipment, only the consumption of the electric equipment was estimated. If natural gas was used exclusively for space heating, the heating end use was not estimated.

Data Sources

The engineering calculations were based primarily on data collected during on-site surveys of buildings in the study. A total of 367 buildings representing both program participants and non-participants were surveyed. The survey form gathered detailed information about the building construction, end-use systems, and building operations. Information from the survey forms were entered into an electronic database. The survey information was used to provide direct inputs to the engineering calculations and to define typical building characteristics for the prototypical building analysis used to estimate the HVAC end use. In addition to the on-site surveys, lighting and HVAC systems were monitored for a sample of buildings in the study. The monitoring served to confirm and calibrate the survey data as well as provide information on building operation not observable during the on-site survey. When necessary, secondary data from standard engineering references were compiled to complete the information needed to perform the engineering analysis. Sources of these data included EPRI documents, ASHRAE handbook data, Washington State Energy and Ventilation Codes, Oregon State Energy Code, the Model Energy Code, and other references as noted in Appendix B.

As-built Analysis

As was described previously, engineering estimates were provided under two scenarios: as-built and reference. The as-built analysis calculated the monthly end-use energy consumption of the building as it was described in the on-site survey. Many of the algorithms used for the non-HVAC end uses were adapted from standard engineering equations, such as those described in EPRI (1993). For this project, an innovative approach to calculating HVAC energy consumption estimates was developed and implemented.

The engineering algorithms used in the project are summarized in this section. For more detailed information about the algorithms, data sources, assumptions, and default values used in the analysis, please consult Appendix B.

Lighting

The following equation was used to calculate as-built interior and exterior lighting electricity consumption:

$$kWh = units \times \frac{W}{1000} \times \left(1 - \frac{\%\ Burned\ out}{100}\right) \times FLH$$

where:

kWh	= monthly lighting energy consumption
units	= number of units of a particular fixture type
W	= connected load (W) assigned to each fixture type
% burned out	= percentage of lamps observed to be burned out during site survey
FLH	= lighting full-load hours

The unit counts and fixture type codes were taken from the site surveys. A standard connected load was associated with each fixture type code. The full-load hours were calculated from hourly values of percentage on time for each fixture type and day type reported by the surveyors.

Miscellaneous Equipment

The following equation was used to calculate electricity consumption for miscellaneous equipment:

$$kWh = units \times kW_{conn} \times RLF \times FLH$$

where:

kWh	= monthly equipment energy consumption
units	= quantity of individual pieces of equipment at each site
kW_{conn}	= nameplate load (kW) of each unit of equipment
RLF	= rated load factor (ratio of the maximum operating load to the connected load)
FLH	= equipment full-load hours

The unit counts and equipment unit connected loads were taken from the site surveys. A rated load factor was introduced to account for the discrepancy in nameplate verses actual running load inherent in certain types of equipment. The full-load hours were calculated from hourly values of percentage on time for each equipment type and day type reported by the surveyors.

Water Heating

The following equation was used to calculate electricity consumption for water heaters and service hot water circulation pumps:

$$kWh = \frac{UA(T_{set} - T_{room}) \times t}{\eta_{WH} \times 3413} + \sum_{j=1}^{3} \frac{GPD_j \times 8.3 \times (T_{use} - T_{cold})}{\eta_{WH}} \times n_j + \frac{hp \times RLF \times .746 \times OH}{\eta_{motor}}$$

where:

kWh = monthly water heating energy consumption

UA = overall water heater tank heat loss coefficient (Btu/hr–°F)

T_{set} = water heater set point temperature

T_{room} = average temperature of water heater surroundings

t = hours per month

η_{WH} = water heater efficiency

GPD = monthly average daily hot water consumption (gal/day)

T_{use} = hot water use temperature

T_{cold} = entering cold water temperature

n_j = number of days per month corresponding to each day type

OH = recirculation pump operating hours

hp = recirculation pump nameplate horsepower

RLF = rated load factor

η_{motor} = pump motor efficiency

The water heating equation accounts for standby losses from the water heater tank, hot water consumption, and recirculation pump energy. The average daily hot water consumption (GPD) was calculated from the building occupancy and standard hot water consumption values from the ASHRAE Handbook (ASHRAE, 1991). Tank heat loss coefficients were set at the values specified in the Washington State Energy Code. Water heater set point temperature, water heater size, hot water use temperature, and recirculation pump H.P. and operating hours were taken from the on-site survey. Entering cold water temperature was varied on a monthly basis according to the building location.

Cooking

The following equation was used to calculate electricity consumption for cooking equipment:

$$kWh = units \times \frac{kWh_{warmup}}{unit} + \left(\frac{kWh_{idle}}{unit} \times t_{idle}\right) + \left(\frac{kWh_{cooking}}{unit} \times t_{cooking}\right)$$

where:

kWh	= monthly cooking energy consumption
units	= size of each piece of cooking equipment (lineal feet, square feet, etc.)
$kWh_{warm\text{-}up}$	= warm-up energy
kW_{idle}	= equipment demand at idle
$kW_{cooking}$	= equipment demand while cooking
t_{idle}	= time spent idling (hr/day)
$t_{cooking}$	= time spent cooking (hr/day)

The cooking equipment equation considers warm-up energy, idle energy, and production energy consumption for typical electric cooking equipment. Equipment counts and size data were taken from the on-site survey. Standard values for warm-up, idle, and cooking energy were taken from food service literature, as described in Appendix B. Equipment operating hours were developed from meal schedules reported in the on-site survey.

Refrigeration

The following equation was used to calculate electricity consumption for refrigeration equipment:

$$kWh = units \times \left[\left(\frac{Case\ Load\ /\ unit}{\overline{EER} \times 1000} \times FLH\right) + \left(\frac{W_{aux}/\ unit}{1000} \times t\right) + \left(\frac{kWh_{def}}{unit}\right)\right]$$

where:

kWh	= monthly refrigeration energy consumption
units	= size of each refrigeration case (lineal feet, square feet, cubic feet, etc.)
Case load/ unit	= design case load (Btu/hr) per unit of case size
$\overline{EER}$	= monthly average compressor energy efficiency ratio (Btu/Wh)
W_{aux}/unit	= refrigeration case auxiliary energy requirements per unit of case dimension

FLH	= monthly compressor full-load hours
t	= hours per month
kWh_{def}/unit	= defrost energy per unit of case dimension

The refrigeration equation considers compressor energy as a function of the refrigeration load associated with each refrigeration case type and temperature; case auxiliary energy for lighting, fans, and anti-sweat heaters; and defrost energy. The refrigerated case descriptions and dimensions were taken from the on-site survey. Standard values of refrigeration load were applied to each case type and temperature. The compressor efficiency was assigned based on the case temperature and compressor system description. Standard values of auxiliary energy and defrost energy were assigned based on the case description supplied from the on-site survey.

Pools and Spas

The following equation was used to calculate electricity consumption for pool and spa heaters and circulation pumps:

$$kWh = SF \times \left[\frac{(Q/A \times t)_{cov} + (Q/A \times t)_{uncov}}{\eta_{boiler} \times 3413}\right] + \frac{hp_{pump} \times RLF \times .748}{\eta_{motor}} \times t_{pump}$$

where:

kWh	= monthly pool/spa energy consumption
SF	= pool or spa surface area (ft^2)
$(Q/A)_{uncov}$	= monthly average pool or spa heat loss per square foot when uncovered
$(Q/A)_{cov}$	= monthly average pool or spa heat loss per square foot when covered
t_{uncov}	= monthly average hours per day pool/spa uncovered
t_{cov}	= monthly average hours per day pool/spa covered
η_{boiler}	= pool/spa boiler efficiency
hp_{pump}	= pool/spa pump nameplate horsepower
RLF	= rated load factor
η_{motor}	= pump motor efficiency
t_{pump}	= pump operating hours

The pool and spa equation considers the energy associated with heating the water and operating the filter pump. The pool or spa surface heat loss is calculated from the water temperature, air temperature, and the presence of an insulated cover. Pool or spa surface area, water temperature, cover use schedules, pump horsepower, and pump operating hours were reported in the on-site survey. The air temperature for indoor pools and spas was also taken from the on-site survey. Air temperature for outdoor pools and spas was tabulated from monthly long-term average weather conditions at each location.

HVAC

The general approach used to estimate HVAC energy consumption was to construct linear regression models from the results of DOE-2 simulations of prototypical buildings. The HVAC equations were described in terms of the key drivers of HVAC energy consumption: lighting heat gains, heat gains from other internal loads (such as office equipment, cooking equipment, and refrigerated casework), outdoor ventilation air, solar heat gains, and overall shell conductance. The building prototypes used in the DOE-2 analysis were defined in terms of the distribution of HVAC system characteristics found in the on-site survey database. A unique prototype was developed for selected combinations of the following HVAC system characteristics:

- HVAC system type (single zone constant volume and central VAV system)
- Outdoor air control (fixed outdoor air and economizer)
- Constant volume fan control (continuous operation and on/off cycling with load)
- VAV fan control (discharge damper, variable inlet vane, and variable-speed drive)
- HVAC system operating schedule (10 hour/day and 24 hour/day)

The monthly energy consumption of each prototype was simulated using long-term average weather data (TMY) for Seattle, Yakima, Portland, Boise, and Pocatello. Based on the results of these parametric runs, a unique regression equation was developed for each climate zone for the building prototypes shown in Table 6-1.

Table 6-1
HVAC System Attributes Defining Building Prototypes

End Use	System Type	Fan Control	OA Control
Heating	Single zone	Constant Volume	N/A
	Single zone	Cycles	N/A
	VAV	N/A	N/A
Cooling	Single zone	Constant Volume	Fixed, Economizer
	Single zone	Cycles	Fixed, Economizer
	VAV	N/A	Fixed, Economizer
Auxiliaries	Single zone	Cycles	N/A
	VAV	Discharge damper, Inlet vane, Variable speed drive	N/A

The equations used to calculate heating and cooling load are:

$$kBtu_{heat} = \sum^{\text{all spaces}} \left[a_1 \frac{U_o A_t}{A_f} + a_2 \frac{L}{A_f} + a_3 \frac{E}{A_f} + a_4 \frac{OA}{A_f} + \sum_{i=1}^{N,S,E,W} \left(a_{4+i} \frac{A_{g,i} SC_i}{A_f} k_{o,i} \right) \right] \times A_f$$

$$kBtu_{cool} = \sum^{\text{all spaces}} \left[b_1 \frac{U_o A_t}{A_f} + b_2 \frac{L}{A_f} + b_3 \frac{E}{A_f} + b_4 \frac{OA}{A_f} + \sum_{i=1}^{N,S,E,W} \left(b_{4+i} \frac{A_{g,i} SC_i}{A_f} k_{o,i} \right) \right] \times A_f$$

where:

U_o = overall envelope thermal conductance, including walls, roof, and glazing (Btu/hr ft^2–°F)

A_t = total surface area of walls, roof, and glazing corresponding to U_o (ft^2)

$A_{g,i}$ = total glazing surface area per orientation i (ft^2)

SC_i = glazing shading coefficient for orientation i, adjusted for interior shading

$k_{o,i}$ = exterior shading adjustment for orientation i

A_f = floor area (ft^2)

L = lighting energy consumption (kWh)

E = internal heat gains (or losses) from plug loads, cooking equipment, refrigerated casework, and so on (kWh)

OA = outdoor air (CFM)

a = regression coefficients for heating load

b = regression coefficients for cooling load

The regression model is based on a simple zone-level energy balance. A similar form was used by Sullivan, et al. (1983), and Fireovid and Misuriello (1990). Once the regression equations were estimated, the response of the equations was compared to the DOE-2 simulations. Examples of these comparisons are shown in Figures 6-1 and 6-2. Overall, the simplified equations did a good job of predicting the DOE-2 simulation results.

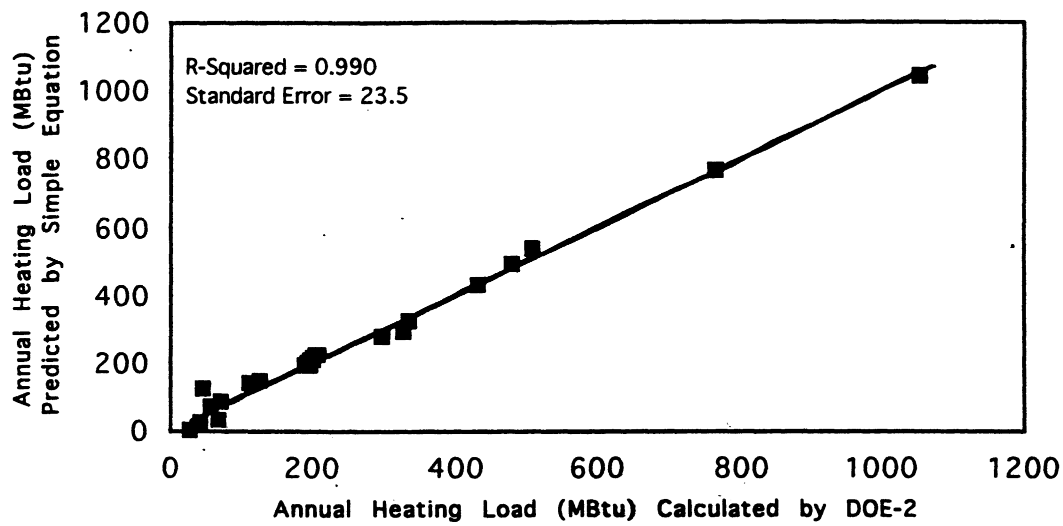

Figure 6-1
Comparison of Simplified Equation Heating Energy Prediction with DOE-2 Annual Heating Loads for Seattle: VAV System

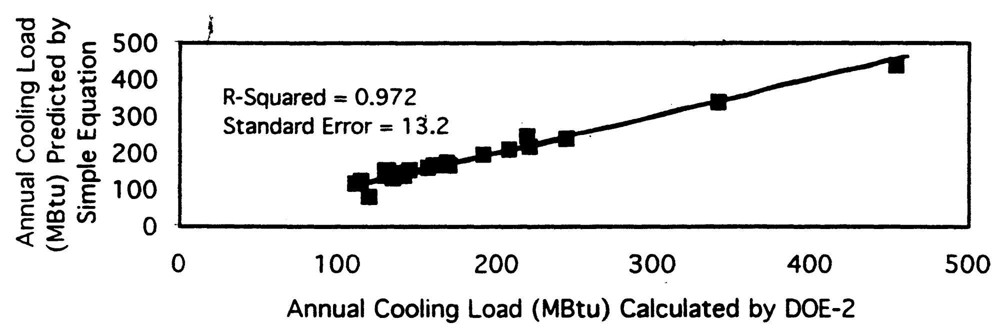

Figure 6-2
Comparison of Simplified Equation Cooling Energy Prediction with DOE-2 Annual Cooling Loads for Seattle: VAV System

The regression equations were used to estimate the heating and cooling loads imposed on the HVAC equipment. Monthly energy consumption was calculated from the estimated monthly heating and cooling loads and the average efficiency of the heating or cooling plant. The average heating and cooling system efficiency was calculated from the full-load system efficiency at rated conditions and an efficiency correction factor that considered the impact of part-load operation and ambient temperature on HVAC plant efficiency.

Using the heating and cooling loads calculated from the regression equations, the HVAC system rated efficiencies, and the efficiency correction factors, the monthly heating and cooling energy consumption was calculated as follows:

$$kWh_{heat} = \frac{kBtu_{heat}}{COP \times 3.413 \times f_{heat}}$$

$$kWh_{cool} = \frac{kBtu_{cool}}{EER \times f_{cool}}$$

where:

COP = heating system coefficient of performance at rated conditions

f_{heat} = efficiency adjustment factor for heating COP

EER = cooling system EER at rated conditions (Btu/W-hr)

f_{cool} = efficiency adjustment factor for cooling EER

Auxiliary energy consumption was calculated for building fans and pumps that serve space heating, space cooling, or ventilation services. These devices were partitioned into two general categories:

- Constant load, fixed operating schedule equipment, such as constant-volume fans and pumps. The energy requirements of these devices do not vary with heating and cooling loads.
- Variable load or variable operating schedule equipment, such as constant volume system fans that cycle with the heating and cooling equipment and VAV system fans. The energy requirements of these equipment change as the building heating and cooling loads change.

For constant load, fixed schedule equipment, the energy consumption was calculated from:

$$kWh_{aux} = \frac{hp \times RLF \times .746 \times OH}{\eta_{motor}}$$

Energy consumption and demand for HVAC system fans that respond to building heating and cooling loads were estimated similarly to heating and cooling:

$$kWh_{aux} = \sum^{\text{all spaces}} \left[c_1 \frac{U_o A_t}{A_f} + c_2 \frac{L}{A_f} + c_3 \frac{E}{A_f} + c_4 \frac{OA}{A_f} + \sum_{i=1}^{N,S,E,W} \left(c_{4+i} \frac{A_{g,i} SC_i}{A_f} k_{o,i} \right) \right] \times A_f \times \frac{\eta_{ref}}{\eta_{motor}}$$

where:

hp	= pump or fan nameplate hp
RLF	= rated load factor (ratio of in-situ demand to nameplate demand)
η_{motor}	= pump or fan motor efficiency
η_{ref}	= reference pump or fan motor efficiency
OH	= pump or fan operating hours
c	= regression coefficients for fan energy

Reference Analysis

The objective of the engineering analysis was to calculate monthly energy consumption for each site under as-built and reference case scenarios. Thus, a set of reference specifications was established for each end use affected by the program. Because the installed measures affected only the lighting, HVAC, and refrigeration end uses, reference specifications were developed for these end uses.

Initially, the reference building analysis was based on the July 1992 version of the Washington State Energy Code (WSEC). The provisions of the code applicable to the project were reviewed by staff at Puget Power, Seattle City Light, and Tacoma Public Utilities. Comments received from the utilities indicated that the WSEC was in line with the prevailing municipal codes in effect at the time of the construction of the buildings studied in this project. Thus, the WSEC formed the basis for the code-based reference. In addition, the Northwest Power Planning Council (NWPPC) provided data from a study of common practice in commercial new construction. The NWPPC data for Washington State were used to establish reference values for lighting power density for the space types common to both studies. For the code-based reference, lighting power density, building shell conductance, and HVAC equipment efficiency requirements from these sources were substituted for the as-built building characteristics.

As the project progressed, a different approach for determining the reference building characteristics emerged. Because the majority of the savings from the program were attained from the prescriptive, direct-rebate component of the ESD program, the code-based approach was modified, and a reference case based on a technology-substitution approach was adopted for lighting and building shell measures. The technology-based reference case substituted standard efficiency equipment of approximately equivalent output for the installed equipment. The final set of reference case specifications used in the analysis are described as follows.

Lighting

For each fixture in the lighting survey, an equivalent "standard-efficiency" fixture type was defined. When lighting controls were present, the reference case analysis assumed that the controls were not present. The conventions used to define the reference fixture type are shown in Tables 6-2 and 6-3. A complete listing of the lighting fixture wattage for as-built and reference case fixtures is provided in Appendix A.

Table 6-2
Lamp Reference Table

Lamp Type	Reference Lamp Type	Comments
Incandescent	Incandescent	No change
Compact fluorescent	Incandescent	Equivalent lumens
Quartz	Quartz	Unique lamp shape, no change
T12 Standard	T12 Standard	No change
T12 EE	T12 Standard	Equivalent number and length
T12 HO	T12 Standard	Equivalent number and length
T12 HO EE	T12 Standard	Equivalent number and length
T12 VHO	T12 Standard	Equivalent number and length
T8 Standard	T12 Standard	Equivalent number and length
T8 EE	T12 Standard	Equivalent number and length
T10 Standard	T12 Standard	Equivalent number and length
Halogen	Halogen	Unique light quality, not all configurations have an incandescent equivalent; no change
Sodium	Mercury vapor	Equivalent lumens
Mercury vapor	Mercury vapor	Equivalent lumens
Metal halide	Mercury vapor	Equivalent lumens

Note: Because of the unique shape and light quality of quartz and halogen lamps, the study assumed that these lamps would not provide a direct substitute for fixtures with other light sources (such as incandescent) in new construction.

Table 6-3
Ballast Reference Table for Fluorescent Fixtures

Ballast Type	Reference Ballast Type
Standard	EE Magnetic
EE Magnetic	EE Magnetic
Electronic	EE Magnetic
Hybrid	EE Magnetic
Dimmable	EE Magnetic

HVAC

The reference case HVAC energy consumption was calculated by substituting reference building characteristics for as-built building characteristics and re-calculating the HVAC energy consumption. The reference case HVAC energy consumption was affected by changes in internal heat gains due to changes in lighting and refrigeration equipment, changes in the building shell, and changes in the HVAC equipment characteristics. Internal heat gains from lighting and refrigeration systems were changed in accordance with the reference case specifications for these equipment. Building shell insulation R-values and glazing system characteristics were substituted with standard-efficiency systems, as described in Table 6-4.

Table 6-4
Reference Building Shell Characteristics

Building Component	Reference Specification	Comments
Opaque wall insulation	R-11	Conforms to prescriptive requirements of WSEC
Opaque roof insulation	R-30	Conforms to prescriptive requirements of WSEC
Glass type	Double pane, non low-e	Conforms to prescriptive requirements of WSEC, glass area and tint unchanged
Frame type	Metal w/o thermal break	

HVAC equipment and control characteristics were substituted with reference case assumptions, as described in Table 6-5.

Table 6-5
Reference Building HVAC System Characteristics

As-built System	Reference System	Comments
Heat pump	Electric-resistance heat	
Evaporative condenser	Air-cooled condenser	
Water loop heat pump system	Air-cooled, packaged single zone air conditioning system	Heating fuel for reference case same as as-built water loop backup boiler fuel (electric resistance or gas)
Setback thermostats	No setback	
Variable speed drive fan control	Variable inlet vane fan control	
Economizers	No economizer for units ≤ 65,000 Btuh cooling capacity (≤ 135,000 Btuh in ID)	In accordance with WSEC and MEC

HVAC equipment efficiencies for non-Idaho sites were changed according to the requirements of the WSEC. As there is no state-wide commercial energy code in Idaho, reference building HVAC efficiencies were taken from the 1986 Model Energy Code (MEC) in accordance with the Idaho Design Excellence Awards Program (DEAP) reference manual. Reference case motor efficiencies were established at values used by TPU in their motor efficiency program.

Refrigeration

The reference case refrigeration energy consumption was calculated by substituting reference refrigeration system characteristics for as-built refrigeration system characteristics, and re-calculating the refrigeration end-use energy consumption. Reference refrigeration system characteristics are summarized in Table 6-6.

Table 6-6
Reference Refrigeration System Characteristics

System Characteristic	Reference Specification
Case type	Open
Compressor type	Stand-alone
Anti-condensate heaters	Yes
Defrost type	Electric resistance
Condenser type	Air-cooled

References

Fireovid, J., and H. Misuriello, "ASEAM-2.1 Applications Using Parametric Studies and Multivariate Regression Techniques," Proceedings of the 1990 Summer Study, American Council for an Energy-Efficient Economy, Washington, DC., 1990.

Sullivan, S., S. Nozaki, R. Johnson, and S. Selkowitz, "Commercial Building Energy Performance Analysis Using Multiple Regression Procedures," LBL-16645, Lawrence Berkeley Laboratory, Berkeley, California, October, 1983.

ASHRAE; *HVAC Applications Handbook*; American Society of Heating, Refrigerating and Air-conditioning Engineers, Inc., Atlanta, Georgia, 1991.

EPRI; *Engineering Methods for Estimating Impacts of Demand-Side Management Programs, Volume 2: Fundamental Equations for Residential and Commercial End Uses*; EPRI TR-100984, V2; Electric Power Research Institute, Palo Alto, California, 1993.

7

REALIZATION MODEL

Introduction

The previous section described the use of refined engineering analysis to estimate the impacts of measures installed under the Energy Smart Design Program. Engineering estimates of site usage were developed for both participating and nonparticipating sites under two alternative scenarios with respect to the construction of the site:

- First, for the site as it was actually built and
- Second, for the site as it had been constructed to minimally comply with either building codes or other reference criteria.

Both sets of estimates were developed under specific assumptions about the actual operation of the site (e.g., operating hours, lighting schedules, etc.). For participants, the difference in energy usage between these two scenarios constitutes a preliminary engineering estimate of the gross savings associated with measures adopted by participants. These engineering estimates, however, are subject to two kinds of potential error: engineering biases (e.g., errors in assumptions with respect to hours of operation) and the dilution of actual energy savings resulting from rebound, or snapback effects.

Engineering biases most often result from the use of erroneous assumptions on occupancy schedules, operating schedules, thermostat settings, or other aspects of site behavior. Regardless of the care taken in establishing these assumptions, problems can be common in practice as a consequence of survey response errors. Rebound effects result from differences in behavior induced by the lower cost of energy services associated with energy efficiency. They can take a variety of forms, including differences in operating patterns (e.g., differences in thermostat settings) as well as variations in sizing criteria (e.g., differences in lighting intensities) or other tradeoffs made as part of the building design. While rebound effects are (arguably) not likely to be of major importance in the commercial sector, it is nonetheless important to recognize the potential for such effects when developing impact estimates for new construction programs.

In this section, we discuss the use of billing analysis to calibrate these engineering estimates to actual site energy usage. The resultant calibrated values of energy savings are traditionally called *realized savings*. The savings developed in this section as are referred to in this section as *gross* realized savings to emphasize that they do not take into account the possibility that some conservation activities conducted by participants would have occurred even in the absence of the program. The estimation of the net realized impacts of the program, which are adjusted for free ridership, is discussed in Section 2.

Performance Measurement Issues

The general method for adjusting engineering estimates for possible engineering biases and rebound effects involves calibrating estimates of program savings to observed differences in energy usage associated with different levels of energy efficiency. While the analysis of such differences is conceptually straightforward, it is plagued by a variety of practical problems. Some of these problems are discussed below.

The Lack of Pre-installation Usage Data

In the context of new construction programs, a study cannot rely on pre- and post-installation comparison of energy bills. Instead, the study is forced to focus on differences in consumption across buildings with different stocks of DSM measures (different levels of energy efficiency). The absence of "pre-measure" bills implies a more difficult impact estimation problem. In the case of retrofit analysis, many extraneous differences across buildings "fall out" in the process of taking differences in pre- and post-installation circumstances. In looking at the changes in energy consumption from a retrofit lighting program, for instance, the study need only control for the influence of changes in weather, occupancy, operating hours, etc., to isolate the impact of changes in lighting efficiency. In assessing the impacts of a new construction lighting program, however, the study must control for a far wider range of factors explaining differences in energy use levels across buildings. This expanded problem of statistical control calls for a very highly structured approach like the one ultimately used in this performance impact project.

Small Sample Sizes

Because relatively few new commercial buildings are constructed in a given service area in a given year and because of the cost of developing detailed on-site inventory data, utility-specific participant and nonparticipant sample sizes are severely constrained. Given the heterogeneity of commercial buildings, limitations on sample size can seriously handicap efforts to statistically control for other factors and isolate program impacts. This project was designed to collect information on a relatively large sample of sites; nonetheless, the sample size is still small enough to require the use of a structured hybrid statistical/engineering approach to the estimation of realized energy impacts. This approach adds structure in the sense that it embodies a wide range of site features in a few engineering estimates of end use consumption levels.

New Building Variability

Estimating impacts of differences in energy efficiency at a sample of sites is even further complicated by the inherent variability of new building loads. In their first few years of operation, new buildings may undergo a variety of changes, including dramatic changes in occupancy, HVAC system calibration and commissioning, changes in operating modes, and additions to equipment stocks. Such changes have two implications for the analysis. First, it necessitates the inclusion of variables reflecting these changes in the statistical models used to adjust engineering estimates (e.g., occupancy histories). Second, it adds further emphasis on the need for refined technology data and structured modeling techniques capable of explaining these variations.

Alternative Performance Measurement Methodologies

There are various means of estimating the energy impacts of new construction programs. Some of the more obvious options are reviewed below.

Direct Bill Comparisons

Perhaps the most obvious approach to estimating energy impacts would be to compare usage levels across participating and nonparticipating sites. For such simple comparisons to yield sensible estimates of energy savings, the nonparticipating sites would have to be chosen extremely carefully to mirror the participant group. That is, the comparison group would have to be a control group in a technical sense.

While it is possible in theory to develop a true control group, it would be extremely difficult in the context of new construction performance impact projects. The number of new buildings is typically relatively small, buildings tend to be very heterogeneous, and the probability of finding "twins" for a sample of participants is remote. Clearly, techniques that control for differences between participants and nonparticipants must be developed if comparisons are to be meaningful. Several statistical techniques for effecting such controls are considered below.

A second caution should be offered with respect to simple bill comparisons. Even with perfect control groups, differences in consumption between participants and nonparticipants will reflect the overall net impact of the program including two major elements: (a) the influence of the program on adoptions of energy conservation measures, and (b) the impacts of these measures on energy usage. While the combined impact is informative, it would be even more useful to have separate estimates of the two elements. That is, it is instructive to obtain information on adoptions of systems and measures, as well as information on how well various types of measures like lighting and HVAC DSM measures are performing. Techniques for isolating these effects are considered later.

Pure Engineering Approaches

A variety of engineering approaches are available for the assessment of new construction program impacts. These methods range from simple engineering algorithms (say, the kind that might be used to estimate savings from high-efficiency lighting) to the use of complex building simulation models like DOE-2 to assess HVAC savings. While these engineering approaches are logical and faithful to physical principles, they are also subject to error. This error may stem from faulty baseline behavioral assumptions, simplifications in physical relationships, or DSM-induced changes in behavior (sometimes referred to as snapback or rebound effects). As a result, engineering approaches are typically blended with other approaches in the performance measurement of new construction programs, and these hybrid approaches are explained in some detail below.

End-use Metering

End-use metering can be an important tool for the performance measurement of the savings from new construction programs. In general, metering is used in conjunction with other approaches for the purpose of estimating savings. For instance, metering can be used to refine engineering estimates of savings by calibrating estimates of connected loads, as well as by testing assumptions with respect to operating patterns. Because of the expense of end-use metering, it is generally prudent to leverage metering results through the development of combined estimators of usage and/or impacts. Leveraging can entail the use of formal and informal approaches. Some of these options are discussed below.

Pure Statistical Modeling Approaches

One performance measurement option is the use of refined statistical techniques to control for non-program differences between participants and nonparticipants. A specific option in this regard is the use of conditional demand analysis (CDA). CDA is a statistical means of decomposing whole-building energy usage into its end use components.

There are a number of ways to design a conditional demand model, distinguished primarily by the means of treating thermodynamic and other physical relationships (which form the core of engineering models). In highly structured CDA approaches, thermodynamic principles (e.g., heat-loss and heat-gain relationships) are embedded into the specification with unknown technical and behavioral parameters. The approach is useful because it imposes valid structure on the model.

Regression analysis is used to estimate the unknown parameters of the CDA model, although some parameters may be specified *a priori* on the basis of technical information. Once the parameters of the conditional demand model are estimated, the model can be used to compute estimates of the energy consumption impacts of measures covered by the program.

This approach offers an obvious advantage over simple bill comparisons. It directly controls for variations in site characteristics and other determinants of differences in energy consumption across participating sites. It also has a number of practical disadvantages, however.

- First, the effects of energy conservation measures on site usage can be complex and very difficult to estimate without considerable engineering structure in the model. In structured CDA specifications, engineering information is embodied in the model through the incorporation of thermodynamic relationships into the specification of the EUI function. It is difficult, however, to include relationships that are complex enough to accommodate the influences of a wide range of energy conservation measures.
- Multicollinearity is a chronic problem in the estimation of conditional demand models. In this context, the correlation of adoptions of individual conservation measures makes it very difficult to isolate the separate impacts of these measures with a freely estimated conditional demand approach.
- Conditional demand estimation typically requires large sample sizes. The samples generated in the course of a commercial new construction performance impact project are likely to be much smaller than needed.
- Because of the heterogeneity of commercial sites, the estimation of pure conditional demand models tends to be very difficult.

Hybrid Statistical/Engineering Approaches

As a result of the weaknesses of the approaches defined above, methods used to evaluate nonresidential new construction programs tend to be hybrid approaches using a mix of engineering, statistics, and metering. In general terms, mixed statistical/engineering approaches make use of statistical analysis to refine or adjust the engineering analysis of end use loads. These techniques are commonly used in the development of end-use load profiles, as well as in modeling of monthly and annual energy consumption. Although there are several variants of the mixed statistical/engineering approach, the basic approach would involve two steps:

- First, engineering estimates are developed for individual sites, including both participants and nonparticipants. These estimates could be based on building simulations or simple rules of thumb. In either case, the engineering estimates make use of the site characteristics as-built and operated. In general, the engineering estimates (*EE*) can be written as:

$$EE_{bet} = h_e(ECM_{be}, SITE_b, OPCHAR_{bet}, WTHR_{bt}, MRKT_t) \quad (1)$$

  where the form of the h_e functions represents the deterministic algorithms used to create the engineering estimates.

- Second, monthly billing data are obtained for the sites in question, and a regression is run to explain whole-building usage in terms of the preliminary engineering estimates. That is, the following regression is estimated:

$$E_{bt} = \sum_{e} \alpha_e EE_{bet} + \varepsilon_{bt} \quad (2)$$

  where E_{bt} is the monthly whole-building usage in month t, EE_{bet} is the engineering estimate for end use e in month t, and α_e is an adjustment coefficient for end use e.

From this point, two closely related options are available: the hybrid statistical engineering methodology (HSEM), and the statistically-adjusted engineering (SAE) approach. In addition, another similar mixed option called the Generalized Least Squares Mixed Estimation (GLSME) approach could be used. These specific options are discussed below.

The HSEM Approach. In the HSEM approach, the results of the above regressions are inspected and cases in which α_e differs appreciably from 1.0 are identified. Engineering assumptions relating to these end uses are then reviewed, and modifications are made. Note that the HSEM process uses the values of adjustment coefficients only as indicators of problems in the engineering algorithms. They are not used to transform estimated end use loads per se. In some HSEM approaches, a final step is taken to reconcile predicted and actual whole-building usage on a site-by-site basis. This essentially entails proportional scaling of some or all end-use estimates so that whole-building predictions are equal to actual values. Once the above steps are completed, the calibrated engineering model is used to simulate the impacts of energy efficiency on consumption. These simulation results are then used in the performance measurement of program impacts.

The Simple SAE Approach. In the simple SAE approach, the adjustment coefficients are actually used directly in the development of calibrated engineering estimates of end use consumption levels as well as savings from DSM measures. Thus, statistically adjusted estimates of the form:

$$AdjEE_{bet} = \alpha_e EE_{bet} \quad (3)$$

are used to assess the impacts of differences in assumptions with respect to the presence of energy conservation measures.

The Generalized Least Squares Mixed Estimation (GLSME) Approach. The GLSME approach is a more flexible form of the SAE method. The basic philosophy of GLSME is that both engineering priors and other information should be taken into account in the estimation process, but that there may be different relative levels of confidence in these estimates for different end uses. For instance, there may be an extremely high level of confidence in the engineering estimate of lighting loads, but relatively little confidence in space heating priors. The GLSME approach essentially involves the specification of weights on the engineering priors and statistical estimates, where the weights reflect relative degrees of confidence. The mixed estimation approach assumes that:

$$\alpha_e = 1 + v_e \tag{4}$$

where v_e is a random error term and where the expected value of $v_e = 0$. The higher the variance, the lower the confidence in the prior estimate of E_e (EE_e). The GLSME estimate of the end use load is then given by:

$$E_{bet} = [(c_e) + (1 - c_e)\alpha_e]EE_{bet} \tag{5}$$

where c_e is a weight that depends on the relative confidence placed on the engineering estimate for end use e. (The weight depends on the variance assigned to the random error term v_e. If complete confidence is placed on this estimate, then $c_e = 1$ and the adjustment coefficient would be equal to 1.0. If no confidence was assigned to the engineering estimate, then $c_e = 0$ would be set, in which case the adjustment coefficient would be equal to α_e.)

In the traditional versions of the HSEM, SAE, and GLSME approaches, the adjustment coefficients are constants, which implies that the degree of over-/understatement of end-use loads is constant. This assumption is unrealistic, however, and seriously affects the viability of these approaches. The use of constant adjustment coefficients ignores many of the key issues discussed earlier.

- First, they ignore variable occupancy. Unless engineering estimates are developed for each month under consideration, they will not capture the effects of variable occupancy. As these effects *will* be embodied in billing information, they will cause the true adjustment coefficients to vary over time and across sites as occupancy rates vary.
- Second, errors in engineering estimates may be correlated with other site features, weather conditions, or other factors.
- Third, they ignore the potential for behavioral changes leading to rebound effects. Constant adjustment coefficients imply that engineering estimates over-/understate uniformly across efficiency levels. If rebound occurs, however, pure engineering estimates will under-predict usage in *relative* terms for high efficiency cases. While it is virtually impossible to isolate these rebound effects from differences in engineering biases across efficiency levels, it is nonetheless important to allow for such variations in the realization rates.

The spirit of the mixed statistical/engineering approaches can be preserved in an alternative approach designed to overcome these problems: *the realization rate approach.* The recommended approach focuses explicitly on differences in consumption associated with differences in conservation stocks across sites. As such, it is tailored to the needs of the performance impact of new construction programs. The realization rate model is described below.

The Realization Rate Model

General Logic. The general logic of the realization rate approach (as applied to new construction programs) is illustrated in Figure 7-1. As shown, the model relies on two types of engineering estimates: estimates of end-use consumption under the scenario of minimal compliance with building standards and estimates of the savings expected from departures from strict compliance. The model also makes use of information on site characteristics (e.g., square footage), weather conditions, and occupancy characteristics that might affect the realization of the engineering estimates of baseline usage and DSM-related savings. The model produces a set of adjustment coefficients (or adjustment functions) that translate these engineering estimates into estimates consistent with observed energy usage and savings. These coefficients are called realization rates. As explained below, the realization rates on savings reflect the proportion of engineering-based savings estimates actually realized in the form of reduced site usage.

Model Specification. To derive the realization rate model, the analysis begins with the standard SAE specification:

$$E_{bt} = \sum_e \alpha_e EE_{bet} + \varepsilon_{bt} \qquad (6)$$

Rather than using a single set of engineering estimates for each site, two such estimates can be defined. The first set is based on assumptions reflecting the actual design and operation of the building. These are the standard estimates that would be used in the approaches described above. Refer to these estimates as $EEActual_{bet}$ to emphasize the use of actual as-built and as-operated assumptions in their development. This gives the following:

$$E_{bt} = \sum_e \alpha_e EEActual_{bet} + \varepsilon_{bt} \qquad (7)$$

As before, the presence of the adjustment coefficient reflects the possibility of general engineering bias. The model can be expanded by decomposing the engineering estimates into two elements:

$$EEActual_{bet} = EEBase_{bet} - [EEBase_{bet} - EEActual_{bet}] \qquad (8)$$

where $EEBase_{bet}$ represents an engineering estimate of usage under a reference assumption with respect to the presence of energy conservation measures. One option in this regard would be to let this estimate reflect minimal compliance with standards. (Note, as explained above, this is only a reference point for the realized savings analysis. The true baseline for the overall program performance measurement is the participant's usage in the absence of the program, and this may differ from the level associated with standards compliance.) The specification shown in (8) simply splits the engineering estimate into a baseline estimate and an estimate of the savings associated with the energy conservation beyond baseline levels. Substituting (8) into (7), the following is obtained:

$$E_{bt} = \sum_e \alpha_e \{EEBase_{bet} - [EEBase_{bet} - EEActual_{bet}]\} + \varepsilon_{bt} \qquad (9)$$

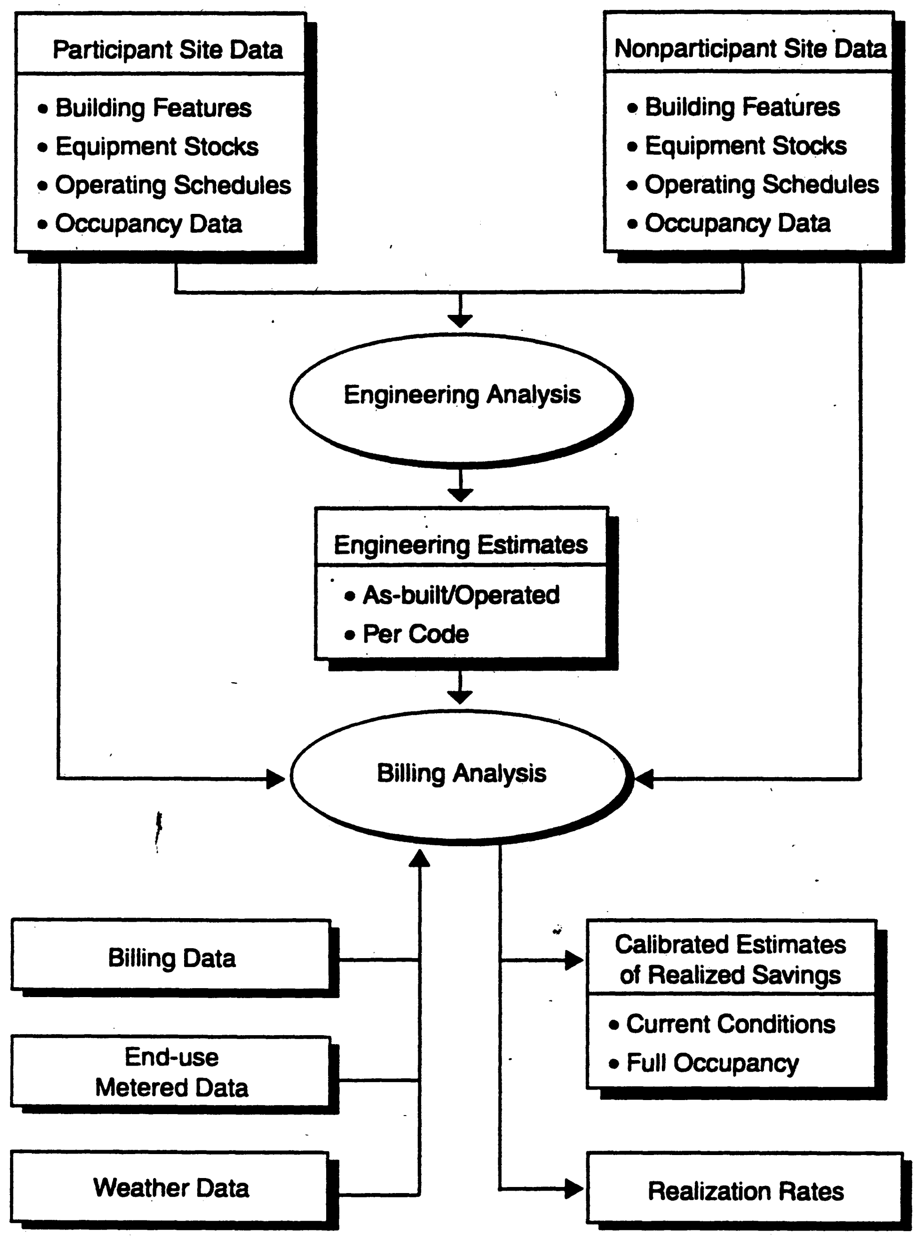

Figure 7-1
Realization Rate Model

Once the model is put into this form, possible modifications are apparent. First, the basic adjustment coefficient on the estimated energy savings should be allowed to be different from the adjustment coefficient of the baseline engineering estimate. Second, these adjustment coefficients should be permitted to vary across sites as conditions vary. One possible version of the revised model is as follows:

$$E_{bt} = \sum_e \alpha_e(X_{bt})\{EEBase_{bet} - \beta_e[EEBase_{bet} - EEActual_{bet}]\} + \varepsilon_{bt} \quad (10)$$

where β_e is an adjustment coefficient encompassing two phenomena: (a) the bias in engineering savings estimates *relative* to the bias in the baseline energy usage estimates, and (b) the presence of behavioral rebound. Note also that the overall adjustment coefficient ($\alpha_e(X_{bt})$) is assumed to be a function of relevant factors. These factors (indicated by the generic variable (X_{bt}) could include site characteristics, like occupancy rates, as well as weather, building category dummies, or other variables thought to affect the overall accuracy of baseline engineering calculations.

Use of the Model to Infer Realization Rates. Given this simple yet flexible framework, the end-use-specific realized savings associated with differences between baseline efficiency levels and the levels of efficiency found in the buildings covered by the analysis would be:

$$Realized\ Savings_{bet} = \alpha_e(X_{bt})\beta_e[EEBase_{bet} - EEActual_{bet}] \quad (11)$$

The associated realization rate can be defined as follows:

$$Realization\ Rate = \alpha_e(X_{bt})\beta_e \quad (12)$$

There are several points to note about this approach:

- It makes full use of engineering estimates under baseline and high-efficiency scenarios. By doing so, it allows for at least some level of rebound.
- It can be used to account for changes in realized savings over time as new building occupancy rates change, and would generate estimates of steady-state (full-occupancy) savings. For instance, (11) could be specified to include occupancy rates as a component of X_{bt}. Once the model is estimated in this form, it can be used to simulate the realized savings under full occupancy just by setting the occupancy rate variable equal to one for all affected buildings.
- It provides a convenient means of adjusting engineering savings for errors associated with weather conditions for weather-sensitive end uses.
- Realization rates derived for a representative sample of participants are applicable to other participants. Thus, these rates can be used to transform engineering estimates of overall gross program savings into calibrated estimates of realized savings.

Choice of Methods for this Project

Two methods of inferring savings were used in this project. The first involved direct comparisons of participant and nonparticipant energy intensities. The results of this comparison are discussed in the following subsection. The second entailed the development of a realization rate model.

These two approaches differ in many important respects, as will be discussed at length below. One relatively subtle difference is that the direct comparisons of intensities is an attempt to estimate net realized savings (with the comparisons of participants and nonparticipants intended to imply attribution of differences to the program), while the realization rate analysis is meant only to estimate gross realized savings experienced by participants. It will be necessary to complement the realization rate approach with another means of attributing gross participant realized savings to the program. This issue will be taken up in the efficiency analysis presented in Section 2.

Results of Direct Bill Comparisons

Introduction

This section presents a comparison of site energy intensities (i.e., energy usage levels per square foot at the covered site) for new construction program participants and nonparticipants. In what follows, the process used to compile and screen the data used in the analysis and present a detailed set of findings is described. These results constituted the first step in the assessment of program impacts. They should not be taken as particularly credible evidence of these impacts, however, as explained later in this section.

Data Compilation and Preparation

Before the development of energy intensity estimates, it was necessary for the project team to assemble energy usage data for sampled sites. Early in the project, billing records were requested from the participating utilities, and these records were sent to the analysis subcontractor. Survey data, including estimates of site square footage, were also provided to the analysis subcontractor. As soon as preliminary as-built engineering estimates of site usage were delivered by engineering subcontractor, the analysis subcontractor began the process of data screening. Building intensities (as derived from billing histories) were reviewed carefully for reasonableness and for consistency with engineering estimates of site intensities. On the basis of this review process, several apparent problems in the billing files were identified. In general, these problems related to missing and mismatched accounts. A second (and in some cases, third) round of requests for billing data was made. In most cases, utilities were able to resolve identified problems through the retrieval of records for additional accounts linked to the sites in question. Two types of problems persisted, however:

- In 11 cases, no billing records could be located for surveyed sites.
- In another 44 cases, accounts matched to the specific sites did not seem to reflect usage at these sites. Generally, it was possible to confirm the presence of a site/account matching problem. For instance, a few discrepancies were obviously the result of the matched account covering far more space than surveyed. In the absence of submetering, the billing records for these sites could not be used in the subsequent analysis. In other instances, surveyor comments pointed to the lack of correspondence between the coverage of the meters identified in

the course of the survey and the space actually surveyed. In a few remaining cases, judgment indicated that at least one account covering the sites in question was still missing. After one further round searches for additional accounts by utility representatives, billing data on a few accounts were deemed incomplete and they were left out of the realization rate analysis.

These sites could not be included in the building intensity comparisons shown below, nor will they be used in the realization rate analysis. They will, however, be used in the efficiency analysis, which does not require data on actual consumption.

Overall Comparison of Participants and Nonparticipants

Several bar charts depicting the comparison of participant and nonparticipant usage are attached. Figure 7-2 presents a comparison of participant and nonparticipant energy intensities by detailed building category. As shown, there is no systematic pattern evidenced by this comparison. Of course, some of the building category subsamples are very small, so these results might not be particularly meaningful. Figure 7-3 presents a more highly aggregated comparison, with offices, warehouses, and retail (all of which have relatively large samples) broken out and other building categories combined. Again, no clear picture emerges from the comparison of participants and nonparticipants.

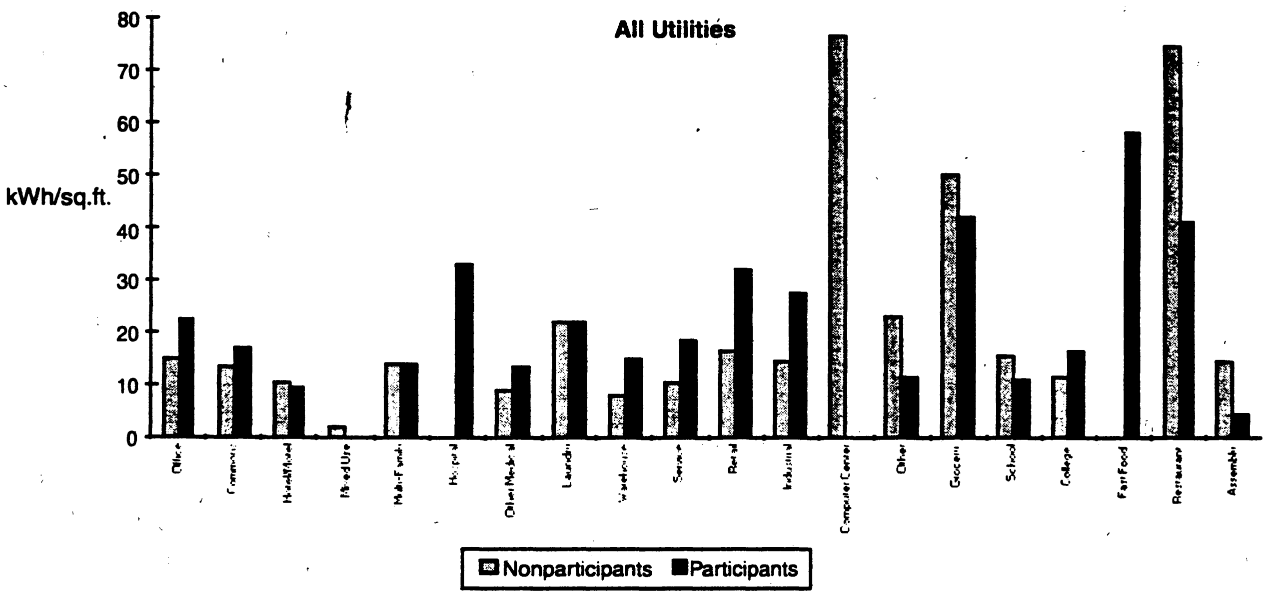

Figure 7-2
Whole-building Energy Intensities from Billing Records by Participation and Detailed Building Category

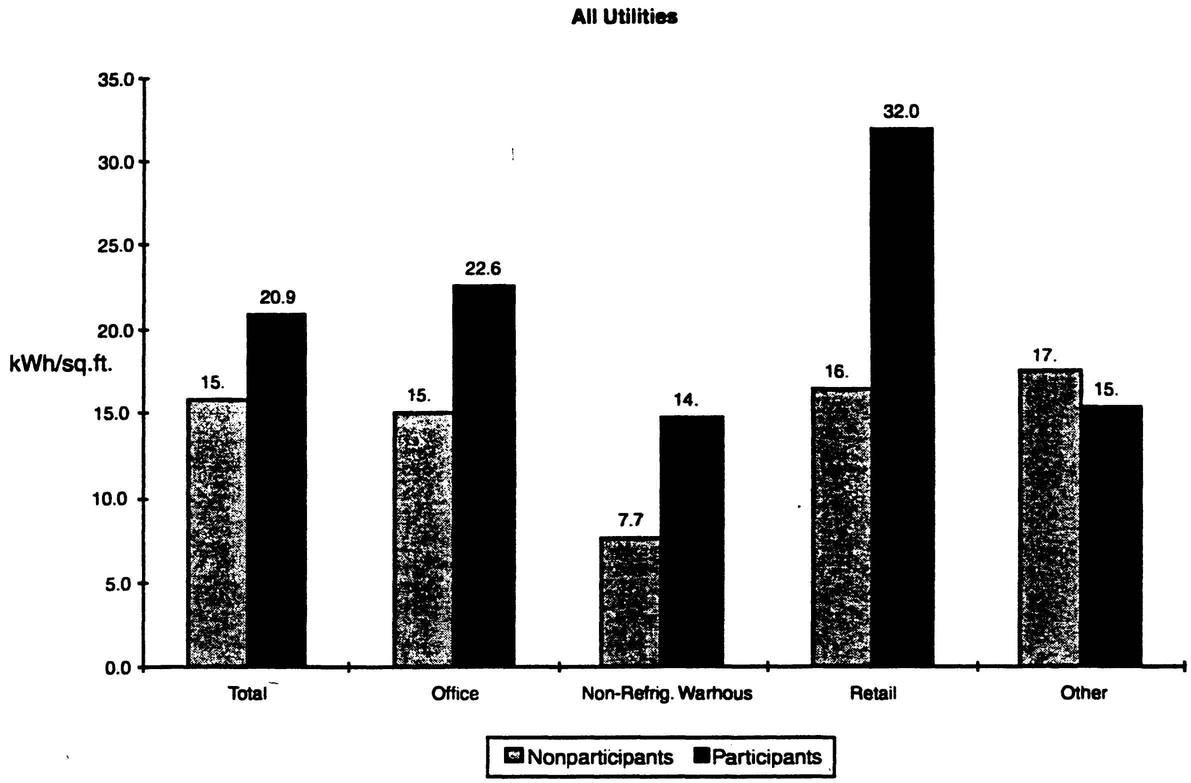

Figure 7-3
Whole-building Energy Intensities from Billing Records by Participation and Aggregated Building Category

Comparison of Participants and Nonparticipants by Utility

Figures 7-4 through 7-8 present detailed comparisons of participant and nonparticipant energy intensities by service area. Note that Figure 7-8 excludes SCL, Puget, and TPU; that is, it includes only BPA "Other." As was the case for the figures presented above, these comparisons do not yield reasonable estimates of savings associated with participation in the new construction programs.

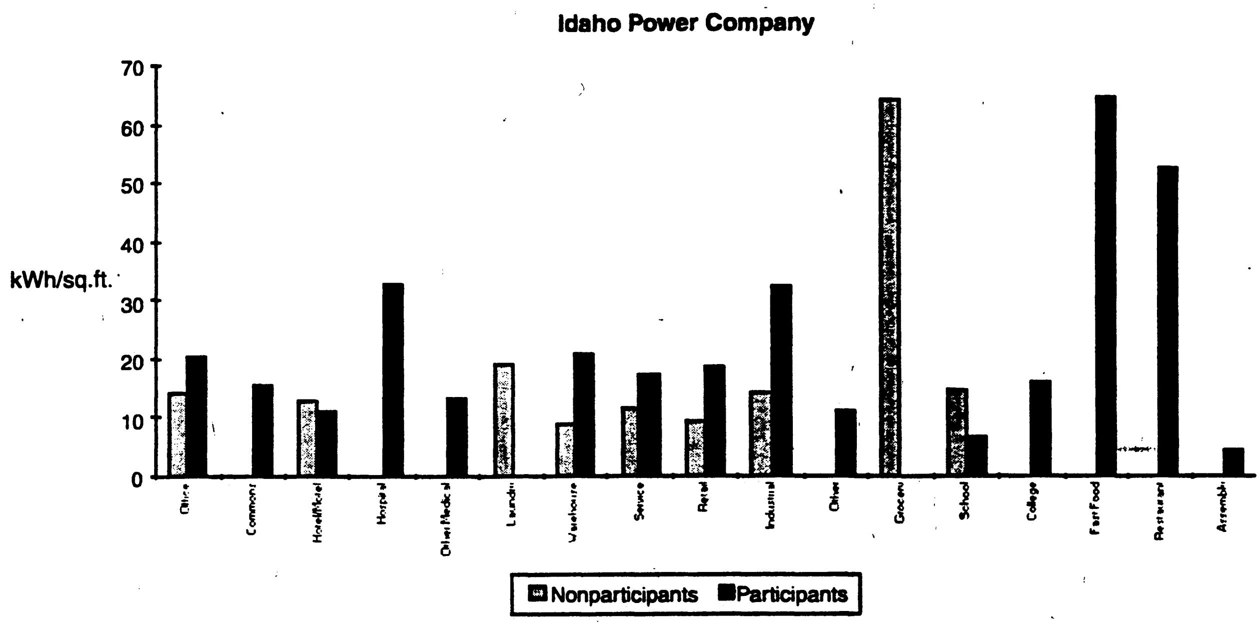

Figure 7-4
Whole-building Energy Intensities from Billing Records by Utility, Participation, and Detailed Building Category

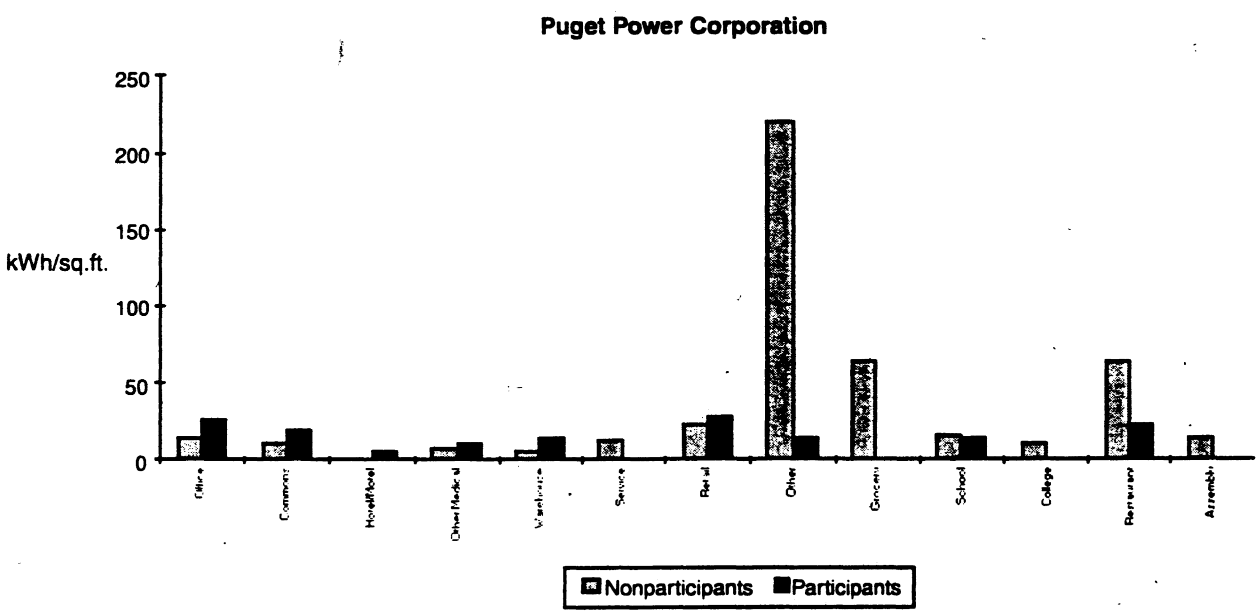

Figure 7-5
Whole-building Energy Intensities from Billing Records by Utility, Participation, and Detailed Building Category

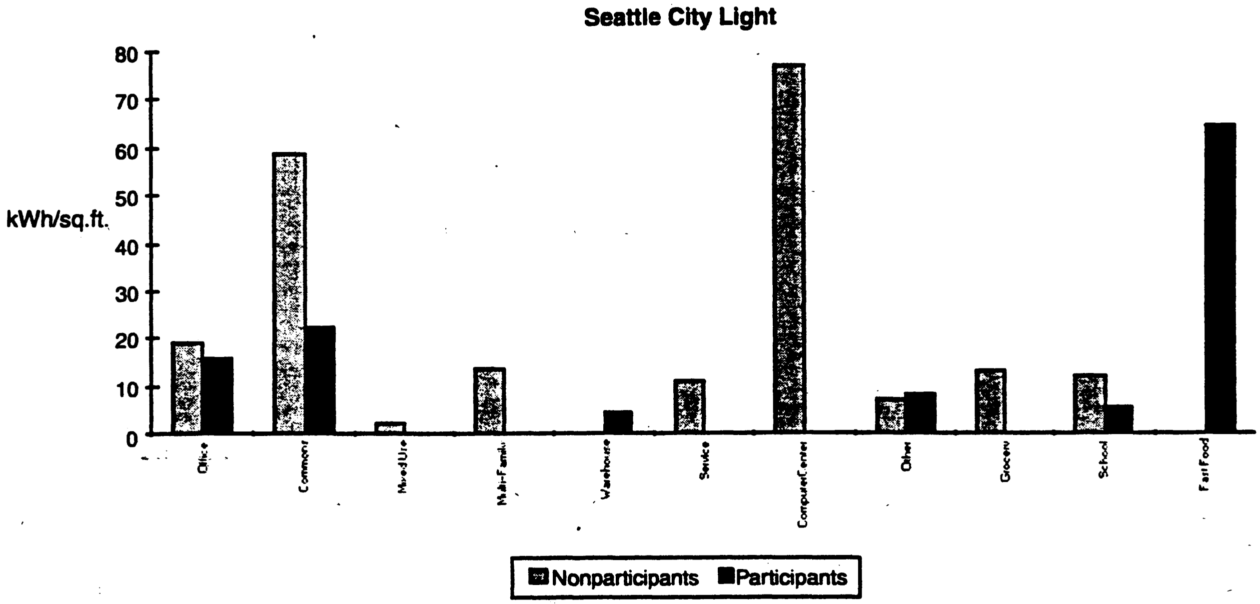

Figure 7-6
Whole-building Energy Intensities from Billing Records by Utility, Participation, and Detailed Building Category

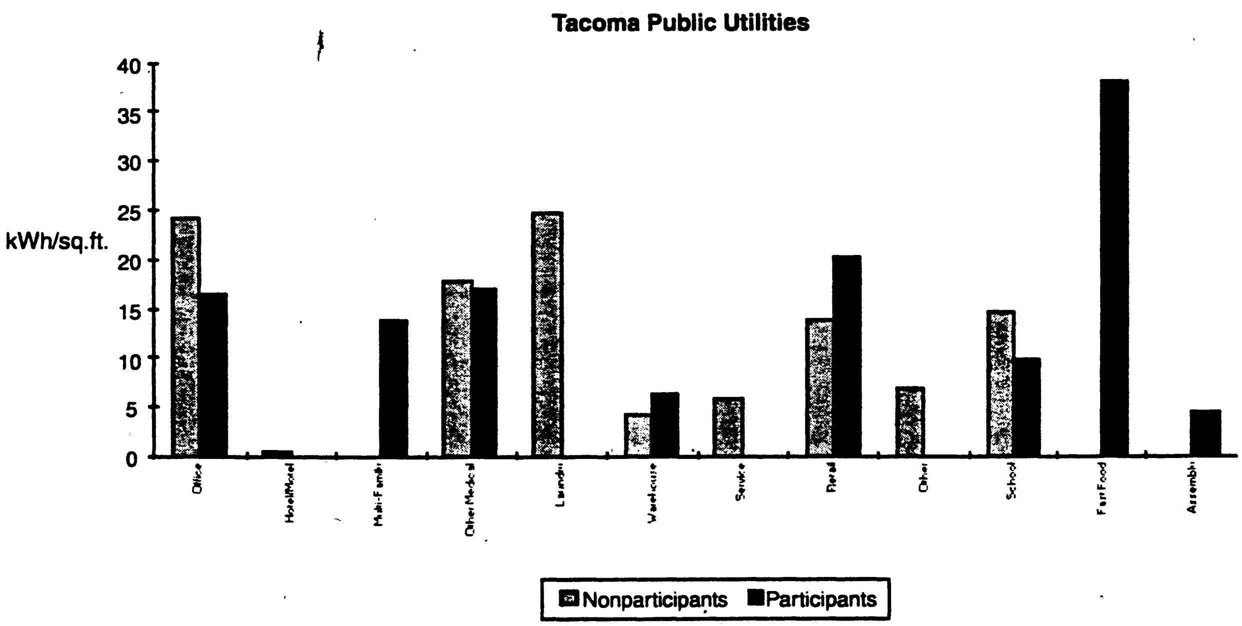

Figure 7-7
Whole-building Energy Intensities from Billing Records by Utility, Participation, and Detailed Building Category

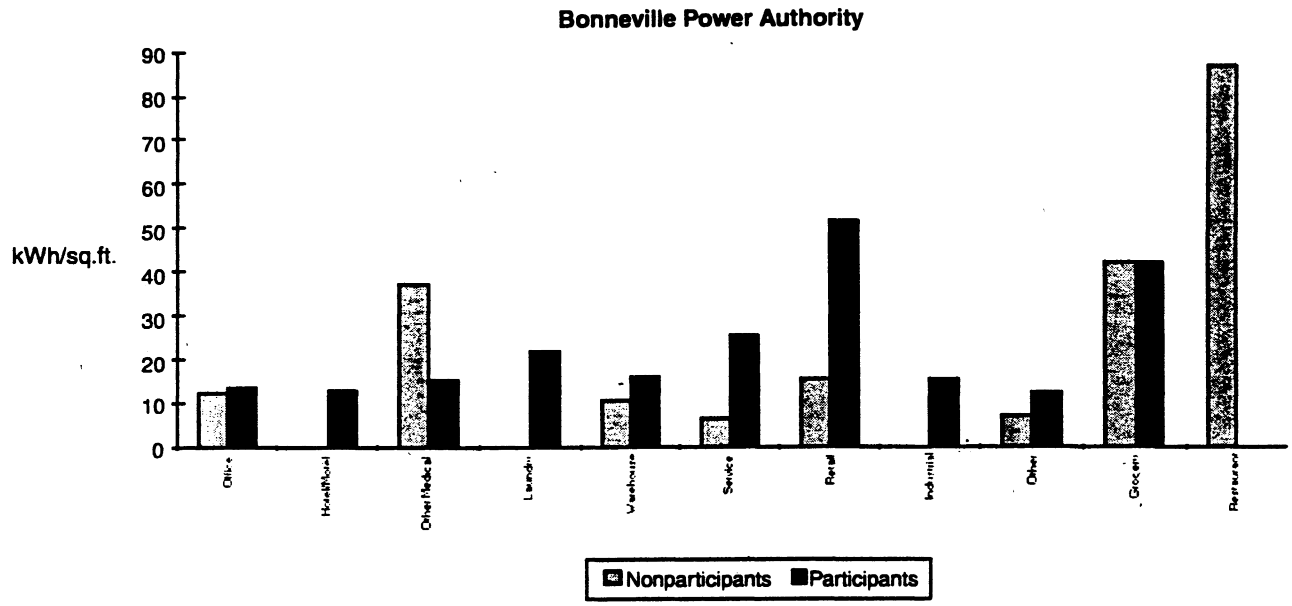

Figure 7-8
Whole-building Energy Intensities from Billing Records by Utility, Participation, and Detailed Building Category

Problems with Simple Intensity Comparisons

The comparison of usage levels across participating and nonparticipating sites is not a particularly useful approach to estimating program energy impacts. For such simple comparisons to yield sensible estimates of energy savings, the nonparticipating sites would have to be chosen extremely carefully to mirror the participant group. That is, the comparison group would have to be a control group in a technical sense. While it is possible in theory to develop a true control group, it is extremely difficult in the context of new construction performance impact projects. The number of new buildings is typically relatively small, buildings tend to be very heterogeneous (even within narrow building categories), and the probability of finding "twins" for a sample of participants is remote. Furthermore, the operation of self-selection bias may cause systematic differences between these two groups. As a result, the sampling plan used in this study provided for similar mixes of building categories in the participant and nonparticipant segment, but made no attempt to ensure pair-matching of participating and nonparticipating sites. Clearly, techniques that control for differences between participants and nonparticipants must be used in the analysis of program impacts. The realization rate analysis will provide such controls.

Realization Rate Analysis

Introduction

The realization rate analysis focuses on the estimation of gross realized savings experienced by ESD participants. The general form of the model has already been explained, and is reproduced below for convenience:

$$E_{bt} = \sum_{e} \alpha_e(X_{bt})\{EEBase_{bet} - \beta_e[EEBase_{bet} - EEActual_{bet}]\} + \varepsilon_{bt} \quad (10)$$

where realized savings are given by:

$$Realized\ Savings_{bet} = \alpha_e(X_{bt})\beta_e[EEBase_{bet} - EEActual_{bet}] \quad (11)$$

and the associated realization rate can be defined as follows:

$$Realization\ Rate = \alpha_e(X_{bt})\beta_e \quad (12)$$

In what follows, the database used for the analysis of ESD realized savings is discussed; the estimated model is presented; the implied realization rates are discussed, and summaries of aggregate realized savings for the 1991 and 1992 program years for the five sponsoring utilities are presented.

Data

Overview. The database used for the analysis consisted of several elements, including:

- Engineering estimates,
- Billing data,
- Weather data, and
- Survey data on site characteristics.

These elements of the database are described below, and practical problems relating to the construction of the database are discussed.

Engineering Estimates. As noted earlier, the engineering subcontractor constructed engineering estimates of monthly end use intensities for each of the sites under consideration. The following points with respect to these estimates are noted:

- As noted earlier, estimates were developed under reference and as-built conditions.
- Engineering estimates were developed using normal, or typical meteorological year (TMY), weather conditions.

- Estimates were constructed for the following end uses: interior lighting, exterior lighting, space heating, space cooling, HVAC auxiliaries, water heating, cooking, refrigeration, swimming pools, miscellaneous uses, and specialized hospital usage.
- While the engineering estimates were initially developed on a calendar-month basis, they were converted to a normalized 30.4-day basis for use in the realization rate analysis.

The following variable names were assigned to the engineering estimates:

- *HTBSPS* is reference heating usage per square foot
- *HTABPS* is as-built heating usage per square foot
- *HTSVPS* is heating savings per square foot
- *CLBSPS* is cooling reference usage per square foot
- *CLABPS* is as-built cooling usage per square foot
- *CLSVPS* is cooling savings per square foot
- *AUXBSPS* is reference auxiliaries usage per square foot
- *AUXABPS* is as-built auxiliaries usage per square foot
- *AUXSVPS* is auxiliaries savings per square foot
- *LTBSPS* is reference interior lighting usage per square foot
- *LTABPS* is as-built interior lighting usage per square foot
- *LTSVPS* is interior lighting savings per square foot
- *ELABPS* is as-built exterior lighting usage per square foot
- *RFABPS* is as-built refrigeration usage per square foot
- *CKABPS* is as-built cooking usage per square foot
- *DHWABPS* is as-built hot water usage per square foot
- *MISCABPS* is as-built miscellaneous usage per square foot
- *HOSPABPS* is as-built hospital usage per square foot
- *POOLABPS* is as-built pool usage per square foot

Billing Data. Billing data were collected for each site. Assembling these data proved to be no small task. The primary problem encountered in this process was the association of surveyed sites with billing records. Considerable efforts were expended to ensure correct matching of sites and bills. At the time of the sample selection, an attempt was made to identify all accounts associated with sites in the sample frame. (Obviously, this was not done in cases in which sample frames were not developed from billing records, as was the case for part of the nonparticipant sample selection process.) The project team requested billing records for the selected sites at this point.

Furthermore, on-site surveyors attempted to record meter numbers whenever meters were accessible, and these were ultimately cross-checked against billing records. Still further, the project team checked the billing intensities against engineering intensities in an attempt to identify major discrepancies, and then worked with utilities to reconcile these discrepancies. Ultimately, some sites had to be omitted from the realization rate analysis because of apparent missing billing data or mismatches. This is not uncommon in new construction performance impact projects, especially when sample frames are developed from non-billing sources (e.g., Dodge reports or building permit data). Site names may differ completely across sources of information, and sites may be metered in a wide range of configurations. Correctly matching surveyed sites and billing records is not a glamorous enterprise, but it is one of the absolute keys to good billing analysis.

Once collected, the billing data were screened for anomalies and billing-cycle usage was converted to calendar-month usage. This latter step was taken to align billing data with the calendar-month engineering estimates of usage, and was done through the use of weighted averages of billing cycle usage falling within the months in question. Calendar month usage was then normalized to standard 30.4-day levels. This same step was taken for the engineering estimates used as regressors in the model.

Weather Data. Weather data were used in the realization rate model in order to account for the effects of weather on the realization of savings associated with heating, ventilation, and cooling (HVAC) end uses. Temperature data were collected for 18 weather stations, and each site was assigned to a station. Daily temperature data were used to construct monthly heating and cooling degree-day measures for each weather station. Normal weather data were also assembled, based on a typical meteorological year (TMY). Like actual weather, TMY weather observations were transformed to monthly degree-day values for each weather station, then assigned to individual sites. Both actual and normal degree-day variables were normalized to a 30.4-day month.

Two weather adjustment ratios were defined using the normal and actual weather data. Each weather adjustment ratio was designed to account for the differences between the normal weather conditions used in the development of engineering estimates and the actual weather conditions driving billed consumption. The heating ratio ($HDDTMYR_{bt}$) is defined as:

$$HDDTMYR_{bt} \equiv [HDD_{bt} - HDDTMY_{bt}]/HDDTMYA_{bt} \tag{13}$$

while the corresponding cooling ratio ($CDDTMYR_{bt}$) is:

$$CDDTMYR_{bt} \equiv [CDD_{bt} - CDDTMY_{bt}]/CDDTMYA_{bt} \tag{14}$$

where:

HDD_{bt} = the actual monthly heating degree-days facing site b in calendar month t

$HDDTMY_{bt}$ = the normal monthly heating degree-days facing site b in calendar month t

CDD_{bt} = the actual monthly cooling degree-days facing site *b* in calendar month *t*

$CDDTMY_{bt}$ = the normal monthly cooling degree-days facing site *b* in calendar month *t*

Site Features. Survey data on the following site features were used in the estimation of the realization rate model:

- **Square Footage.** Site square footage was used to normalize the realization rate model. That is, both energy usage and end-use engineering estimates were expressed per square foot of floor space.
- **Building Category.** A series of building category binary variables was used in the realization rate model to test for systematic differences in realization rates across building types. The following variables were defined: office buildings (*OFFICE*), retail and grocery (*RETAIL*), large retail and grocery more than 100,000 square feet (*RETBIG*), schools and colleges (*SCHOOL*), restaurants and kitchens (*RESTAUR*), hospitals and other health (*HEALTH*), warehouses (*WAREHS*), assembly (*ASSEMBLY*), and services (*SERVICE*).
- **Occupancy Rate.** The occupancy rate of the building in question (*OCCUPANCY*) was used to recognize that actual usage depends on occupancy, whereas the engineering estimates were based on occupancy of developed spaces at the time of the survey.
- **Presence of an Economizer.** There was some question about the accuracy of survey data relating to the presence of economizers. To test for errors in the data (which could cause overstatement of cooling usage for sites mistakenly characterized as lacking economizers), a binary variable (*NOECONOMIZER*) was defined to indicate the lack of an economizer at the site.
- **Constant Volume Ventilation Fraction.** In the course of the analysis, it became clear that the actual billing data did not track the monthly engineering estimates of HVAC auxiliaries usage. To test for the potential for differential engineering biases across types of auxiliaries systems, a variable representing the fraction of space ventilated with constant volume systems (*CONVOLFRAC*) was used in the ventilation portion of the model.
- **Lumen Density.** Some sites seemed to have fairly low lumen levels relative to building category averages. On the possibility that there was some measurement error in the lumen counts (and the associated lighting usage predications), a variable (*LUMENDENSITY*) was defined to represent the deviation of the site's lumen density from its respective building category mean
- **Utility Service Area.** A set of utility service area dummies (*SCL, IPC, TPU, PUGET* and *BPA*) was defined to test the hypothesis that miscellaneous usage realization rates could vary across service areas.

Estimation of the Realization Rate Model

Because of the non-linear restrictions among the model parameters stemming from the interactive effects of $\alpha_e(X_{bt})$ and β_e, it was necessary to use a two-step estimation procedure. First, non-linear regression was used to estimate the model parameters, and the values of β_e were retained.

Then, the model was re-estimated using linear generalized least squares with a correction for autocorrelation and with restrictions on the values of β_e. To help the first-stage estimation process to converge, it became useful to constrain the values of some of β_e to equal 1.0. This constraint essentially implies that the engineering errors in estimating savings and reference usage will be the same within each affected end use. Such restrictions were initially placed on exterior lighting, auxiliaries, and refrigeration. For water heating, miscellaneous, swimming pool, and hospital usage, no savings estimates were developed, so no such restrictions were necessary. For space heating, interior lighting, and cooling, three of the major end uses affected by the program, the values of β_e were estimated freely.

The estimated coefficients and t-values are presented in Table 7-1. Several points should be made with respect to the estimated realization rate model:

- The overall fit of the model is good, with an adjusted R^2 of just less than 0.9.
- Most of the model coefficients are highly significant. On the basis of t-values, the auxiliaries portion of the model appears weakest.
- For some end uses, only the as-built engineering estimates (rather than the reference estimates and the savings estimates) are included in the model. This is because of the restriction on the value of β_e for these end uses. Note that when β_e is set equal to 1.0 for an end use, the portion of the model relating to that end use simplifies considerably. That is, the base usage and savings terms essentially collapse into a single set of as-built terms.
- The degree-day terms in the heating and cooling portion of the model are quite significant and take on the expected signs. (Variables with positive influences on loads should have positive coefficients on base usage and negative coefficients on the savings term.) This suggests that adjusting normal-weather engineering estimates to reflect current weather conditions is an important part of the realization rate analysis.
- The economizer term in the cooling expression suggests that actual cooling loads are lower than predicted by the engineering model when the survey data indicate that no economizer is present. This result is consistent with the hypothesis that some economizers may have been missed in the course of the survey.
- The occupancy variable performed very well for non-weather-sensitive end uses, but was ultimately dropped from the heating and cooling portions of the model. This probably makes sense. Some end uses (e.g., lighting) depend on occupancy levels, but heating and cooling may be invariant to occupancy if central plants are used.
- The constant-volume indicator in the auxiliaries portion of the model is barely significant at the 10 percent level. This provides weak evidence that constant volume auxiliaries are more likely to be overstated by the engineering estimates than variable volume loads. (Of course, it could also indicate that constant volume loads are simply more difficult to isolate from other constant loads through regression analysis.)

- The lumen density term has a negative coefficient for reference interior lighting and a negative coefficient for the interior lighting savings variable. This suggests that when sites have recorded lumen densities greater than the average value for their respective building categories, the engineering estimates tend to overstate lighting usage. This is consistent with the hypothesis that extreme values of lumen densities result from survey errors. For example, if a site has a much higher density than its building category counterparts, the density is likely to be overstated and the associated engineering estimate of lighting usage is likely to be overestimated. The realized savings model essentially adjusts savings estimates to account for this phenomenon.

Table 7-1
Estimated Realization Rate Model

Explanatory Variable	Estimate	t-statistic
INTERCEPT	0.08610	9.38
HEATING		
HTBSPS	1.04853	22.60
HTSVPS	–1.17436	–22.60
HTBSPS*HDDTMYR	7.83466	9.82
HTSVPS*HDDTMYR	–8.77482	–9.82
HTBSPS*RESTAUR	1.58549	14.12
HTSVPS*RESTAUR	–1.77575	–14.12
COOLING		
CLBSPS	0.48488	8.45
CLSVPS	–0.63034	–8.45
CLBSPS*CDDTMYR	0.28577	4.31
CLSVPS*CDDTMYR	–0.37149	–4.31
CLBSPS*RESTAUR	1.69388	10.01
CLSVPS*RESTAUR	–2.20204	–10.01
CLBSPS*HEALTH	0.56758	5.89
CLSVPS*HEALTH	–0.73786	–5.89
CLBSPS*NOECONOMIZER	–0.34704	–4.80
CLSVPS*NOECONOMIZER	0.45116	4.80
AUXILIARY		
AUXABPS*OCCUPANCY	0.77480	4.68
AUXABPS*ID20074	–0.79927	–4.56
AUXABPS*CONVOLFRAC	–0.29367	–1.83
AUXABPS*OFFICE*PUGET	0.24373	1.93

Table 7-1 (Continued)
Estimated Realization Rate Model

Explanatory Variable	Estimate	t-statistic
INTERIOR LIGHTING		
LTSBSPS*OCCUPANCY	1.26708	27.44
LTSSVPS*OCCUPANCY	–1.14037	–27.44
LTSBSPS*LUMENDENSITY	–0.00253	–5.60
LTSSVPS*LUMENDENSITY	0.00227	5.60
EXTERIOR LIGHTING		
ELABPS	1.25980	22.39
REFRIGERATION		
RFABPS*OCCUPANCY	1.03946	50.49
RFABPS*GROCERY	0.42454	7.72
COOKING		
CKABPS*OCCUPANCY	0.83105	21.90
WATER HEATING		
DHWABPS	1.43863	10.01
MISCELLANEOUS		
MISABPS*OFFICE	0.66972	11.27
MISABPS*RESTAUR	1.37123	15.69
MISABPS*HEALTH	–0.22701	–1.12
MISABPS*WAREHS	1.94582	14.10
MISABPS*SERVICE	0.26022	1.85
MISABPS*OCCUPANCY	0.11131	1.86
MISABPS*SCLN-03-09	1.70110	17.94
MISABPS*SCL	–0.17318	–2.55
MISABPS*TPU	0.50084	5.75
MISABPS*BPA	0.74326	7.20
MISABPS*IPC	0.80466	10.57
OTHER END USES		
HOSPABPS	2.14806	8.81
POOLABPS	1.16437	3.59

Implied Realization Rates

With the realization rate model specified above, realization rates vary across sites and end uses. Table 7-2 presents average realization rates by building category. Only those end uses for which actual savings are estimated through the engineering analysis are shown, as these are the rates that influenced the performance measurement. Note carefully that these realization rates apply only to the engineering estimates developed by the engineering subcontractor as part of this project. They do not apply to the engineering estimates constructed by the participating utilities as part of the operation of the program (tracking system estimates).

As shown in Figure 7-9, the realization rates for heating, interior lighting, exterior lighting, and refrigeration are slightly above 1.0, suggesting the full realization of engineering estimates for these end uses. The realization rates for auxiliaries and cooling savings, however, are significantly below 1.0, indicating only partial realization. It is unlikely that these results suggest any rebound effects for these latter two end uses. It is considerably more probable that they imply errors in the assumptions underlying the engineering estimates. Engineering estimates of cooling loads, for instance, seemed considerably higher than suggested by the variation in actual consumption data across weather conditions. Of course, it must be kept in mind that data problems can have an appreciable effect on the results. For instance, it is possible that, in spite of the efforts expended in this project, some billing data relating to cooling loads (which could be separately metered) could be missing. It is also possible that some of the ventilation loads in billing data were "assigned" to other end uses by the regression analysis.

A few realization rates for specific end uses and building categories appear anomalous (e.g., the cooling realization rate for the service sector). These few extreme values are the result of very small samples, however, and have very little impact on the overall results of the study. The general story told by Figure 7-9 appears to be clear: engineering estimates of energy savings are generally confirmed by actual differences in energy consumption. While realization rates associated with project engineering estimates vary somewhat across end uses and building types, the overall realization rate is very close to 1.0. Table 7-2 shows the estimated average realization rates by building category.

Table 7-2
Estimated Average Realization Rates by Building Category

Building Type	Heating	Cooling	Auxiliary	Interior Lighting	Exterior Lighting	Refrig	All End Uses
Office	1.174	0.427	0.822	1.141	1.260	1.039	0.930
Retail or grocery	1.174	0.576	0.525	1.129	1.260	1.184	1.031
School or college	1.174	0.451	0.616	1.139	1.260	1.039	1.088
Restaurant or kitchen	2.950	3.519	0.775	1.144	1.260	1.039	1.426
Assembly	1.174	0.240	0.775	1.134	1.260	—	1.208
Health	1.174	1.123	0.695	1.134	1.260	—	1.134
Warehouse	1.174	0.331	0.506	1.095	1.260	1.039	1.026
Service	1.174	7.756	0.750	1.019	1.260	—	1.132
Other	1.174	0.229	0.613	1.123	1.260	1.039	1.063
Overall	1.271	0.506	0.679	1.124	1.260	1.147	1.020

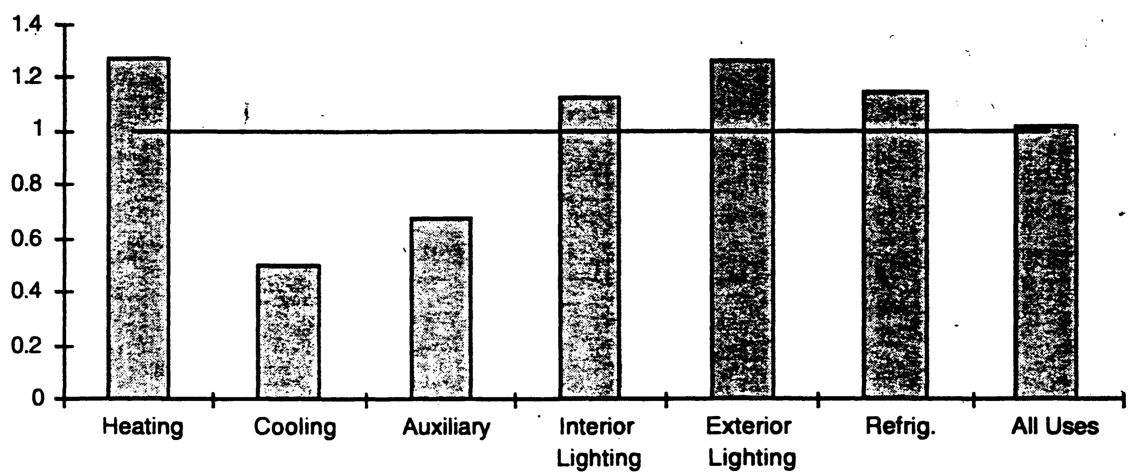

Figure 7-9
Estimated Realization Rates: Overall

Summary and Conclusions

This section has developed estimates of the actual energy savings experienced by participants in the Energy Smart Design and Design Energy Assistance Programs. The primary analysis made use of a hybrid statistical/engineering approach called realization rate analysis. In this analysis, engineering analysis was used to develop initial estimates of program savings at the site level and billing histories were then used to calibrate these estimates to be consistent with actual energy usage at the sites in question.

Figure 7-10 presents the realized savings estimates developed through the application of the realization rate model. The model was used to generate realized savings estimates at the site level, and these estimates were weighted and aggregated across sites. As indicated in Table 7-3 and illustrated in Figure 7-10, there is a fairly close correspondence between the engineering estimates developed by the engineering subcontractor and the realized savings estimates.[1] Indeed, the estimate of total realized savings amounts to almost 97 percent of the total subcontractor engineering estimate. The primary shortfall of realized savings is found in the cooling and auxiliaries end uses.

Table 7-3
Summary of Savings Estimates: All Utilities

End Use	Tracking System Estimates	Performance Measurement Engineering Estimates	Realized Savings
Internal Lighting		23,091,251	25,944,933
External Lighting		12,950,071	16,122,249
Total Lighting		36,041,323	42,067,181
Space Heating		797,147	924,992
Cooling		10,722,434	5,044,786
Auxiliaries		11,447,111	8,180,062
HVAC & Envelope		22,966,691	14,149,842
Water Heating		8,273	11,902
Refrigeration		7,163,297	7,744,710
Misc & Power		0	0
Total Other		7,171,570	7,756,612
All End Uses	52,835,826	66,182,869	63,973,635

[1] The realization rates implied by Table 7-3 are slightly different from those depicted in Table 7-2, due to somewhat different conventions used in the calculations. The rates in 7-2 are computed as weighted averages, where negative weights (which result from negative engineering savings estimates) are set equal to zero. The realized savings values computed for each site and aggregated to yield the realized savings estimates in Table 7-3, on the other hand, have weights that do not depend on the engineering estimates, so negative values are treated symmetrically with positive values.

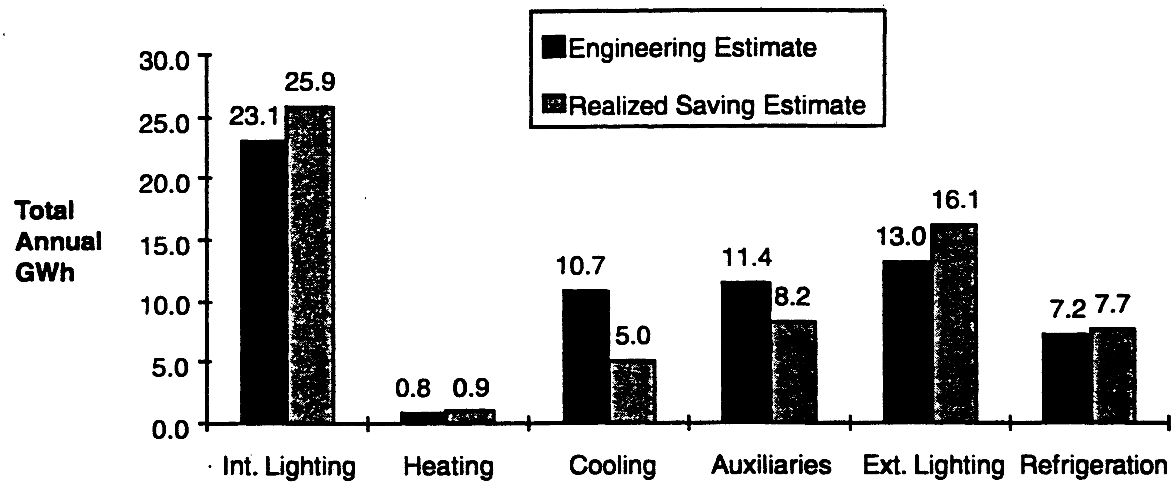

Figure 7-10
Realized Savings by End Use (All Utilities)

Table 7-4 compares realized savings at the end-use level against not only the performance measurement engineering estimates but also the tracking system estimates. The table relates only to the ESD utilities (i.e., all utilities other than IPC), because end-use breakdowns of tracking system estimates were not available for IPC. As shown, for the four utilities in question realized savings actually exceed tracking system estimates. This occurs partly because the performance measurement engineering estimates and the realized savings estimates are based on all DSM measures installed, rather than just on those for which credit was taken through the program. Thus, these estimates may include some participant free drivership. Furthermore, the reference against which the performance measurement engineering estimates were defined may differ in some cases from the reference used for the purposes of developing tracking system estimates. It should also be noted that there were some substantial differences between the performance measurement engineering estimates and the tracking system estimates for some sites and specific measures. (This is probably most important in the area of exterior lighting, where mercury vapor was used as the reference case in the development of performance measurement engineering estimates.) In spite of these differences, there appears to be fairly close correspondence between the overall levels of savings found in the tracking systems and the gross realized savings estimated in the course of this project.

Table 7-4
Summary of Savings Estimates: All Utilities Except IPC

End Use	Tracking System Estimates	Performance Measurement Engineering Estimates	Realized Savings
Interior Lighting	NA	20,347,456	22,907,287
Exterior Lighting	NA	11,723,919	6,807,144
Total Lighting	19,973,405	32,071,376	37,677,131
Space Heating	NA	759,176	891,552
Cooling	NA	7,093,194	3,346,367
Auxiliaries	NA	10,768,652	7,535,284
HVAC & Envelope	20,501,207	18,621,021	11,773,205
Water Heating	0	8,970	12,904
Refrigeration	3,312,541	7,136,002	7,716,338
Misc & Power	2,622,660	0	0
Total Other	5,935,211	7,144,972	7,729,242
All End Uses	46,409,823	57,837,369	57,179,578

The realization rate analysis yields what can be called *gross* realized savings, in the sense that the estimates do not take into account the possibility of free ridership. In Section 8, the analysis of the attribution of the realized savings to the ESD and DEAP programs is discussed.

8

EFFICIENCY CHOICE MODEL

Overview

The previous section discussed the estimation of gross realized savings associated with the Energy Smart Design Program. These gross savings relate to the DSM measures installed by participants in the program. Of course, some of these measures might have been adopted even in the absence of the program. This phenomenon is often termed the *free-rider effect*. The ultimate goal of the efficiency choice analysis is to estimate the *net* level of DSM adoptions actually attributable to the program (i.e., net of the free-rider effect). Conceptually, this entails comparing observed adoptions by program participants to the levels that would have occurred for these same participants without the program. Insofar as the latter levels of adoptions are not directly observable, they are typically estimated in one of two ways:

- Through the use of nonparticipant adoptions as a proxy for what participants would have done had they not participated in the program, or
- Through the use of statistical models of customer efficiency choice behavior to predict what participants would have done had no program been available.

The ratio of net attributable adoptions to gross participant adoptions is sometimes called a *net-to-gross ratio*. The analysis conducted as part of this performance measurement was designed to estimate a net-to-gross ratio for each of the end uses affected by program measures.

Defining and Measuring Efficiency Choices

In general, the Energy Smart Design Program is designed to increase the level of efficiency chosen for new buildings. In formal terms, the net-to-gross ratio reflects the portion of participants' improvements in efficiency that can be attributed to the program. Three operational issues were central to the net-to-gross analysis: the choice of reference levels for the definition of improved efficiency, the development of a quantitative index of improved efficiency, and the definition of participants and nonparticipants.

Choosing Reference Levels of Efficiency

New construction programs are multi-dimensional, covering multiple end uses and a variety of DSM equipment and measures that impact each use. A participant can go through the design-assistance phase and receive incentive money for a wide variety of measure bundles. That is, each participant will adopt some measures and will bypass others. Defining DSM or energy efficiency for participants and nonparticipants also requires reference points. Energy efficiency is typically measured relative to common practice or the level of efficiency that would prevail from strict compliance with standards. This does not mean, however, that common practice or standards comprise the overall baseline for the performance measurement; they merely comprise convenient intermediate baselines, or reference points, for the realized savings analysis. The important consideration for these reference points is that they be applied consistently across participants and nonparticipants. As explained in an earlier section, the reference points used in this study consisted of a mix of lighting technologies, insulation levels and equipment efficiencies that reflected either code or standard construction practice. In the case of Idaho, there were no building codes; the codes applicable to Oregon and Washington, however, were applied to Idaho sites to ensure consistency with the rest of the analysis.

Measuring Efficiency Improvements

Much of the literature in performance impact projects concentrates on the effects of utility programs on the adoption of discrete DSM measures. This approach is sensible for the analysis of programs with purely prescriptive offerings, like heat pump, high efficiency air conditioning, or compact fluorescent programs. New construction programs are multi-dimensional, however, covering multiple end uses and a variety of DSM equipment and measures that impact each use. Satisfaction of code and (in many cases) adherence to program requirements may be accomplished on a performance, rather than a prescriptive, basis. To provide a comprehensive assessment of the impacts of the program on energy efficiency decisions, the analysis focused on several comprehensive end-use indicators of energy efficiency, rather than on the adoptions of discrete measures. Engineering estimates of proportional savings relative to the reference level of usage were developed for each end use. Two sets of indices were defined. The first, referred to as unadjusted efficiency indices, were quantified as:

$$EEF_{be} = [EEBase_{be} - EEActual_{be}]/EEBase_{be}$$

The second set, termed adjusted efficiency indices, was specified as:

$$AEEF_{be} = rr_{be}[EEBase_{be} - EEActual_{be}]/adj_{be}EEBase_{be}$$

where rr_{be} is the realization rate on savings from end use e for building b and adj_{be} represents the adjustment coefficient on base usage. Both rr_{be} and adj_{be} were derived from the estimated realization rate model.

Defining Participants and Nonparticipants

As strange as it may seem, one conceptual performance measurement issue that must be resolved is the definition of participants and nonparticipants to be used for the purposes of end-use efficiency comparisons. One option would be to define a participant as a site that participated *for the end use in question* (for programs with incentives, this would mean that the site received an incentive to adopt DSM measures affecting the end use). Another would be to label a site as a participant if it participated (e.g., received an incentive) for *any end use*. For the purpose of this performance measurement, the second approach was used. To some extent, this choice is determined by the nature of new construction programs. Participants can sometimes satisfy both standards and utility program requirements through a *performance-based approach*, rather than a strict *prescriptive path*. When this is true, efficiency choices are interrelated across technologies and end uses. The choice of high-efficiency lighting, for instance, may allow the installation of lower-efficiency HVAC systems. Even though a utility may require compliance with both prescriptive and performance standards for incentive payments, these interrelationships across end uses affect the assessment of the net impacts of the program on overall efficiency. If, as in the example, participants receiving lighting incentives install relatively inefficient HVAC systems, then the potential for this kind of response must be considered in the analysis. This means that it is important to use the broader definition of participation in making efficiency comparisons.

Simple Comparisons of Efficiency Choices

Comparisons of Participant and Nonparticipant Efficiency Levels

The first method of estimating net-to-gross ratios is to compare efficiency levels chosen by participants and nonparticipants. Tables 8-1 through 8-3 present unadjusted efficiency levels for participants and nonparticipants. Tables 8-4 through 8-6 depict the corresponding adjusted efficiency levels, where (as noted before) the adjustments are based on the application of the realization rates and base usage adjustment coefficients. These coefficients, it may be recalled, are used to convert engineering estimates of reference usage and savings (relative to the reference case) into realized values. Because the realization rates and baseline adjustment coefficients tend to be very similar for each end use, the adjusted and unadjusted efficiency ratios are very similar. Indeed, in some cases (exterior lighting, cooling, and refrigeration) these values were constrained to be equal in order to simplify the estimation process. For the purpose of brevity, the discussion refers to the unadjusted estimates in Tables 8-1 through 8-3.

Tables 8-1 through 8-6 also present the free-ridership ratios and net-to-gross ratios implied by the simple efficiency comparisons. The following definitions were used to obtain these ratios:

$$\text{Net-to-Gross Ratio} \equiv \frac{[\text{Participant Efficiency} - \text{Nonparticipant Efficiency}]}{\text{Participant Efficiency}}$$

$$\textit{Free-Rider Ratio} \equiv 1 - \textit{Net-to-Gross Ratio}$$

Efficiency comparisons are presented for three perspectives:

- A regional perspective covering all five sponsoring utilities,
- The standpoint of from Idaho Power, and
- The perspective of all sponsoring utilities other than Idaho Power.

Table 8-1
Comparisons of Unadjusted Efficiency Levels: All Utilities

	Unadjusted Efficiency Levels			Implied Free Rider	Implied Net-to-Gross
End Use	**Nonparticipant**	**Participant**	**All**	**Ratio**	**Ratio**
Interior lighting	0.149	0.221	0.179	0.674	0.326
Exterior lighting	0.433	0.483	0.453	0.896	0.104
Space heating	0.130	0.114	0.125	1.140	–0.140
Cooling	0.223	0.300	0.256	0.743	0.257
Auxiliaries	0.057	0.229	0.151	0.249	0.751
All HVAC	0.134	0.241	0.187	0.556	0.444
Refrigeration	0.209	0.176	0.194	1.188	–0.188
All covered end uses	0.182	0.240	0.208	0.758	0.242

The comparisons of participant and nonparticipant efficiency levels yield several observations. First, refer to the comparisons for all utilities (the regional perspective) presented in Table 8-1 (unadjusted efficiency). The following general findings are noted at this level:

- Nonparticipants perform nearly as well as participants in the choice of interior lighting efficiency. While participants installed lighting systems that are roughly 22 percent more efficient than the reference case (which is defined to reflect standard practice for conventional lighting), nonparticipants installed lighting that is approximately 15 percent more efficient than the reference. Based on this simple comparison, the implied net-to-gross ratio is 0.33. This means that only one-third of the high-efficiency lighting adopted by participants can be attributed to their participation in the ESD or DEAP program. Of course, it should be remembered that not all participants were incentivized for interior lighting (even in the service areas offering incentives); nonetheless, this simple comparison paints a relatively dim picture of the net effects of the program on lighting efficiency.
- There is little difference in the exterior lighting efficiency levels chosen by participants. Whereas participants, taken as a whole, install exterior lighting 48 percent more efficient than the reference case, nonparticipants choose efficiency levels 43 percent higher than the

reference. Comparison of these efficiency levels implies a net-to-gross ratio in the vicinity of 10 percent. To some extent, this comparison is an artifact of the choice of a reference case, and must be interpreted cautiously. Mercury vapor was used as a reference case for exterior lighting, and this technology appears to understate the efficiency associated with common practice. In other words, commercial establishments in general seem to choose exterior lighting that is more efficient than mercury vapor. Furthermore, it should be kept in mind that exterior lighting was not a strong focus of either the ESD program or the DEAP program. Relatively few of the participants in the program were incentivized to install high-efficiency exterior lighting, so the program would be expected to have relatively little impact on the efficiency associated with this end use.

- Space heating efficiency is actually higher for nonparticipants than for participants. This actually implies a negative net-to-gross ratio, which makes little sense in practical terms. To some extent, this result is due to the comprehensive nature of the efficiency measure. Space heating efficiency is defined in terms of the engineering estimates of usage under the actual and reference cases, and these predictions are strongly affected by internal gains. Because participants tend to adopt higher efficiency interior lighting, they tend to experience lower internal gains; and these lower internal gains lead to higher heating loads when electric heating is present. This phenomenon *partly* explains the relatively poor performance of participants (or, depending on one's perspective, the relatively good performance of nonparticipants). As seen later, however, participants and nonparticipants do tend to choose similar equipment and shell efficiencies (neither of which depends on internal gains).

- Cooling efficiencies are only slightly higher for participants than for nonparticipants. As shown in Table 8-1, participants tend to beat the reference case by 30 percent, while nonparticipants exceed the reference by 22 percent. A simple comparison of these values implies a net-to-gross ratio of only 26 percent. Again, however, the comparison must be interpreted in a way that takes into account the nature of the efficiency measure in question. As noted in the discussion of heating efficiencies, differences in internal gains between the reference case and the as-built case can affect measures of HVAC efficiency. The cooling measure reflects the cooling benefits of the installation of high efficiency lighting. Because both participants and nonparticipants tend to choose lighting as considerably more efficient than reference lighting, internal gains are lower in the as-built case than in the reference case for both participants and nonparticipants, and this leads to higher cooling efficiencies as defined here. Of course, this is only part of the story. The efficiency values in Table 8-1 also reflect equipment and shell efficiencies, and these site attributes will be compared later in "Simple Comparisons of Efficiency Choices."

- Efficiencies associated with HVAC auxiliaries (principally ventilation) tend to be considerably higher for participants than for nonparticipants. As shown in Table 8-1, participants choose auxiliaries that are 22 percent more efficient (in terms of usage) than the reference case, while nonparticipants select systems that are only six percent more efficient than the reference. (The reference case assumptions were discussed earlier in the section on engineering analysis.) This suggests a net-to-gross ratio of 75 percent for auxiliaries. This result probably reflects the fairly aggressive promotion of variable air volume systems through the ESD program.

- When all HVAC end uses were combined, it was found that participants have full HVAC system efficiencies almost twice as high as nonparticipants. A simple comparison would imply a net-to-gross ratio of just more than 44 percent.
- Refrigeration efficiencies are slightly higher for nonparticipants than for participants. Because of the small sample of sites with heavy refrigeration loads, however, this comparison is probably spurious. Moreover, the ESD program does not have a strong focus on refrigeration.
- The overall efficiency level of all end uses (which encompasses the efficiency of water heating, which is trivial in comparison with other end uses) is somewhat higher for participants than for nonparticipants, but indicates on overall net-to-gross ratio of only 24 percent.

The efficiency comparisons shown in Table 8-1 are repeated in Tables 8-2 and 8-3 for two subsets of the sponsoring utilities: Idaho Power and all other utilities operating the Bonneville ESD Program (Seattle City Light, Tacoma Public Utilities, Puget Power, and Other BPA). There are two reasons for breaking out these comparisons. First, there are no building codes in the State of Idaho, which covers virtually all of Idaho Power's service area. General efficiency levels were expected to be different for Idaho Power than for the other service areas. Second, Idaho Power's new construction program differs from the other regional utilities' programs in two important ways. It offers no financial incentives, relying instead on design assistance to encourage efficiency. It also focuses on bringing participants up to efficiency levels consistent with the Model Conservation Standards, while the other programs focus on improvements beyond those standards.

As shown by a comparison of Tables 8-2 and 8-3 and illustrated by the following figures, there are some major differences between Idaho Power and the other utilities.

- Idaho Power nonparticipants exhibit lower efficiency levels than other nonparticipants for all end uses except outdoor lighting.
- Idaho Power participants also have uniformly lower efficiency levels than participants from other service areas.

As seen later, it is important to take these differences into account when trying to use statistical models to infer the impacts of the program on efficiency choices.

Table 8-2
Comparisons of Unadjusted Efficiency Levels—Idaho Power

	Unadjusted Efficiency Levels			Implied Free Rider	Implied Net-to-Gross
End Use	Nonparticipant	Participant	All	Ratio	Ratio
Interior lighting	0.059	0.125	0.095	0.472	0.528
Exterior lighting	0.439	0.447	0.443	.9802	0.018
Space heating	–0.005	0.086	0.008	–0.058	1.058
Cooling	0.197	0.249	0.231	0.791	0.209
Auxiliaries	0.015	0.092	0.066	0.163	0.837
All HVAC	0.102	0.186	0.153	0.548	0.452
Refrigeration	0.035	0.051	0.040	0.686	0.314
All covered end uses	0.098	0.168	0.138	0.583	0.417

Table 8-3
Comparisons of Unadjusted Efficiency Levels—All Utilities Except IPC (ESD Program)

	Unadjusted Efficiency Levels			Implied Free Rider	Implied Net-to-Gross
End Use	Nonparticipant	Participant	All	Ratio	Ratio
Interior lighting	0.162	0.247	0.195	0.656	0.344
Exterior lighting	0.432	0.487	0.453	0.887	0.113
Space heating	0.170	0.117	0.150	1.453	–0.453
Cooling	0.223	0.300	0.256	0.767	0.233
Auxiliaries	0.063	0.262	0.167	0.240	0.760
All HVAC	0.141	0.261	0.197	0.540	0.460
Refrigeration	0.213	0.178	0.197	1.197	–0.197
All covered end uses	0.192	0.257	0.220	0.747	0.253

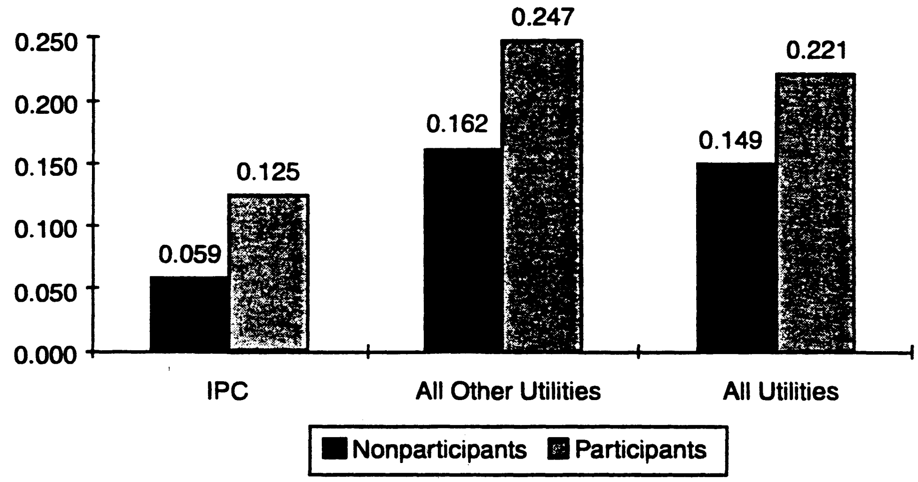

Figure 8-1
Lighting Efficiency Levels (Unadjusted)

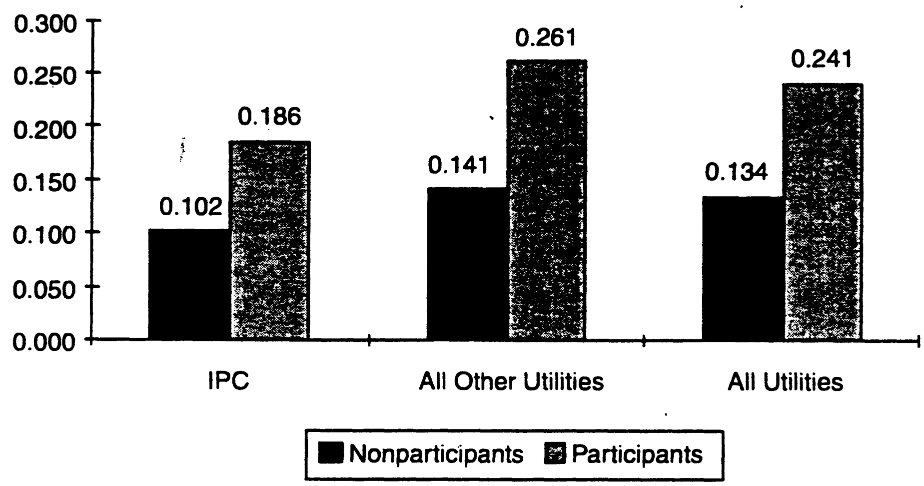

Figure 8-2
HVAC Efficiency Levels (Unadjusted)

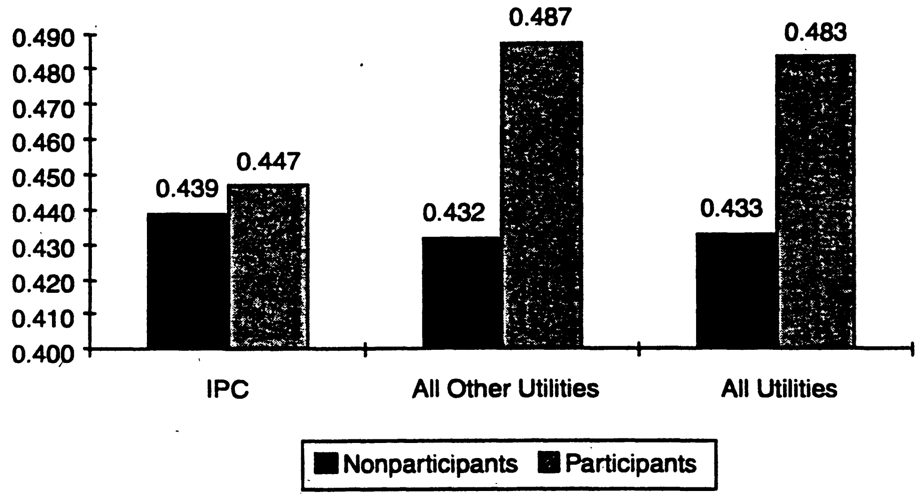

Figure 8-3
Exterior Lighting Efficiency Levels (Unadjusted)

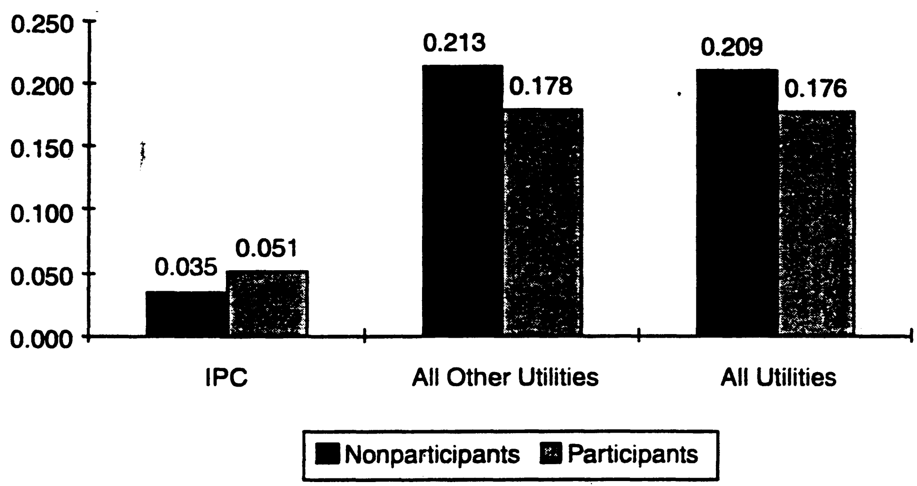

Figure 8-4
Refrigeration Efficiency Levels (Unadjusted)

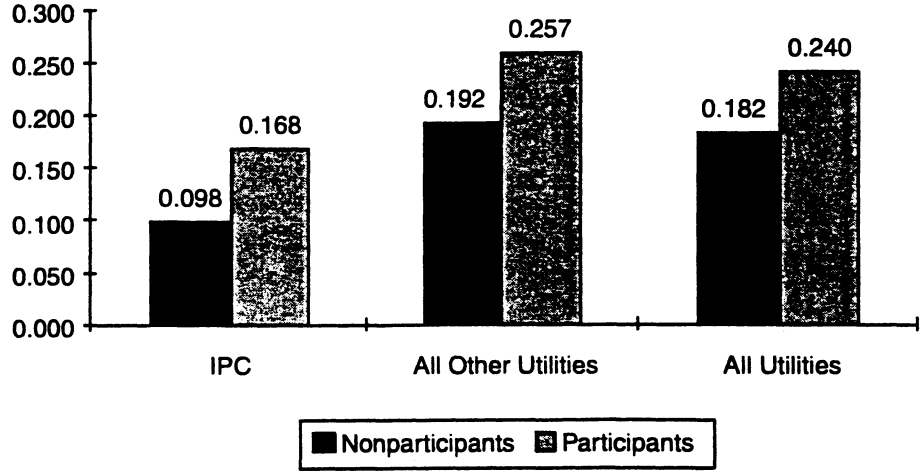

Figure 8-5
Efficiency Levels for All Covered End Uses (Unadjusted)

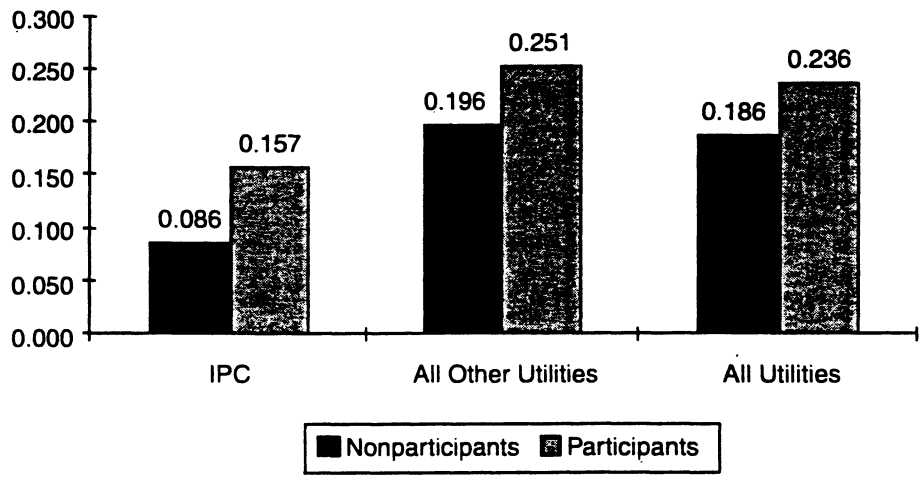

Figure 8-6
Efficiency Levels for All Covered End Uses (Adjusted)

Tables 8-4 through 8-6 depict adjusted efficiency levels. As may be recalled from above, the adjustments entail the multiplication of savings and base usage by the adjustment coefficients derived from the realization rate analysis. Because the patterns exhibited by these adjusted efficiencies are virtually the same as those traced out by the unadjusted values, they will not be commented on in detail. It might be useful, however, to point out two aspects of the adjusted values:

- First, the adjusted efficiency values will be *lower* than the unadjusted values whenever the realization rate (which is used to adjust the engineering estimate of savings relative to the reference case) is lower than the adjustment coefficient used to transform the estimate of reference usage. Correspondingly, the adjusted efficiency values will be *higher* than the unadjusted values whenever the realization rate is *higher* than the reference usage adjustment coefficient.
- Second, in no case did the value of any realization rate (which applies to estimated savings) differ appreciably from the respective reference adjustment coefficient (which applies to the reference usage) for the end use. This suggests that the engineering error in estimating DSM-related savings tends to be roughly the same as the error in estimating reference usage.

Table 8-4
Comparisons of Adjusted Efficiency Levels—All Utilities

	Unadjusted Efficiency Levels			Implied Free Rider	Implied Net-to-Gross
End Use	Nonparticipant	Participant	All	Ratio	Ratio
Interior lighting	0.134	0.199	0.161	0.673	0.327
Exterior lighting	0.433	0.483	0.453	0.896	0.104
Space heating	0.143	0.123	0.136	1.163	–0.163
Cooling	0.223	0.300	0.256	0.743	0.257
Auxiliaries	0.059	0.265	0.177	0.223	0.777
All HVAC	0.146	0.272	0.206	0.537	0.463
Refrigeration	0.209	0.176	0.194	1.188	–0.188
All covered end uses	0.186	0.236	0.207	0.788	0.212

Table 8-5
Comparisons of Adjusted Efficiency Levels—Idaho Power

End Use	Unadjusted Efficiency Levels: Nonparticipant	Participant	All	Implied Free Rider Ratio	Implied Net-to-Gross Ratio
Interior lighting	0.045	0.112	0.082	0.357	0.643
Exterior lighting	0.439	0.447	0.443	0.982	0.018
Space heating	–0.006	0.057	0.003	–0.105	1.105
Cooling	0.197	0.249	0.231	0.791	0.209
Auxiliaries	0.015	0.110	0.081	0.136	0.864
All HVAC	0.092	0.205	0.156	0.449	0.551
Refrigeration	0.035	0.051	0.040	0.686	0.314
All covered end uses	0.086	0.157	0.125	0.548	0.452

Table 8-6
Comparisons of Adjusted Efficiency Levels—All Utilities except IPC

End Use	Unadjusted Efficiency Levels: Nonparticipant	Participant	All	Implied Free Rider Ratio	Implied Net-to-Gross Ratio
Interior lighting	0.146	0.222	0.176	0.658	0.342
Exterior lighting	0.432	0.487	0.453	0.887	0.113
Space heating	0.180	0.128	0.163	1.406	–0.406
Cooling	0.223	0.300	0.256	0.743	0.257
Auxiliaries	0.064	0.301	0.194	0.213	0.787
All HVAC	0.156	0.292	0.217	0.534	0.466
Refrigeration	0.213	0.178	0.197	1.197	–0.197
All covered end uses	0.196	0.251	0.219	0.781	0.219

Comparisons of Estimated Savings per Square Foot

The efficiency measures discussed above are comprehensive, useful, and intuitive in that they reflect the DSM-related energy savings relative to reference usage. Of course, there are many other comprehensive ways of representing efficiency levels. One way would be in energy savings per square foot. This section presents estimates of energy savings per square foot of floor space for participants and nonparticipants. As indicated by a comparison of Tables 8-1 through 8-3 and

Tables 8-7 through 8-9, the net-to-gross ratios yielded by the savings-per-square-foot formulation tend to be somewhat higher than those generated by the percentage savings specification. The former indices are affected by differences in energy intensities across participants and nonparticipants, however. That is, participants tend to have higher reference intensities than nonparticipants. As a consequence, the percentage indicators seem more reasonable than the per foot indices. These percentage indicators will be used throughout the remainder of this section.

Table 8-7
Comparisons of Adjusted Savings per Square Foot—All Utilities

	Unadjusted Efficiency Levels			Implied Free Rider	Implied Net-to-Gross
End Use	**Nonparticipant**	**Participant**	**All**	**Ratio**	**Ratio**
Interior lighting	1.062	1.827	1.357	0.581	0.419
Exterior lighting	0.980	1.151	1.046	0.871	0.129
Space heating	0.113	0.065	0.094	1.739	–0.739
Cooling	0.202	0.356	0.261	0.567	0.433
Auxiliaries	0.060	0.577	0.259	0.104	0.896
All HVAC	0.375	0.998	0.615	0.376	0.624
Refrigeration	0.580	0.546	0.567	1.062	–0.062
All covered end uses	3.00	4.523	3.586	0.663	0.337

Table 8-8
Comparisons of Adjusted Savings per Square Foot—Idaho Power

	Unadjusted Efficiency Levels			Implied Free Rider	Implied Net-to-Gross
End Use	**Nonparticipant**	**Participant**	**All**	**Ratio**	**Ratio**
Interior lighting	0.209	0.977	0.511	0.214	0.786
Exterior lighting	0.269	0.503	0.361	0.535	0.465
Space heating	–0.004	0.011	0.002	–0.364	1.364
Cooling	0.167	0.553	0.319	0.302	0.698
Auxiliaries	0.008	0.210	0.088	0.038	0.962
All HVAC	0.170	0.774	0.408	0.220	0.780
Refrigeration	0.008	0.009	0.009	0.889	.111
All covered end uses	0.656	2.264	1.289	0.290	0.710

Table 8-9
Comparisons of Adjusted Savings per Square Foot—All Utilities Except IPC (ESD Program)

	Unadjusted Efficiency Levels			Implied Free Rider	Implied Net-to-Gross
End Use	Nonparticipant	Participant	All	Ratio	Ratio
Interior lighting	1.288	2.063	1.585	0.624	0.376
Exterior lighting	1.168	1.330	1.230	0.878	0.122
Space heating	0.143	0.080	0.119	1.788	–0.788
Cooling	0.211	0.301	0.246	0.701	0.299
Auxiliaries	0.074	0.678	0.306	0.109	0.891
All HVAC	0.429	1.060	0.671	0.405	0.595
Refrigeration	0.731	0.695	0.717	1.052	–0.052
All covered end uses	3.619	5.148	4.205	0.703	0.297

Comparisons of Related Attributes

In earlier discussion of HVAC efficiencies, it was noted that the results were affected by differences in internal gains as well as shell and equipment efficiencies. This subsection focuses on equipment and shell efficiencies chosen by participants and nonparticipants. Tables 8-10 through 8-12 present estimated system heating COPs, cooling EERs, and overall whole-building U-values for participants and nonparticipants. Again, Idaho Power was separated from the other sponsoring utilities to assess differences in efficiency choices caused by building codes and program features.

Table 8-10
Comparison of As-built and Reference Heating COPs

	Participants		Nonparticipants	
Utility	Reference COP	As-built COP	Reference COP	As-built COP
Idaho	1.117	1.148	1.000	1.000
All but Idaho	1.054	1.235	1.144	1.365
All Utilities	1.063	1.222	1.121	1.305

Table 8-11
Comparison of As-Built and Reference Cooling EERs

	Participants		Nonparticipants	
Utility	**Reference EER**	**As-built EER**	**Reference EER**	**As-built EER**
Idaho	8.949	9.074	8.746	10.215
All but Idaho	9.529	9.621	9.856	9.832
All Utilities	9.401	9.494	9.619	9.914

Table 8-12
Comparison of As-built and Reference Whole-Building U-values

	Participants		Nonparticipants	
Utility	**Reference U**	**As-built U**	**Reference U**	**As-built U**
Idaho	0.120	0.104	0.078	0.081
All but Idaho	0.140	0.169	0.081	0.135
All Utilities	0.135	0.153	0.080	0.123

Tables 8-10 through 8-12 suggest the following findings:

- As-built heating COPs tend to be higher than reference values for both participants and nonparticipants. The gap between as-built and reference COPs is very similar between participants and nonparticipants. Note, however, that these COPs are driven by the prevalence of heat pumps, and heat pumps may not be appropriate for some types of buildings. Note that nonparticipant COPs are slightly higher than participant COPs, in spite of the fact that participants have somewhat higher overall heating efficiencies than nonparticipants. This is because the latter measure of efficiency includes both equipment efficiency and shell efficiency, the latter of which is apparently higher for participants with electric space heating than for nonparticipants with this end use.
- As-built cooling EERs are only slightly higher than reference values for participants, but considerably higher for nonparticipants.
- Surprisingly, as-built U-values exceed the reference values (which are based on code compliance) for both participants and nonparticipants. The gap between as-built and reference U-values is particularly large for nonparticipants. Also, note that the general level of as-built and reference U-values is considerably higher for participants than for nonparticipants. This suggests some fairly distinct differences in construction types between participants and nonparticipants. These differences, in turn, imply that comparisons of participant and nonparticipant efficiency levels should be designed to control for structural features.

Problems with Simple Comparisons

There are at least three important reasons why simple comparisons of participants and nonparticipants can yield misleading estimates of net program impacts.

- First, participants and nonparticipants may differ *randomly* (non-systematically) with respect to factors affecting efficiency choices. For instance, the sample of participants may simply contain a different building-type mix than the sample of nonparticipants. Unless some sort of matching sample designs are used to control for these differences, they may mask the impacts of program participation. Note that if these differences are truly random, they do not bias the estimates of program impacts based on simple comparisons; they do increase the standard errors of these estimates, however. Of course, one option here is to segment the comparisons (e.g., by building type), but this becomes very difficult when sample sizes are small. This lesson was learned earlier when viewing the comparisons of energy intensities within building categories.
- Second, participants and nonparticipants may differ *systematically* with respect to characteristics influencing efficiency decisions. One obvious example of this problem is the tendency for utilities to focus on the recruitment of large construction projects. In most programs, marketing personnel make a special effort to the recruitment of large buildings. If efficiency choices in large buildings tend to differ systematically from those in smaller buildings (say, because of the use of large amounts of glass in high-rise office buildings, or because of the possible inappropriateness of heat pumps in high-rise offices), simple comparisons of participants and nonparticipants will yield a biased view of program impacts. When such systematic differences between participants and nonparticipants are present, there is a clear need to control for these factors to avoid these biases.
- Third, participants may differ from nonparticipants due to self-selection bias. Because DSM programs are voluntary, participants and nonparticipants are self-selected. (That is, decision makers decide which group they will join.) Indeed, decisions to participate in a program are often highly interrelated with the decision to adopt DSM measures. Simple comparisons do not recognize this interdependence. (In formal terms, self-selection can be viewed as a case of simultaneity of the efficiency and participation decisions.) If the decision to participate in a program is influenced by intentions to adopt energy efficiency, participants are inherently are more likely to adopt conservation measures in the absence of programs than are nonparticipants. Thus, nonparticipant behavior is a biased estimate of what participants would have done in the absence of the program. If a straight comparison of participants and nonparticipants is used, then the net adoption impact will be misstated. The size of the self-selection bias could be large, implying a need for corrective action in the estimation step. As shown later, econometric methods can be used to mitigate self-selection bias.

Because of the these problems, a modeling approach was developed to estimate free ridership and net-to-gross ratios. This model is discussed in the next section. It must be noted here, though, that both simple comparisons and statistical modeling techniques suffer from the common problem of ignoring what are called free-driver effects. Both participants and nonparticipants may be influenced by a program. The influence on participants is fairly straightforward. In the case of the Energy Smart Design Program, it is at least partly the result of engineering design assistance and/or incentives; DSM programs may also spawn choices of higher efficiency levels through the transformation of the market, however. This may occur because of program-induced improvements in DSM supply channels, reductions in costs of DSM measures, or increased awareness. This latter effect may be particularly important for new construction programs, where decision makers (developers, architects, etc.) may be involved in decisions relating to both participating and nonparticipating buildings. Market transformation gives rise to what is known as free-driver effects. These effects can be disaggregated into participant free-drivership and nonparticipant free-drivership. To the extent that all participant actions (not just incentivized actions) are included in participant efficiency measures, participant free drivership is taken into account in the simple comparisons and in the statistical analysis. Nonparticipant free drivership (in both the current period and future periods), however, is ignored. One could argue that the ESD programs were young enough in 1991 and 1992 that market transformation was minimal as of that time, so nonparticipant behavior was probably not significantly affected by these programs. (This means that the statistical estimation of free-rider effects is probably largely unaffected.) The 1991 and 1992 programs may very well have moved the market and influenced future behavior of decision makers in general, however. If so, this beneficial program effect will not be reflected in either simple comparisons or in the results of the statistical analysis. The reader should note that, because the statistical methodology discussed below does not specifically address market transformation, the estimated net-to-gross ratios may be understated.

Efficiency Modeling

Need for Modeling

A rigorous means of mitigating self-selection bias and controlling for other differences between participants and nonparticipants must be used if net program savings are to be estimated in an unbiased way (again, ignoring the issue of market transformation). This entails the specification of a model of behavior covering both adoption decisions and participation decisions. When an efficiency index approach is used to reflect energy efficiency choices, the net-to-gross ratio is estimated through the application of an efficiency choice model.

The General Efficiency Model

The general logic of an efficiency model is illustrated in Figure 8-7. As shown, several factors are recognized to affect the choice of efficiency. Program participation, of course, is expected to encourage adoptions of high-efficiency equipment as a consequence of better information and incentives. Note, though, that adoptions also affect program participation. Therefore, participation is endogenous to adoptions (indeed, this is one characterization of self-selection bias). Other factors also influence these decisions. Site characteristics can affect the viability or attractiveness of various DSM options. Decision-maker characteristics (attitudes, perceptions, and decision criteria) affect the likelihood of installation of these measures. These characteristics are included in the model to control for differences across sites.

The general algebraic form of the efficiency model used for the net-to-gross analysis is:

$$PART_b = f(EFF_{be}, INCENT_b, MARKET_b, DECISION_b, SITE_b, \varepsilon_b)$$

$$EFF_{be} = g_e(PART_b, INCENT_b, MARKET_b, SITE_b, DECISION_b, \mu_b)$$

where

EFF_{be}	= efficiency level for end use e in building *b*
$PART_b$	= binary variable indicating participation in the New Construction program
$INCENT_b$	= variable representing the incentive rate facing building *b*
$MARKET_b$	= set of market conditions facing building *b*
$SITE_b$	= set of site characteristics
$DECISION_b$	= set of features relating to decision-making at the site
g_e	= the efficiency function for end use *e*
ε_b and μ_b	= random error terms

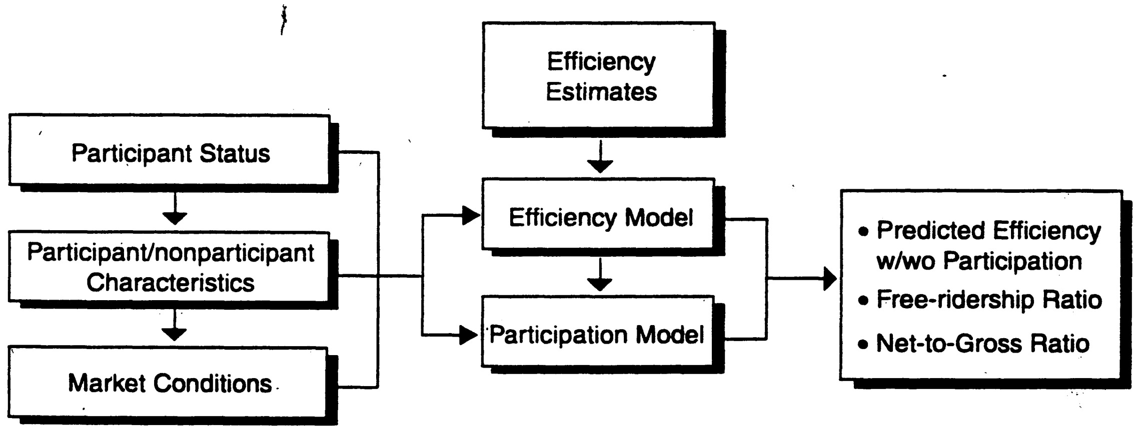

Figure 8-7
Efficiency Choice Model

The Energy Smart Design Model

Factors Assumed to Affect Efficiency Decisions. The model used to analyze the impact of the Energy Smart Design Program was designed to include a reasonably large number of factors thought to affect efficiency decisions. It was assumed that the participation decision and/or the efficiency decision depended on the following factors:

- **Owner Occupancy.** Owner occupancy (indicated by the binary variable *OWNEROCC*) can affect program participation and the likelihood of energy efficiency investments. Because the benefits of energy efficiency are likely to be greater for owner occupants, the expected sign of the coefficient on this variable is positive.
- **Private Occupancy.** Occupancy by a private firm(s), as opposed to public agencies, can affect program participation and energy investments because of differences in access to capital, concern with costs, and other factors. The sign of the coefficient on this term (the binary variable *PRIVATEOCC*) is ambiguous.
- **Chain Occupancy.** Chains and franchises may behave differently than other occupants with respect to energy decisions. This variable (*CHAINOCC*) is included in the model to account for this.
- **Owner-Builder.** If the building is constructed by the owner (as indicated by the binary variable *OWNERBLD*), greater concern for energy efficiency is expected. This can affect both participation and energy adoptions.
- **Built to Suit.** Because of uncertainty with respect to the market's valuation of energy efficiency, greater levels of efficiency might be expected if a building is built to suit a tenant than if it is built on speculation. The variable *BLTTOSUIT* indicates that the building was built to suit.
- **Building Age.** The participating buildings in the sample were built in the years 1991–1992; nonparticipating buildings, however, were generally built over the period 1990–1993. To control for differences in efficiency choices over time, a variable reflecting building age (*BUILDINGAGE*) was included in the efficiency model.
- **Square Footage.** The size of a building (as indicated by its total square footage, *TOTSQFT*) could affect its level of energy efficiency and its likelihood of participation. The former influence could be related to design features and equipment viability, while the latter could be related to intensive recruiting efforts aimed at large buildings.
- **Number of Floors.** The number of floors in the structure (as indicated by the binary variable for the presence of three or more floors, *FLOORS≥3*) could affect the feasibility of certain HVAC systems, thereby influencing efficiency choices.

- **Weather Conditions.** Weather conditions affect the savings from a variety of measures, and are thus included in the participation and efficiency models as normal annual cooling degree-days (*ANNCDDTMY*) and normal annual heating degree-days (*ANNHDDTMY*).
- **Variable Ventilation Loads.** The presence of variable ventilation loads (as indicated by the variable *VARVENTLOAD*) affects the viability of variable air volume systems.
- **Enforcement of Codes.** The degree of code enforcement could be an important factor in determining both participation and efficiency choices, especially for nonparticipants. Each of several sets of jurisdictions was rated for code enforcement on the basis of the proportion of sampled buildings in the areas in question that exceeded the code or fell short of code by less than 10 percent. Code enforcement was quantified for two code requirements: lighting densities and whole-building U-values. The degree of code enforcement is indicated by *ENFORCELIGHT* for lighting and *ENFORCEUVAL* for U-values. The reason for allowing a 10 percent margin in the definition of compliance is to account for possible errors in the estimation of lighting densities and whole-building U-values.
- **Window Percentage.** The window area as a percentage of total wall area (*WINDOWPERC*) was used to test for the impact of this design feature on engineering estimates of HVAC efficiencies. The use of this control variable implicitly assumes that window area is determined by design considerations and is unaffected by program participation.
- **HID Interior Lighting.** Some building categories tend to use high-intensity discharge (HID) lighting because of the ability to tolerate relatively poor color rendition. Improvements in efficiency relative to the baseline used for such lighting areas (mercury vapor) can be extremely large relative to improvements stemming, say, from the use of high-efficiency fluorescent lighting. To control for this factor, a variable (*MERCVAPOR*, to reflect the assumed reference type) was defined to account for the presence of interior HID lighting at the site. Controlling for this factor implies the plausible assumption that the choice of general HID lighting is not affected by the program.
- **Lighting Levels.** Different buildings require different lighting levels. These lighting levels can be quantified as lumens per square foot (*LUMENDENSITY*). On the assumption that lighting levels are determined largely independently from the choice of efficiency, this variable is entered into the lighting model. The assumption that lumen levels are not influenced by program participation and efficiency choices is made reasonable by the practice of defining the reference for lighting efficiency as the lumen-adjusted level of usage; that is, by defining efficiency such that both the as-built case and the reference case are based on the same lumen intensity.
- **Presence of Electric Space Heating and Air Conditioning.** The presence of such systems can affect the choice of shell measures. Their presence at the site is indicated by the binary variables *ELECSH* and *ELECAC*, respectively.
- **Energy Management System.** The presence of an energy management system can influence savings from shell measures as well as the HVAC interactions of lighting measures. The

proportion of the conditioned space with such systems indicated as the thermostat type is captured by the variable *EMCS*.

- **Viability of Heat Pumps.** Heat pumps tend to be more viable in certain kinds of spaces than in others. For instance, packaged heat pumps are typically installed in low-rise buildings rather than high-rise structures. Based on an engineering assessment, the percentage of floor space for which heat pumps would be viable was determined. This percentage is indicated by the variable (*HEATPUMPOK*).
- **Design-only Participation.** For all utilities other than Idaho Power, participation in the new construction program was defined as having received an incentive for one or more measures. This characterization of participation ignores the fact that some builders participate in a design review, but do not proceed through the incentive portion of the program for one reason or another. Design assistance may have an influence on efficiency choices, and it is important to control for this so that it is not interpreted as an indication of naturally-occurring efficiency and reflected in an overstatement of free ridership. Design-only participation in the non-IPC service areas was indicated by the binary variable (*DESIGNONLY*).
- **Incentive Rate.** The incentive rate offered by the utility in question in the year of participation can influence the participation decision as well as the choice of efficiency. The incentive rate (*INCENTIVE*) is measured two ways for the purposes of the analysis: as a percentage of incremental cost of the measures, and as cents per first-year kWh savings. Estimates of these incentive rates, which were provided by the utilities, were based on tracking system records. Both specifications are used in the analysis.
- **Building Category.** Different building categories may have different potentials for energy savings, or have decision makers with different inherent propensities to invest in efficiency. To control for this phenomenon, a series of building category binary variables were used in the efficiency models: office buildings (*OFFICE*), retail and grocery (*RETAIL*), large retail and grocery more than 100,000 square feet (*RETBIG*), schools and colleges (*SCHOOL*), restaurants and kitchens (*RESTAUR*), hospitals and other health (*HEALTH*), warehouses (*WAREHS*), assembly (*ASSEMBLY*), and services (*SERVICE*).
- **Self-selection Correction Term.** A self-selection correction term was included in the model when the Heckman approach was used. This variable is called *MILLSRATIO*. Note that no such variable is needed using the FIML approach.
- **Service Areas.** Due to inherent differences across service areas, a set of service area binary variables were included for Seattle City Light (*SCL*) and Idaho Power (*IPC*).

One possible weakness of the ESD/DEAP efficiency model was that it contained no direct information on the attitudes of decision makers. It was decided early in the project that no decision-maker survey would be conducted. This decision was made partly on the basis of economics (like other performance impact projects, this project was faced with a limited budget). It was also based on practical considerations relating to the difficulties of collecting attitudinal data. New construction decisions typically involve decision teams. Members of the teams include both decision makers and decision influencers. Further, eventual building occupants rarely know about the decision-making process or criteria that were used in the design and construction phase. This makes it difficult to develop data relevant to modeling the net impact of programs on DSM measure adoptions.

Estimation of the Model. The participation equation and a set of efficiency equations can be estimated using data on efficiency choices, site features, decision-maker characteristics, a binary participation variable, and the factors affecting participation. Because of endogeneity of program participation and self-selection of the participants and nonparticipants, the simple empirical association of participation and adoptions will give a biased estimate of the effect of the former on the latter.

To mitigate the presence of self-selection bias, one of three approaches can be used:

- First, a self-selection correction term (an inverse Mills Ratio) could be included in the efficiency equation. This term is a function of the predicted probability of participation, which is derived from the estimated reduced-form equation for the participation decision. (A reduced-form equation is one in which only exogenous variables appear on the right-hand side.) The reduced form of the participation equation could be obtained by solving the above efficiency/participation system for participation in terms of the exogenous variables contained in the system. This method is typically attributed to Heckman.
- Second, the efficiency/participation model could be estimated using two-stage least squares, thus dealing with the simultaneous equation bias inherent in the application of ordinary least squares. In this approach, often attributed to Train, the predicted probability of participation would be used as an instrument for (i.e., substituted for) the participation variable in the efficiency model, and the coefficient of the predicted participation variable would be interpreted as conveying the net program impact on efficiency.
- Third, the efficiency/participation model could be estimated simultaneously using full information maximum likelihood estimation. This approach, which can be attributed to Wang, is more efficient that the two-stage approach, but also mitigates simultaneous equation bias.

The first and last approaches were used in this project. The third is preferable to the second because it is more efficient, so the second was dropped. Efficiency models were estimated for the following end uses: interior lighting, HVAC (the combined total of space heating, cooling and auxiliaries), refrigeration, and exterior lighting. Appendix A describes the technical details of the two estimation techniques (Heckman and Wang) and presents the participation models estimated as part of the analysis. In what follows, these efficiency models and the insights they provide are focused on. Participation models were also estimated as part of the overall efficiency analysis.

The estimated *interior lighting efficiency model* is presented in Tables 8-13 and 8-14. Table 8-13 presents the estimated versions of the model derived using the Heckman approach, while Table 8-14 contains model estimates developed using the Full Information Maximum Likelihood (FIML) approach. Note that two alternative program incentive levels were used in the analysis, thus creating two versions of the Heckman and FIML approaches. Version A entails the use of the incentive as a percentage of incremental cost, while Version B involves the use of the incentive in terms of cents per kWh. The results of these analyses are summarized below.

Table 8-13
Estimated Interior Lighting Model, Heckman Approach

	Version A Incentive as % of Inc. Cost		Version B Incentive as $ per kWh	
Explanatory Variable	**Estimated Coefficient**	**t-Statistic**	**Estimated Coefficient**	**t-Statistic**
INTERCEPT	0.105181	3.2888	0.103696	3.279
PRIVATEOCC	–0.01705	–1.080	–0.016825	–1.073
CHAINOCC	–0.046462	–2.387	–0.047148	–2.433
BUILDINGAGE	–0.007816	–0.854	–0.008875	–0.989
OFFICE	–0.008889	–0.518	–0.010688	–0.621
SERVICE	0.048608	1.439	0.048137	1.435
MERCVAPOR	0.069889	5.338	0.072761	5.611
RETBIG	0.049348	2.900	0.048040	2.793
DESIGNONLY	0.114386	1.980	0.116604	2.030
LUMENDENSITY	0.000175	0.997	0.000185	1.055
IPC	–0.059312	–2.440	–0.056014	–2.320
PART	–0.229161	–2.512	–0.152703	–2.428
PART * INCENTIVE	0.480806	3.628	1.207307	4.176
PART * SCL	0.154776	3.536	0.192903	4.258
PART * IPC	0.292659	3.115	0.217256	3.233
MILLSRATIO	–0.010505	–1.575	–0.011459	–1.688

Table 8-14
Estimated Lighting Efficiency Model, FIML Approach

	Version A Incentive as % of Inc. Cost		Version B Incentive as $ per kWh	
Explanatory Variable	**Estimated Coefficient**	**t-Statistic**	**Estimated Coefficient**	**t-Statistic**
INTERCEPT	0.0233138	0.8518	0.0046239	0.1840
PRIVATEOCC	0.0016383	0.1333	0.0120929	1.0909
CHAINOCC	−0.035509	−2.3670	−0.016694	−1.1204
BUILDINGAGE	0.0050825	0.7143	0.0021478	0.3206
OFFICE	0.0191312	1.5833	0.0257153	2.3364
SERVICE	0.035355	1.4583	0.03497	1.5174
MERCVAPOR	0.0790078	8.3157	0.0883254	9.9213
RETBIG	0.038232	3.8000	0.024937	2.0763
DESIGNONLY	0.1215263	2.4200	0.1190279	2.2933
LUMENDENSITY	0.0002828	1.6471	0.0003511	3.1818
IPC	−0.05456	−1.6778	−0.05129	−2.0400
PART	−0.297431	−4.6774	−0.139677	−3.3528
PART * INCENTIVE	0.5892957	6.3988	1.742993	5.9390
PART * SCL	0.1219415	3.0250	0.1421932	3.1555
PART * IPC	0.3550301	4.9859	0.203142	4.0600

- Chains and franchises generally choose lower efficiency levels than single-site establishments.
- The presence of interior HID lighting is associated with higher efficiency improvements (relative to the reference case).
- Large retail establishments tend to choose higher lighting efficiency levels.
- Both participant and nonparticipant lighting efficiencies tend to be lower in Idaho Power's service area, all other factors considered. This probably stems from the lack of new construction building standards in Idaho.
- Design assistance has a significant impact on the choice of lighting efficiency.
- The influence of participation is significantly affected by the level of the incentive being offered under the program.
- *Given the size of the incentive*, the program impact tends to be higher for Idaho Power and Seattle City Light. Note that this does *not* mean that Idaho Power's program has a greater effect

than the others (indeed, it does not), but rather that it has a greater effect than would be expected given its lack of financial incentives. The stronger impact of Seattle City Light's program probably relates to SCL's relatively stringent standards for participation.

The estimated HVAC efficiency model is presented in Tables 8-15 and 8-16. Table 8-15 presents the Heckman estimates and Table 8-16 contains model estimates developed using the FIML Approach. The implications of these analyses are presented below.

- Building age has a marginally significant positive impact on HVAC efficiency. This result is counter-intuitive, and probably stems from the short time span covered by the sample. Participating buildings were virtually all constructed in 1991 or 1992, and most nonparticipating buildings were built in the 1990–93 period.
- Unsurprisingly, weather conditions (particularly heating degree-days) affect the choice of HVAC efficiency.
- HVAC efficiency tends to be higher when ventilation loads are variable, presumably because of the opportunity for variable air volume systems.
- The presence of an EMCS is typically associated with higher overall HVAC efficiency relative to the reference case.
- According to two versions of the model, the viability of heat pumps has a significant effect on HVAC efficiency. Insofar as nonparticipants tend to have higher heat pump viability, the use of this term in the model controls for this phenomenon and increases the estimated impact of the program on HVAC efficiencies.
- Window area has a strong positive association with efficiency. While this was a surprising result at first, it makes sense upon further reflection. To a great extent, it traces back to the specified definition of efficiency. Recall that efficiency is defined as the difference between the reference usage and the as-built usage, as a proportion of reference usage. In developing reference and as-built engineering estimates of HVAC usage, AEC assumed the same window area for both scenarios. The implicit assumption was that window area is a design feature, and that it is unlikely to be affected by participation in a DSM program. As a result, the HVAC efficiency indicator does not reflect the direct impact of window area on HVAC usage. It may, however, reflect the indirect effect of window area on the choice of DSM features. For instance, builders may be more likely to install high-efficiency glass and other shell measures when high window areas are incorporated into the design of a building (partly to satisfy code). These indirect influences are reflected in the HVAC efficiency indicator. Thus, a positive association between window percentage and the efficiency indicator is perfectly reasonable. Insofar as participants tend to have high window percentages, the inclusion of this term in the efficiency model tends to reduce the estimated impact of the program.
- HVAC efficiencies tend to be lower in the Idaho Power service area. Again, this is probably due to the lack of building codes in Idaho.

- There are some significant variations in HVAC efficiency levels across building categories.
- The influence of program participation is significant in most versions of the HVAC efficiency model. The incentive rate interaction term is not significant, however. This latter result may stem from the relatively strong emphasis of the Idaho Power program on HVAC measures. While end-use estimates were not available from the IPC tracking system, the project estimates developed by AEC suggest a much higher HVAC savings share for IPC than for other utilities. In a sense, then, the regression is confounding apparent variations in program emphases with differences in incentive levels between IPC and the other utilities.

Table 8-15
Estimated HVAC Efficiency Model, Heckman Approach

	Version A Incentive as % of Inc. Cost		Version B Incentive as $ per kWh	
Explanatory Variable	Estimated Coefficient	t-Statistic	Estimated Coefficient	t-Statistic
INTERCEPT	-0.986801	-3.242	-0.988738	-3.261
BUILDINGAGE	0.043818	2.242	0.040650	2.067
ANHDDTMY	0.000131	2.469	0.000132	2.511
ANCDDTMY	0.00006682	0.471	0.000066383	0.469
SCHOOL	-0.199116	-2.084	-0.165590	-1.703
WAREHS	-0.130417	-2.235	-0.133583	2.295
ASSEMBLY	0.208293	1.434	0.203929	1.408
VARVENTLOAD	0.071191	1.948	0.074442	2.047
ELECSH	-0.017397	-0.555	-0.016830	-0.539
ELECAC	0.132484	1.469	0.133856	1.491
EMCS	0.351881	1.956	0.3207832	1.775
HEATPUMPOK	0.077656	2.124	0.076019	2.113
DESIGNONLY	0.142792	1.296	0.149810	1.363
WINDOWPERC	0.272310	2.637	0.247352	2.362
IPC	-0.144345	-1.819	-0.152890	-1.954
PART	0.129570	1.918	0.157707	2.395
PART * INCENTIVE	0.063908	0.686	0.163460	0.581
MILLSRATIO	-0.042108	-3.064	-0.047959	-3.380

Table 8-16
Estimated HVAC Efficiency Model, FIML Approach

	Version A Incentive as % of Inc. Cost		Version B Incentive as $ per kWh	
Explanatory Variable	**Estimated Coefficient**	**t-Statistic**	**Estimated Coefficient**	**t-Statistic**
INTERCEPT	−0.849233	−3.9342	−0.587939	−2.8713
BUILDINGAGE	0.0601954	4.2857	0.0876167	6.6923
ANHDDTMY	0.000129	4.0000	0.0000756	2.1477
ANCDDTMY	0.0002549	2.8090	0.0001459	1.5425
SCHOOL	−0.235271	−3.6154	−0.179816	−2.6153
WAREHS	−0.023039	−0.5897	−0.072806	−1.5860
ASSEMBLY	0.2436767	0.1182	0.1666495	0.1683
VARVENTLOAD	0.0731684	2.7037	0.0889129	3.7042
ELECSH	−0.003664	−0.1818	0.0279758	1.5882
ELECAC	−0.051729	−0.7027	−0.050697	−0.7246
EMCS	0.5217568	4.7750	0.3562532	3.0435
HEATPUMPOK	0.027865	1.0385	0.0234306	1.2332
DESIGNONLY	0.1210633	1.1331	0.1814568	2.3264
WINDOWPERC	0.3616206	5.3852	0.253612	4.4722
IPC	−0.252725	−5.3617	−0.162683	−3.7209
PART	0.1308557	2.1836	0.1336193	0.8564
PART * INCENTIVE	−0.015731	−0.3955	0.0153329	0.4814

The estimated exterior lighting efficiency model is presented in Tables 8-17 and 8-18. Table 8-17 presents the Heckman estimates and Table 8-18 contains model estimates developed using the FIML approach. The models are relatively Spartan compared with the HVAC and interior lighting models, due to the insignificance of many of the variables tried in earlier versions. The results suggest the following findings:

- Chains and franchises tend to choose lower levels of exterior lighting efficiency.
- Office building decision makers opt for lower exterior lighting efficiencies.
- Design assistance has a significant effect in the Heckman versions, but not in the FIML estimates.

- The effect of program participation on exterior lighting efficiency is highly significant. (Note, however, that the absolute impact, as indicated by the net-to-gross ratio, is small.) The incentive rate was omitted from the equation due to its poor performance, which in turn probably relates to the minimal number of cases where outdoor lighting savings (relative to the mercury vapor base) were incentivized by the participating utilities.

Table 8-17
Estimated Exterior Lighting Efficiency Model, Heckman Approach

	Version A Incentive as % of Inc. Cost		Version B Incentive as $ per kWh	
Explanatory Variable	**Estimated Coefficient**	**t-Statistic**	**Estimated Coefficient**	**t-Statistic**
INTERCEPT	0.475769	20.069	0.4774	20.234
CHAINOCC	−0.066435	−3.492	−0.0695	−3.622
BUILDINGAGE	−0.012675	−1.264	−0.0142	−1.407
OFFICE	−0.048448	−2.380	−0.0536	−2.576
DESIGNONLY	0.108458	2.520	0.1116	2.592
PART	0.087310	3.761	0.0971	3.941
MILLSRATIO	−0.010339	−1.357	−0.0140	−1.746

Table 8-18
Estimated Exterior Lighting Efficiency Model, FIML Approach

	Version A Incentive as % of Inc. Cost		Version B Incentive as $ per kWh	
Explanatory Variable	**Estimated Coefficient**	**t-Statistic**	**Estimated Coefficient**	**t-Statistic**
INTERCEPT	0.5060409	18.7407	0.5156	16.968
CHAINOCC	−0.064159	−2.7826	−0.0661	−5.293
BUILDINGAGE	−0.017514	−1.3461	−0.0225	−0.408
OFFICE	−0.066469	−3.1652	−0.0677	−3.129
DESIGNONLY	0.0653538	0.7506	0.2926	0.975
PART	0.0744479	3.7835	0.0757	3.679

The estimated refrigeration efficiency model is presented in Tables 8-19 and 8-20. Table 8-19 presents the Heckman estimates, while Table 8-20 contains model estimates developed using the FIML Approach. The refrigeration model is even more streamlined than the exterior lighting model, due to the fact that relatively few sites had refrigeration. The results suggest the following findings:

- Owner occupancy contributes significantly to efficiency choices for refrigeration.
- Refrigeration efficiencies tend to be higher in retail/grocery stores than in other building types. The variable IDBIG was used to control for two nonparticipation sites in the Idaho Power service area that had high refrigeration efficiencies but no counterparts among participating sites.
- In the Heckman model, program participation has a significant impact on refrigeration efficiency.

Note that the FIML approach yields low 5-values because of the paucity of observations available for the simultaneous estimation of the participation and efficiency models.

Table 8-19
Estimated Refrigeration Efficiency Model, Heckman Approach

	Version A Incentive as % of Inc. Cost		Version B Incentive as $ per kWh	
Explanatory Variable	**Estimated Coefficient**	**t-Statistic**	**Estimated Coefficient**	**t-Statistic**
INTERCEPT	–0.085822	–2.642	–0.0881	–2.763
OWNEROCC	0.121062	3.769	0.1089	3.409
RETAIL	0.099249	5.043	0.1096	5.931
IDBIG	0.187552	9.741	0.1847	10.319
PART	0.061567	3.099	0.0786	3.690
MILLSRATIO	–0.007186	–0.941	–0.0172	–2.045

Table 8-20
Estimated Refrigeration Efficiency Model, FIML Approach

	Version A Incentive as % of Inc. Cost		Version B Incentive as $ per kWh	
Explanatory Variable	**Estimated Coefficient**	**t-Statistic**	**Estimated Coefficient**	**t-Statistic**
INTERCEPT	–0.040732	–0.2105	–0.1276	–0.841
OWNEROCC	0.0977221	1.7962	0.1738	1.967
RETAIL	0.731054	0.3842	0.0929	0.621
IDBIG	0.0951327	0.0688	0.2918	0.719
PART	0.0470872	1.3239	0.0387	1.446

Deriving the Net Effects of Program Participation. Once the model is estimated, it is used to estimate the impact of program participation on efficiency levels for specific sites. Based on these estimates, a set of net-to-gross ratios was computed for each service area. For any individual participant (say, participant i), the net-to-gross ratio is defined as:

$$\textit{Net-to-Gross Ratio}_i = \textit{Net Impact}_i / \textit{Adjusted Efficiency}_i$$

where the net impact is derived as the effect of the participation variable on the site's adjusted efficiency, and the adjusted efficiency is defined in "Measuring Efficiency Improvements." Net-to-gross ratios are developed for all participants (as well as for subsets of participants) through the development of weighted averages of these ratios across sites. The weights take into account not only expansion weights, but also adjusted base usage (the base for the efficiency ratios).

The results of the net-to-gross analysis are summarized in Tables 8-21 through 8-23. Table 8-21 provides a summary for all participating utilities, while Tables 8-22 and 8-23 break out the results for Idaho Power (which does not offer incentives) and the other utilities. To relate these estimates to specific efficiency models, each ratio presented in Table 8-21 is accompanied by a model reference in parentheses. These references consist of two indicators: the table number (without the section prefix) and the version. For instance, the reference 13A indicates that the lighting results in question were developed using version A of the efficiency model shown in Table 8-13.

As shown in Figure 8-8, the net-to-gross ratios estimated through the use of the efficiency choice models are considerably higher than the values obtained from the simple comparisons of participant and nonparticipant efficiency levels. This difference results from the model's capability to control for other factors affecting efficiency levels. Some of these factors proved to be important. For instance, participants tend to be considerably larger than nonparticipants and this makes installations of heat pumps less applicable.

Table 8-21
Model-Based Net-to-Gross Ratios, All Utilities

End Use	Net-to-Gross Ratios					
	Heckman $/IncCost	Heckman cts/kWh	FIML $/IncCost	FIML cts/kWh	Overall Average	Average, cts/kWh
Interior Lighting	0.452 (13A)	0.462 (13B)	0.461 (14A)	0.480 (14B)	0.464	0.471
HVAC (comb)	0.590 (15A)	0.669 (15B)	0.471 (16A)	0.610 (16B)	0.585	0.640
Exterior Lighting	0.180 (17A)	0.201 (17B)	0.153 (18A)	0.151 (18B)	0.172	0.178
Refrigeration	0.350 (19A)	0.447 (19B)	0.278 (20A)	0.235 (20B)	0.328	0.341

Table 8-22
Model-Based Net-to-Gross Ratios, Idaho Power

End Use	Net-to-Gross Ratios					
	Heckman $/IncCost	Heckman cts/kWh	FIML $/IncCost	FIML cts/kWh	Overall Average	Average, cts/kWh
Interior Lighting	0.571	0.580	0.532	0.568	0.563	0.574
HVAC (comb)	0.610	0.735	0.753	0.723	0.705	0.729
Exterior Lighting	0.176	0.198	0.150	0.152	0.169	0.175
Refrigeration	NA	NA	NA	NA	NA	an

Table 8-23
Model-Based Net-to-Gross Ratios, All Utilities except IPC (ESD Program)

End Use	Net-to-Gross Ratios					
	Heckman $/IncCost	Heckman cts/kWh	FIML $/IncCost	FIML cts/kWh	Overall Average	Average, cts/kWh
Interior Lighting	0.432	0.451	0.449	0.471	0.451	0.461
HVAC (comb)	0.589	0.661	0.430	0.582	0.566	0.622
Exterior Lighting	0.181	0.201	0.153	0.156	0.173	0.179
Refrigeration	0.350	0.441	0.278	0.234	0.326	0.338

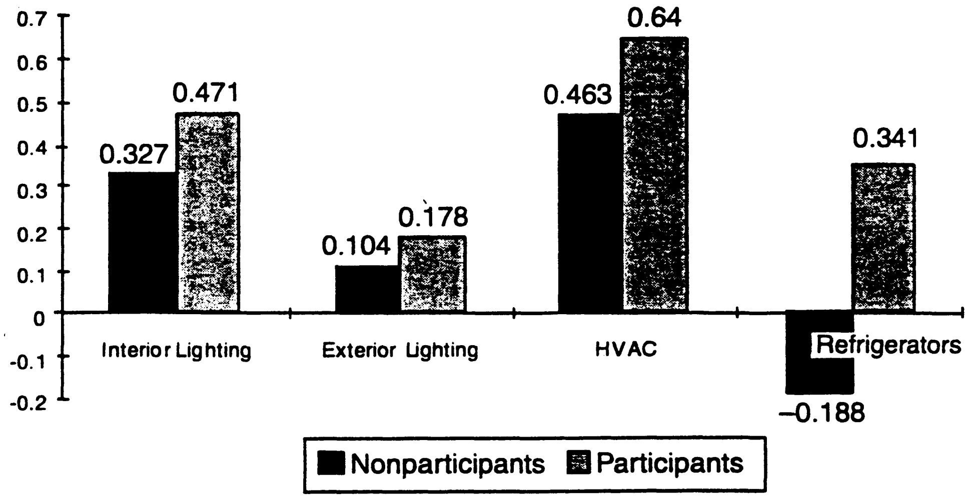

Figure 8-8
Comparison of Net-to-Gross Ratios (Model-Based vs. Simple)

Summary and Conclusions

This section has focused on the estimation of net-to-gross ratios. These ratios are attribution factors in the sense that they reflect the extent to which observed participant savings can be attributed to the influence of the ESD program. They can be used to transform the gross realized savings estimates into corresponding estimates of net savings. This application of the ratios is illustrated in Tables 8-24 through 8-26. Note that the average of the Heckman and FIML estimates were used for the versions using incentives cast in terms of cents per kWh. The reason for using the versions associated with this incentive specification is that the incentive per dollar of incremental cost may not be defined identically across utilities. There seemed to be at least some cases in the tracking records where total cost, rather than incremental cost, had been entered into the tracking system. It should be noted, however, that the final estimates of net program impacts do not differ a great deal if the efficiency models with the alternative incentive level are used. Also note that, due to the small sample available for the refrigeration efficiency modeling, the overall (all utilities) net-to-gross ratio is used for each of the utilities in question.

The results suggest that overall net program savings for all utilities amount to more than 26 annual GWh. This is 42 percent of the gross realized savings estimated in Section 1. (This share is indicated by the unitalicized fraction at the bottom of the fifth column.) Net savings are almost exactly 50 percent of the savings indicated by the tracking system estimates, however. (Net realized savings as a proportion of tracking system savings are indicated by the italicized fraction at the bottom of the fifth column of each table.)

Table 8-24
Summary of Net Savings Estimates, All Utilities

End Use	Tracking System Estimates	Performance Measurement Engineering Estimates	Realized Savings Estimate	Net-to-Gross Ratio	Net Program Savings
Int. Lighting		23,091,251	25,906,511	0.47	12,252,218
Ext. Lighting		12,950,071	16,314,556	0.18	2,925,533
Total Lighting		**36,041,323**	**42,221,067**	**0.36**	15,177,750
Envelope			0		0
HVAC		23,448,898	14,149,842		
Space Heating		787,651	924,992		
Cooling		11,000,498	5,044,786		
Auxiliaries		11,660,749	8,180,062		
HVAC & Envelope		**23,448,898**	**14,149,842**	**0.63**	8,916,537
Water Heating		8,273	11,902	1.00	11,902
Refrigeration		7,163,297	7,744,710	0.33	2,548,964
Other		0	0		0
Total Other		**7,171,570**	**7,756,612**	**0.33**	2,560,866
All End Use	52,835,826	**66,661,791**	**64,127,520**	**0.42**	26,655,153
				0.50	

Table 8-25
Summary of Net Savings Estimates, IPC

End Use	Tracking System Estimates	Performance Measurement Engineering Estimates	Realized Savings Estimate	Net-to-Gross Ratio	Net Program Savings
Int. Lighting		2,743,795	2,999,224	0.57	1,709,558
Ext. Lighting		1,226,152	1,544,712	0.18	278,048
Total Lighting		**3,969,947**	**4,543,936**	**0.44**	1,987,606
Envelope		0	0		0
HVAC		4,827,877	2,376,637		
Space Heating		28,475	33,440		
Cooling		3,907,304	1,698,419		
Auxiliaries		892,097	644,778		
HVAC & Envelope		**4,827,877**	**2,376,637**	**0.73**	1,734,945
Water Heating		2,318	3,335	1.00	3,335
Refrigeration		27,295	28,372	0.34	9,646
Other		0	0		0
Total Other		**29,613**	**31,707**	**0.41**	12,981
All End Use	**6,012,491**	**8,827,437**	**6,952,280**	**0.54**	3,735,532
				0.62	

Table 8-26
Summary of Net Savings Estimates, All Utilities except IPC (ESD Program)

End Use	Tracking System Estimates	Performance Measurement Engineering Estimates	Realized Savings Estimate	Net-to-Gross Ratio	Net Program Savings
Int. Lighting	0	20,347,456	22,907,287	0.46	10,542660
Ext. Lighting	0	11,723,919	14,769,844	0.18	2,647,485
Total Lighting	**19,973,405**	**32,071,376**	**37,677,131**	**0.35**	13,190,145
Envelope	2,005,983				0
HVAC	18,906,957	18,621,021	11,773,205		
Space Heating	0	759,176	891,552		
Cooling	0	7,093,194	3,346,367		
Auxiliaries	0	10,768,652	7,535,284		
HVAC & Envelope	**20,912,940**	**18,621,021**	**11,773,205**	**0.61**	7,181,592
Water Heating	1,779	5,955	8,567	1.00	8,567
Refrigeration	3,312,541	7,136,002	7,716,338	0.33	2,539,317
Other	2,622,670	0	0		0
Total Other	**5,936,990**	**7,141,957**	**7,724,905**	**0.33**	2,547,884
All End Use	**46,823,335**	**57,834,354**	**57,175,240**	**0.40**	22,919,621
				0.49	

9

COST EFFECTIVENESS

Overview

Using the net savings results of the performance measurement and the program tracking data on measure costs, incentives, and expected measure lives, levelized costs of conserved energy were developed for the programs (on a Mills-per-kWh basis). The analysis used the methodology and assumptions provided by BPA.

Methodology

For the analysis, the present value of all costs and savings were calculated using a three percent real discount rate. Present-value costs then were divided by present-value kWh savings. Levelized costs were calculated from a regional program perspective (using paid incentives as the measure cost indicator for ESD and modeling costs as the indicator for DEAP) and from a total regional perspective (using total incremental measure costs). The following equations were used:

$$\textit{Levelized regional program costs} = \frac{PV(Incentives\ /\ Modeling\_Costs + Fixed\_Program\_Costs)}{PV(kWh\_Savings)}$$

$$\textit{Levelized total regional costs} = \frac{PV(Incremental\_Costs + Fixed\_Program\_Costs)}{PV(kWh\_Savings)}$$

Using the BPA methodology, all included costs were assumed to be financed at BPA's treasury borrowing rate of 8.35 percent for 20 years (which incorporates an assumed inflation rate of four percent). To calculate the present value of cost, the following steps were used:

- First, the one time costs were translated into a 20-year stream on annual payments using the 8.35 percent rate and the following equation:

$$Cost_t = Cost \times \frac{.0835}{1-(1.0835)^{-20}}$$

- Second, the present value of the 20-year stream on annual payments, $Cost_t$, was calculated using a 7.12 percent nominal discount rate (implying a three percent real rate and three percent inflation) and the following equation:

$$PV(Cost) = \sum_{t=1}^{20} \frac{Cost_t}{(1.0712)^t}$$

The present value of kWh savings was calculated using as real discount rate of three percent and the appropriate measure life, as follows:

$$PV(kWh\_savings) = \sum_{t=1}^{Measure\_life} \frac{kWh\_savings_t}{(1.03)^t}$$

Prior to the calculations, adjustments to tracking system costs were required for the total regional cost calculation because the program tracking systems sometimes contained *total* measure costs rather than *incremental* measure costs. Based on discussions with ESD utility staff about the program-imposed relationship between incremental costs and incentive levels, ESD incremental cost limits were set to the minimum of the total measure cost, or a maximum of 2.5 times the paid incentive.

Measure cost data in the DEAP tracking system also appeared to be incomplete and inaccurate in some cases. At times, incremental measure costs are set equal to the DEAP energy analysis modeling costs. Because of these limitations, the DEAP measure cost data was adjusted upward to average $0.21 per kWh saved, based on additional measure cost information provided by DEAP utility staff.

In addition, only a fraction of the incremental measure costs were included in the calculations to net out measure costs paid by free riders. The fraction was based on adjusted net-to-gross ratios that were calculated from data in Table 8-25 in Section 8 of this report and the following equations:

$$NG = \frac{NetSavings}{RealizedTrackingSavings}$$

where

$$RealizedTrackingSavings = TrackingSavings \times \frac{RealizedSavings}{EngineeringSavings}$$

The net-to-gross ratio for the DEAP was calculated to be 0.789. For ESD, the lighting net-to-gross ratio was calculated as 0.562 and the net-to-gross ratio for other measures was calculated at 0.479.

Fixed program costs for the analysis include: utility administration costs, BPA administration costs, marketing costs, training costs, and the utility component of performance measurement costs. Costs for EPRI component of the performance impact project, the *Electric Ideas Clearinghouse*, and the *Lighting Design Lab* were not included in the calculations.

A summary of data used in the cost calculations is presented in Table 9-1.

Table 9-1
Summary of Cost Analysis Data

	ESD	DEAP
Tracking MWh savings	46,824	6,012
Performance measurement MWh savings	22,898	3,735
Incentive/modeling paid ($1,000s)	9,078	282
Incremental costs ($1,000s)	12,391	1,258
Utility fixed program costs ($1,000s)	1,522	175
BPA fixed program costs ($1,000s)	3,741	—
Average measure lives (years)	14.1	15.0

Results

Levelized costs estimates are presented in Table 9-2. The regional program costs include all program costs paid by BPA or the utilities to achieve the energy savings. Program costs include incentives, marketing, performance measurement, and administrative activities. The total region costs include the incremental cost of the measure and program costs other than incentives paid by BPA and the utilities.

Two set of cost estimates are provided in Table 9-2. The first set are derived using tracking system estimates of savings and costs. The second set of levelized cost estimates were developed using the results from the performance measurement.

Table 9-2
Levelized Costs—Mills per kWh

	Tracking System Results		Net Performance Measurement Results	
End Use	Regional Program Costs[1]	Total Regional Costs[2]	Regional Program Costs[1]	Total Regional Costs[2]
ESD lighting	25.4	31.0	54.3	47.3
ESD other	34.2	40.3	64.2	46.7
ESD total	29.5	35.3	59.3	47.0
DEAP	7.7	22.6	11.0	26.6
Total	27.6	34.2	53.5	44.6

1 Cost includes all program costs paid by utilities and BPA.
2 Cost includes incremental measure costs and program costs other than incentives.

The levelized cost using the performance measurement results are higher than those using the tracking system information. The primary cause of the difference is free-ridership. Low realization rates for HVAC measures are also a small contributor to the higher levelized cost estimates.

Free ridership tends to affect the regional program cost much more than the total regional cost. In determining the total regional costs, the measure costs for free riders are not considered. Thus, free ridership will reduce both the cost and kWh savings for determining the total regional cost. In determining the regional program costs, however, all incentive costs are considered regardless of whom they were paid to. Thus, free ridership reduces the amount of savings but does not have any affect on the program costs.

Incremental measure costs were estimated using information provided in the tracking system. Adjustments to tracking system measure costs were required because the program tracking systems sometimes contained *total* measure costs rather than incremental measure costs. Based on discussions with ESD utility staff about the program-imposed relationship between incremental costs and incentive levels, *incremental* cost limits were set to the minimum of the total measure cost, or a maximum of 2.5 times the paid incentive. For DEAP, incremental costs were set to an average to $0.21 per kWh, based on discussions with DEAP utility staff.

For ESD, lighting savings are more cost-effective than savings from other measures from a regional program perspective, while lighting and non-lighting costs are similar from a total regional perspective. Levelized costs are lowest for DEAP. Costs are disaggregated by cost element in Table 9-3.

Table 9-3
Levelized Cost Disaggregation—Mills per kWh

	ESD		DEAP	
Cost Element	**Regional Program Costs[1]**	**Total Regional Costs[2]**	**Regional Program Costs[1]**	**Total Regional Costs[2]**
Site cost per kWh saved	37.7	25.5	6.2	21.5
Utility fixed program cost[1]	7.3	7.3	4.9	4.9
BPA fixed program cost	14.2	14.2	—	—
Total	59.3	47.0	11.0	26.6

[1] Cost includes all program costs paid by utilities and BPA.
[2] Cost includes incremental measure costs and program costs other than incentives.

As the table indicates, DEAP costs are lower for several reasons:

- DEAP does not pay incentives—only energy modeling assistance is provided, thus site-based costs are lower;
- Fixed program costs are lower for DEAP; and
- There are no energy codes for new buildings in the DEAP area, thus much of the low cost savings often attributed to codes can be captured by DEAP.

A

ESTIMATING MODELS AND EQUATIONS

This appendix is provided for two purposes: first, to discuss three options for estimating the efficiency model used to develop net-to-gross ratios; and second, to present the participation equations estimated as part of the process of estimating efficiency equations.

Methods for Estimating Efficiency and Participation Models

The net effect of participating in the new construction program is defined as the difference in the expected efficiency of participants in the program and the efficiency that would have been chosen by these parties in the absence of the program. More formally, this is:

$$E[EFF_{ep}|X, PART = 1] - E[EFF_{e}|X, PART = 0] \tag{1}$$

where $E(EFF_{ep} \mid X, PART = 1)$ is the efficiency realized by participants and $E(EFF_{ep} \mid X, PART = 0)$ is the efficiency realized by participants if they had *not* participated in the program. The latter efficiency level is unobservable, but can be estimated econometrically. A model commonly employed before in evaluating program impacts is the following:

$$EFF_{be} = X_2\beta_2 + \delta PART_b + \varepsilon_2. \tag{2}$$

The estimate of δ is interpreted as the program impact. This method simply replaces $E(EFF_{ep} \mid X, PART = 0)$ with $E(EFF_{e,np} \mid X, PART = 0)$ that is the efficiency realized by nonparticipants. This, however, produces a performance measurement bias equal to:

$$E[EFF_{ep}|X, PART = 0] - E[EFF_{e,np}|X, PART = 0] \tag{3}$$

To mitigate the presence of self-selection bias, three approaches can be used: Heckman's two-stage method, Train's instrument variable method and the FIML method.

The Heckman two-stage method has two statistical problems, though it corrects selection bias. The first problem is that the self-selection correction term may be linearly correlated with the participation indicate variable $PART_b$ where $PART_b = 1$ if an agent participates, and $PART_b = 0$

otherwise. Assume that the error term in participation equation ε_1 has a CDF F and PDF f. The correction term λ_b for selection bias can be written as follows:

$$\lambda_b = PART_b \cdot \left(\frac{1}{1 - F(-X_{1b}\hat{\beta}_1)} \int_{-X_{1b}\hat{\beta}_1}^{\infty} \varepsilon_{1b} f(\varepsilon_{1b}) d\varepsilon_{1b} \right)$$

$$+(1 - PART_b) \cdot \left(\frac{1}{F(-X_{1b}\hat{\beta}_1)} \int_{\infty}^{-X_{1b}\hat{\beta}_1} \varepsilon_{1b} f(\varepsilon_{1b}) d\varepsilon_{1b} \right) \qquad (4)$$

where $X_{1b}\ \beta_1$ are endogenous variables in the participation equation discussed before. The problem here is that the correction term λ_b is linearly correlated with the binary variable $PART_b$ especially if the participation equation is a poor predictor of the likelihood of participation. This linear correlation translates into problems when estimating the coefficient for participation in the efficiency model, including incorrect signs and / or implausible magnitudes. The second problem is that its two-stage process leads to inefficient estimates, since energy efficiency and program participation are actually decided simultaneously. A Monte Carlo study[1] showed that estimates of two-stage process are also not robust under any model specification errors that exist generally in empirical studies.

Train's method is an instrument variable (IV) method. Train argues that self-selection bias arises because the participation binary variable $PART_b$ is endogenous in the efficiency equation. A decision to participate in a conservation program depends on the expected efficiency generated by the conservation program. He proposes a two-stage IV method. A logit model of customers' decisions to participate is estimated at the first stage. The predicted probability of program participation is used as an instrumental variable in the efficiency model that is estimated at the second stage. Such a two-stage IV method cannot provide efficient and robust estimates, however. Particularly, a poorly fitted probability of program participation P may lead to an implausible estimate of program impact.

The FIML method constructs a log likelihood function for the two-equation simultaneous system:

$$\sum_b \begin{bmatrix} PART_b \cdot \log[f(PART_b = 1, EFF_{eb} = eff_{eb})] + \\ (1 - PART_b) \cdot \log[f(PART_b = 0, EFF_{eb} = eff_{eb})] \end{bmatrix} \qquad (5)$$

1 Wang, B(1994). "Maximum Likelihood Estimation with Sample Selection", Ph.D. Dissertation, Washington State University.

where eff_{eb} is an observed value of end use e's efficiency in building b. The PDF f is:

$$f(PART_b = 1, EFF_{eb} = eff_{eb}) = \frac{1}{\sigma_e}\frac{\partial}{\partial V_2}\left(\frac{e^{\frac{V_1}{\lambda}}}{e^{\frac{V_1}{\lambda}} - e^{\frac{V_2}{\lambda}}} \cdot \frac{1}{1+e^{-V_2}} - \frac{e^{\frac{V_2}{\lambda}}}{e^{\frac{V_1}{\lambda}} - e^{\frac{V_2}{\lambda}}} \cdot \frac{1}{1+e^{-V_1}}\right)$$

$$f(PART_b = 0, EFF_{eb} = eff_{eb}) = \frac{1}{\sigma_e}\frac{\partial}{\partial V_2}\left(\frac{e^{\frac{-V_1}{\lambda}}}{e^{\frac{-V_1}{\lambda}} - e^{\frac{V_2}{\lambda}}} \cdot \frac{1}{1+e^{-V_2}} - \frac{e^{\frac{V_2}{\lambda}}}{e^{\frac{-V_1}{\lambda}} - e^{\frac{V_2}{\lambda}}} \cdot \frac{1}{1+e^{V_1}}\right)$$

where $\lambda = \sqrt{1-\rho}$, and ρ is the correlation of ε_1 and ε_2, and σ_e is the standard deviation of ε_2. V_1 and V_2 are defined as:

$$V_1 = X_1\beta_1$$

$$V_2 = (X_2\beta_2 + \gamma Part)/(\sigma_e \cdot)$$

The maximum likelihood estimates are solved with assumption of a bivariate logistical distribution. The FIML model provides a consistent and robust estimate for the net program impact on the population.

Estimated Participation Equations

The efficiency/participation model was estimated using both the Heckman and the FIML approach. The main body of this report presented the estimated efficiency equations. The associated participation equations are presented below. All variables are defined in Section 8.

Table A-1
Heckman Two-stage Estimation - Participation Equation—Interior Lighting ($/kWh)

Variable	Parameter Estimate	Wald Chi-Square
INTERCEPT	1.0518	0.0350
PRIVATEOCC	–0.6430	2.2031
OWNERBLD	1.2434	4.8266
BLTTOSUIT	0.8512	2.1860
BUILDINGAGE	–0.0634	0.0486
TOTSQFT	0.00003	11.2133
ANHDDTMY	–0.00026	0.0885
ANCDDTMY	–0.00690	8.6064
SCHOOL	–2.0163	5.6095
WAREHS	–0.2341	0.1143
ASSEMBLY	0.2788	0.0374
VARVENTLOAD	–0.0108	0.0006
ENFORCELIGHT	–4.5474	3.3130
INCENTIVE	6.4210	1.1143
IPC	2.2718	1.2436
PUGET	–1.2593	5.5679
ELECSH	1.1673	6.7024
ELECAC	0.5126	0.7344
FLOORS>3	2.2119	2.6461
WINDOWPERC	2.7581	3.4379

Table A-2
FIML Participation Equation—Interior Lighting ($/kWh)

Variable	Parameter Estimate	t for Ho: parameter=0
INTERCEPT	4.1388324	0.6494
PRIVATEOCC	–1.113126	–2.4130
OWNERBLD	1.0921568	1.8166
BLTTOSUIT	–0.664973	–1.2000
BUILDINGAGE	–0.689116	–1.1485
TOTSQFT	0.0000192	3.8000
ANHDDTMY	0.0004123	0.4456
ANCDDTMY	–0.016818	–5.6666
SCHOOL	–2.001906	–2.6666
WAREHS	–1.117372	–1.3058
ASSEMBLY	–0.320094	–0.2191
VARVENTLOAD	–0.249844	–0.5952
ENFORCELIGHT	–10.2364	–3.3333
INCENTIVE	15.705937	2.5600
IPC	8.8625487	4.3009
PUGET	–0.538764	–0.9607
ELECSH	0.2453248	0.4444
ELECAC	0.4835086	0.6400
FLOORS>3	1.7857904	1.3588
WINDOWPERC	3.4419627	1.4827

Table A-3
Heckman Two-stage Estimation - Participation Equation—Interior Lighting ($/Incentive Cost)

Variable	Parameter Estimate	Wald Chi-Square
INTERCEPT	–8.2361	1.5459
PRIVATEOCC	–0.5943	1.8458
OWNERBLD	1.5816	6.8315
BLTTOSUIT	0.9939	2.7570
BUILDINGAGE	0.6217	2.4765
TOTSQFT	0.00003	11.4958
ANHDDTMY	–0.000342	0.1611
ANCDDTMY	–0.00637	7.5518
SCHOOL	–1.4056	2.5332
WAREHS	–0.1401	0.0382
ASSEMBLY	0.8955	0.3180
VARVENTLOAD	0.3129	0.4348
ENFORCELIGHT	–3.7949	2.5437
INCENTIVE	12.8268	7.2413
IPC	9.4434	7.0391
PUGET	–1.4458	7.3069
ELECSH	1.2110	6.8181
ELECAC	0.5504	0.8382
FLOORS>3	2.3605	2.7346
WINDOWPERC	2.9868	3.9647

Table A-4
FIML Participation Equation—Interior Lighting ($/Incentive Cost)

Variable	Parameter Estimate	t for Ho: parameter=0
INTERCEPT	–5.905781	–0.7066
PRIVATEOCC	–0.836163	–1.6720
OWNERBLD	2.1316196	3.2769
BLTTOSUIT	0.208658	0.3684
BUILDINGAGE	0.6278798	1.4250
TOTSQFT	0.0000192	3.1667
ANHDDTMY	–0.000504	–0.4545
ANCDDTMY	–0.018095	–5.8065
SCHOOL	–1.900001	–2.1591
WAREHS	–0.753644	–0.6640
ASSEMBLY	3.3358732	2.4130
VARVENTLOAD	0.008751	0.0168
ENFORCELIGHT	–11.96882	–3.3066
INCENTIVE	21.874256	4.3136
IPC	19.325431	5.2925
PUGET	–0.592193	–0.9184
ELECSH	0.1673908	0.2765
ELECAC	1.2874698	1.2673
FLOORS>3	1.866535	1.2872
WINDOWPERC	5.7676982	2.2709

Table A-5
Heckman Two-stage Estimation - Participation Equation—HVAC ($/kWh)

Variable	Parameter Estimate	Wald Chi-Square
INTERCEPT	–4.5038	0.9477
PRIVATEOCC	–0.5723	1.7699
OWNERBLD	1.1802	4.5305
BLTTOSUIT	0.8565	2.2317
BUILDINGAGE	–0.1169	0.1752
TOTSQFT	0.00003	12.4566
ANHDDTMY	0.00042	0.2369
ANCDDTMY	–0.00567	6.8988
SCHOOL	–2.0644	6.2485
WAREHS	–0.1847	0.0720
ASSEMBLY	0.4580	0.1036
VARVENTLOAD	–0.0545	0.0149
ENFORCEUVAL	–1.8373	1.1176
INCENTIVE	6.7572	1.2971
IPC	3.0610	1.9704
PUGET	–1.3192	6.4908
ELECSH	1.0424	5.6182
ELECAC	0.4859	0.6827
FLOORS>3	1.7307	1.7813
WINDOWPERC	2.8197	3.5437

Table A-6
FIML Participation Equation—HVAC ($/kWh)

Variable	Parameter Estimate	t for Ho: parameter=0
INTERCEPT	–4.523311	–0.7895
PRIVATEOCC	–0.595804	–1.2826
OWNERBLD	2.3105419	3.7156
BLTTOSUIT	1.028082	1.8614
BUILDINGAGE	–0.378861	–1.5916
TOTSQFT	0.0000179	4.2500
ANHDDTMY	0.0008811	0.8888
ANCDDTMY	–0.010692	–3.3333
SCHOOL	–2.316132	–3.7217
WAREHS	–0.248655	–0.1893
ASSEMBLY	0.0193609	0.0009
VARVENTLOAD	–0.245031	–0.0042
ENFORCEUVAL	–3.674876	–1.0988
INCENTIVE	6.5421403	0.9370
IPC	5.7999038	1.8506
PUGET	0.2168066	0.4565
ELECSH	0.3146744	0.6596
ELECAC	0.96199	0.3038
FLOORS>3	–0.103693	–0.0826
WINDOWPERC	2.5209209	1.0815

Table A-7
Heckman Two-stage Estimation - Participation Equation—HVAC ($/Incentive Cost)

Variable	Parameter Estimate	Wald Chi-Square
INTERCEPT	–13.6822	5.8228
PRIVATEOCC	–0.4999	1.3294
OWNERBLD	1.5559	6.8652
BLTTOSUIT	1.0041	2.8369
BUILDINGAGE	0.6479	2.7056
TOTSQFT	0.00003	12.5610
ANHDDTMY	0.00022	0.0676
ANCDDTMY	–0.00528	6.1670
SCHOOL	–1.3937	2.5862
WAREHS	–0.0759	0.0115
ASSEMBLY	1.1236	0.5094
VARVENTLOAD	0.3140	0.4481
ENFORCEUVAL	–1.5956	0.8300
INCENTIVE	13.9629	8.6285
IPC	10.6916	8.8081
PUGET	–1.5087	8.2775
ELECSH	1.1077	5.9431
ELECAC	0.5102	0.7455
FLOORS>3	2.0147	2.0707
WINDOWPERC	3.0881	1.5077

Table A-8
FIML Participation Equation—HVAC ($/Incentive Cost)

Variable	Parameter Estimate	t for Ho: parameter=0
INTERCEPT	−14.05729	−1.5550
PRIVATEOCC	−1.103406	−2.2917
OWNERBLD	3.0865859	4.6183
BLTTOSUIT	1.6901233	2.8167
BUILDINGAGE	0.4825632	1.2105
TOTSQFT	0.0000193	3.8000
ANHDDTMY	0.0013	0.8125
ANCDDTMY	−0.016365	−4.7096
SCHOOL	−2.616535	−3.8478
WAREHS	−0.542689	−0.3424
ASSEMBLY	0.676174	0.0154
VARVENTLOAD	0.5206668	0.8387
ENFORCEUVAL	−4.63104	−1.4606
INCENTIVE	11.57657	2.7033
IPC	14.554315	3.8594
PUGET	0.2066862	0.4120
ELECSH	0.5956996	1.1706
ELECAC	0.6190481	0.2365
FLOORS>3	−1.064724	−0.8947
WINDOWPERC	3.6729398	1.4563

Table A-9
Heckman Two-stage Estimation - Participation Equation—Refrigeration ($/Incentive Cost)

Variable	Parameter Estimate	Wald Chi-Square
INTERCEPT	–8.2361	1.5666
PRIVATEOCC	–0.5943	1.8705
OWNERBLD	1.5816	6.9230
BLTTOSUIT	0.9939	2.7939
BUILDINGAGE	0.6217	2.5097
TOTSQFT	0.00003	11.6498
ANHDDTMY	–0.000342	0.000847
ANCDDTMY	–0.00637	7.6529
SCHOOL	–1.4056	2.5672
WAREHS	–0.1401	0.0387
ASSEMBLY	0.8955	0.3222
VARVENTLOAD	0.3129	0.4406
ENFORCEUVAL	–3.7949	2.5777
INCENTIVE	12.8268	7.3383
IPC	9.4434	7.1334
PUGET	–1.4458	7.4048
ELECSH	1.2110	0.4607
ELECAC	0.5504	0.8494
FLOORS>3	2.3605	2.7712
WINDOWPERC	2.9868	4.0178

Table A-10
FIML Participation Equation—Refrigeration ($/Incentive Cost)

Variable	Parameter Estimate	t for Ho: parameter=0
INTERCEPT	–8.58792	–0.1086
PRIVATEOCC	1.0361069	0.3676
OWNERBLD	7.3226595	0.2398
BLTTOSUIT	–5.229139	–0.1851
BUILDINGAGE	–4.011583	–0.2666
TOTSQFT	0.0001151	0.5282
ANHDDTMY	0.0019037	0.0974
ANCDDTMY	0.0177312	0.3688
SCHOOL	–1.436996	–0.0368
WAREHS	2.6688986	0.1333
ASSEMBLY	–0.218255	–0.0057
VARVENTLOAD	0.4927786	0.0636
ENFORCEUVAL	–4.107516	–0.0683
INCENTIVE	12.947055	0.0992
IPC	9.8394662	0.0928
PUGET	–4.150969	–0.5714
ELECSH	2.6906773	0.1125
ELECAC	1.3457647	0.0500
FLOORS>3	2.3606473	0.0000
WINDOWPERC	3.2356477	0.0430

Table A-11
Heckman Two-stage Estimation - Participation Equation—Exterior Lighting ($/Incentive Cost)

Variable	Parameter Estimate	Wald Chi-Square
INTERCEPT	–8.2361	1.5459
PRIVATEOCC	–0.5943	1.8458
OWNERBLD	1.5816	6.8315
BLTTOSUIT	0.9939	2.7570
BUILDINGAGE	0.6217	2.4765
TOTSQFT	0.00003	11.4958
ANHDDTMY	–0.000342	0.1611
ANCDDTMY	–0.00637	7.5518
SCHOOL	–1.4056	2.5332
WAREHS	–0.1401	0.0382
ASSEMBLY	0.8955	0.3180
VARVENTLOAD	0.3129	0.4348
ENFORCEUVAL	–3.7949	2.5437
INCENTIVE	12.8268	7.2413
IPC	9.4434	7.0391
PUGET	–1.4458	7.3069
ELECSH	1.2110	6.8181
ELECAC	0.5504	0.8382
FLOORS>3	2.3605	2.7346
WINDOWPERC	2.9868	3.9647

Table A-12
FIML Participation Equation—Exterior Lighting ($/Incentive Cost)

Variable	Parameter Estimate	t for Ho: parameter=0
INTERCEPT	16.550427	2.3441
PRIVATEOCC	0.7672521	1.3333
OWNERBLD	4.8546539	6.0000
BLTTOSUIT	3.1144782	3.8400
BUILDINGAGE	1.0066068	1.6393
TOTSQFT	0.0000201	3.7736
ANHDDTMY	−0.003436	−3.4000
ANCDDTMY	−0.026719	−6.5000
SCHOOL	2.1910388	2.2813
WAREHS	0.7452119	0.6282
ASSEMBLY	−1.358857	−0.5000
VARVENTLOAD	0.3590072	0.5318
ENFORCEUVAL	−27.6273	−7.1052
INCENTIVE	25.69977	4.6446
IPC	13.423969	3.5500
PUGET	−2.388551	−3.1944
ELECSH	−2.388551	−3.1058
ELECAC	−1.440727	−1.8000
FLOORS>3	3.2774291	2.4961
WINDOWPERC	19.070139	6.8592

B

ENGINEERING ALGORITHMS, DATA SOURCES, DEFAULT VALUES

The purpose of this appendix is to provide more detailed documentation of the engineering algorithms, data sources, and default values used in the Northwest Performance Impacts for Commercial New Construction.

General Assumptions

For all calculations, the following set of general assumptions were used:

1. Sunday schedules are used for Sundays and holidays
2. 1993 calendar used; holidays are: 1/1, 2/15, 5/31, 7/5, 9/6, 10/11, 11/25, 12/24. The daytypes per month are shown in Table 1.

Table B-1
Daytypes per Month

Month	Weekdays	Saturdays	Sunday/Holiday
Jan	20	5	6
Feb	19	4	5
Mar	23	4	4
Apr	22	4	4
May	20	5	6
Jun	22	4	4
Jul	21	5	5
Aug	22	4	5
Sep	21	4	5
Oct	20	5	6
Nov	21	4	5
Dec	21	4	6

Lighting

Basic Equations

The following equations were used to calculate as-built interior and exterior lighting electricity consumption:

$$kWh = units \times \frac{W}{1000} \times \left(1 - \frac{\%\ Burned\ out}{100}\right) \times FLH \qquad (L\text{-}1)$$

$$FLH = \sum_{j=1}^{3}\sum_{i=1}^{24} \frac{\%\ on_i}{100} \times n_j \qquad (L\text{-}2)$$

Variable Descriptions and Data Sources

Variable Name	Description	Source	Comments
kWh	Monthly lighting energy consumption.	Equation L-1	These values were summed over all entries in the lighting survey
units	Quantity of lighting fixtures corresponding to connected load data	Lighting Inventory, Section 9 of survey.	
W	Connected load (W) assigned to each fixture type	Table B-3	
% Burned out	Percentage of lamps observed to be burned out during site survey	Lighting Inventory, Section 9 of survey.	
FLH	Lighting full-load hours	Equation L-2	FLH from Table B-4 for fixtures on photocell control
n_j	number of days per month corresponding to daytype j (weekday, saturday, sunday/holiday)	Table B-1	

Table B-2
Lighting Fixture Code Description

Tube Fluorescent Four-digit Identification Code

1st Digit	2nd	3rd	4th
Length of Lamp (Feet)	Ballast Type (Code)	Lamp Type (Code)	Number of Lamps (Quantity)

Ballast Type Codes:

S = Standard Magnetic

M = Energy Efficient Magnetic

E = Electronic

H = Hybrid Magnetic/Electronic

D = Dimmable

Lamp Type Codes:

1 = T12 Standard Efficiency

2 = T12 Energy Efficient

3 = T12 High Output

4 = T12 High Output Energy Efficient

5 = T12 Very High Output

6 = T12 Very High Output Energy Efficient

7 = T8 Standard

8 = T10 Standard

General Lighting Four-digit Identification Code

1st Digit	2nd	3rd	4th
Technology type (Code)	Power Consumption (Watts)		

Technology Type Codes:

C = Compact Fluorescent

I = Incandescent

L = Low Pressure Sodium

H = Halogen

M = Metal Halide

S = High Pressure Sodium

T = Tungsten

V = Mercury Vapor

Q = Quartz

* Notes regarding Power Consumption Rating:
An "x" in the last digit indicates "00." This allows the identification code to accommodate power ratings more than 999 Watts (e.g., if a fixture is rated at 1,500 Watts, the last three digits of the code would read: "15x").

Table B-3
Lighting Fixture Wattage and Lumen Assumptions

Lighting Fixture Code	As-Built		Reference	
	Fixture Watts	Lamp lumens	Fixture Watts	Lamp lumens
2E11	18	1050	23	1050
2E12	36	2100	44	2100
2E13	53	3150	66	3150
2E14	71	4200	88	4200
2E21	15	1000	23	1050
2E22	31	2000	44	2100
2E23	45	3000	66	3150
2E24	61	4000	88	4200
2E71	15	1200	23	1050
2E72	31	2400	44	2100
2E73	45	3600	66	3150
2E74	61	4800	88	4200
2M11	23	1050	23	1050
2M12	44	2100	44	2100
2M13	66	3150	66	3150
2M14	88	4200	88	4200
2M21	20	1000	23	1050
2M22	37	2000	44	2100
2M23	56	3000	66	3150
2M24	75	4000	88	4200
2M71	20	1200	23	1050
2M72	37	2400	44	2100
2M73	56	3600	66	3150
2M74	75	4800	88	4200
2S11	24	1050	23	1050
2S12	48	2100	44	2100
2S13	72	3150	66	3150
2S21	21	1000	23	1050
2S22	41	2000	44	2100
2S23	61	3000	66	3150

Table B-3 (Continued)
Lighting Fixture Wattage and Lumen Assumptions

Lighting Fixture Code	As-Built		Reference	
	Fixture Watts	Lamp lumens	Fixture Watts	Lamp lumens
3M21	29	1700	35	1950
4E11	36	2700	46	2700
4E12	72	5400	88	5400
4E13	107	8100	132	8100
4E14	142	10800	176	10800
4E16	213	16200	264	16200
4E21	31	2350	46	2700
4E22	61	4700	88	5400
4E23	91	7050	132	8100
4E24	121	9400	176	10800
4E31	55	3500	46	2700
4E32	108	7000	88	5400
4E43	160	10500	132	8100
4E44	214	14000	176	10800
4E71	29	2600	46	2700
4E72	58	5200	88	5400
4E73	85	7800	132	8100
4E74	114	10400	176	10800
4E91	36	3300	46	2700
4E92	72	6600	88	5400
4E93	107	9900	132	8100
4E94	142	13200	176	10800
4M11	46	2700	46	2700
4M12	88	5400	88	5400
4M13	132	8100	132	8100
4M14	176	10800	176	10800
4M21	39	2350	46	2700
4M22	75	4700	88	5400
4M23	112	7050	132	8100
4M24	150	9400	176	10800

Table B-3 (Continued)
Lighting Fixture Wattage and Lumen Assumptions

Lighting Fixture Code	As-Built		Reference	
	Fixture Watts	Lamp lumens	Fixture Watts	Lamp lumens
4M32	132	7000	88	5400
4M41	63	3200	88	2700
4M42	121	6400	132	5400
4M71	37	2600	46	2700
4M72	70	5200	88	5400
4M73	106	7800	132	8100
4M74	141	10400	176	10800
4M91	46	3300	46	2700
4M92	88	6600	88	5400
4M93	132	9900	132	8100
4M94	176	13200	176	10800
4S11	48	2700	46	2700
4S12	96	5400	88	5400
4S13	144	8100	132	8100
4S14	192	10800	176	10800
4S32	144	7000	88	5400
4S91	48	3300	46	2700
4S92	96	6600	88	5400
4S93	144	9900	132	8100
4S94	192	13200	176	10800
5M11	58	3050	58	3050
5M31	86	4500	58	3050
6E12	101	7800	123	7800
6M11	64	3900	64	3900
6M31	98	5500	64	3900
6M32	187	11000	123	7800
6S32	204	11000	135	7800
8E11	68	5300	86	5300
8E12	135	10600	165	10600
8E13	200	15900	248	15900

Table B-3 (Continued)
Lighting Fixture Wattage and Lumen Assumptions

Lighting Fixture Code	As-Built		Reference	
	Fixture Watts	Lamp lumens	Fixture Watts	Lamp lumens
8E14	267	21200	330	21200
8E21	55	4700	86	5300
8E22	108	9400	165	10600
8E23	160	14100	248	15900
8E24	214	18800	330	21200
8E31	100	7650	86	5300
8E32	198	15300	165	10600
8E34	392	30600	330	21200
8E42	171	15300	165	10600
8E44	338	27800	330	21200
8M11	86	5300	86	5300
8M12	165	10600	165	10600
8M13	248	15900	248	15900
8M14	330	21200	330	21200
8M21	69	4700	86	5300
8M22	132	9400	165	10600
8M23	198	14100	248	15900
8M24	264	18800	330	21200
8M31	127	7650	86	5300
8M32	242	15300	165	10600
8M34	484	30600	330	21200
8M41	109	6950	86	5300
8M42	209	13900	165	10600
8M44	418	27800	330	21200
8S11	90	5300	86	5300
8S12	180	10600	165	10600
8S13	270	15900	248	15900
8S14	360	21200	330	21200
8S21	72	4700	86	5300
8S22	144	9400	165	10600

Table B-3 (Continued)
Lighting Fixture Wattage and Lumen Assumptions

Lighting Fixture Code	As-Built		Reference	
	Fixture Watts	Lamp lumens	Fixture Watts	Lamp lumens
8S23	216	14100	248	15900
8S24	288	18800	330	21200
8S31	132	7650	86	5300
8S32	264	15300	165	10600
8S33	396	22950	248	15900
8S34	528	30600	330	21200
8S41	114	6950	86	5300
8S42	228	13900	165	10600
8S43	342	20850	248	15900
8S44	456	27800	330	21200
8S51	258	10700	86	5300
8S52	516	21400	165	10600
8S53	774	32100	248	15900
8S54	1032	42800	330	21200
8S61	175	7140	86	5300
8S62	350	14280	165	10600
8S63	525	21420	248	15900
8S64	700	28560	330	21200
C005	7	250	25	240
C007	9	400	40	400
C009	11	600	50	790
C011	13	750	50	790
C013	15	900	60	890
C015	15	1000	60	890
C018	18	1200	75	1220
C022	24	1400	100	1750
C026	28	1700	100	1750
C028	30	1900	100	1750
C034	36	2250	135	2580
C036	38	2400	135	2580

Table B-3 (Continued)
Lighting Fixture Wattage and Lumen Assumptions

Lighting Fixture Code	As-Built		Reference	
	Fixture Watts	Lamp lumens	Fixture Watts	Lamp lumens
C052	54	3500	200	3900
C054	56	3600	200	3900
C070	72	3750	200	3900
H020	30	290	30	290
H025	35	375	35	375
H030	40	500	40	500
H035	45	600	45	600
H042	52	750	52	750
H050	60	960	60	960
H065	75	1170	75	1170
H070	80	1330	80	1330
H075	85	1400	85	1400
H150	160	2800	160	2800
I015	15	126	15	126
I020	20	90	20	90
I025	25	232	25	232
I034	34	365	34	365
I036	36	400	36	400
I040	40	415	40	415
I042	42	420	42	420
I045	45	570	45	570
I050	50	800	50	800
I052	52	705	52	705
I055	55	520	55	520
I060	60	890	60	890
I065	65	1000	65	1000
I067	67	1130	67	1130
I072	72	1150	72	1150
I075	75	1220	75	1220
I080	80	1100	80	1100

Table B-3 (Continued)
Lighting Fixture Wattage and Lumen Assumptions

Lighting Fixture Code	As-Built		Reference	
	Fixture Watts	Lamp lumens	Fixture Watts	Lamp lumens
I085	85	930	85	930
I090	90	1620	90	1620
I096	96	1700	96	1700
I100	100	1750	100	1750
I10X	1000	23100	1000	23100
I120	120	1450	120	1450
I125	125	61740	125	61740
I12X	1200	26400	1200	26400
I130	130	2210	130	2210
I135	135	2580	135	2580
I150	150	2850	150	2850
I15X	1500	30000	1500	30000
I16X	1600	35200	1600	35200
I200	200	3900	200	3900
I20X	2000	44000	2000	44000
I250	250	3100	250	3100
I300	300	3720	300	3720
I30X	3000	66000	3000	66000
I350	350	6000	350	6000
I400	400	6760	400	6760
I470	470	9400	470	9400
I500	500	10850	500	10850
I50X	5000	110000	5000	110000
I51X	5100	112200	5100	112200
I54X	5400	118800	5400	118800
I600	600	13200	600	13200
I625	625	13750	625	13750
I680	680	14960	680	14960
I700	700	15400	700	15400
I725	725	15950	725	15950

Table B-3 (Continued)
Lighting Fixture Wattage and Lumen Assumptions

Lighting Fixture Code	As-Built		Reference	
	Fixture Watts	Lamp lumens	Fixture Watts	Lamp lumens
I750	750	16700	750	16700
I900	900	19800	900	19800
L035	60	4800	205	7560
L055	85	8000	205	7560
L090	130	13500	455	20100
L135	180	22500	455	20100
L180	230	33000	775	37600
M032	40	1900	95	2240
M050	75	3300	95	2240
M070	95	4750	120	3560
M075	100	5100	205	7560
M100	130	6800	205	7560
M106	130	6800	205	7560
M10X	1080	88000	2150	97000
M150	195	13000	290	11000
M15X	1620	132000	3100	150400
M175	210	10800	290	11000
M200	247	13400	455	20100
M250	300	17000	455	20100
M300	350	21000	455	20100
M400	460	28800	775	37600
M500	565	37300	775	37600
M750	825	60000	1365	60300
Q050	50	500	50	500
Q075	75	1050	75	1050
Q100	100	1600	100	1600
Q10X	1000	21500	1000	21500
Q150	150	2700	150	2700
Q15X	1500	35800	1500	35800
Q175	175	3250	175	3250

Table B-3 (Continued)
Lighting Fixture Wattage and Lumen Assumptions

Lighting Fixture Code	As-Built		Reference	
	Fixture Watts	Lamp lumens	Fixture Watts	Lamp lumens
Q200	200	3800	200	3800
Q250	250	4900	250	4900
Q300	300	6000	300	6000
Q350	350	9600	350	9600
Q400	400	8250	400	8250
Q425	425	8900	425	8900
Q500	500	10750	500	10750
Q750	750	17000	750	17000
Q900	900	32000	900	32000
S035	45	2025	120	3560
S050	65	3600	120	3560
S060	80	4500	205	7560
S070	95	5450	205	7560
S075	100	5670	205	7560
S100	130	8550	290	11000
S10X	1100	126000	2730	120600
S150	195	14400	455	20100
S175	220	17100	455	20100
S200	245	19800	455	20100
S20X	2200	252000	4300	291000
S250	300	24750	455	20100
S300	365	33300	775	37600
S310	365	37000	775	37600
S400	465	45000	1075	48500
S500	575	49500	1075	48500
S800	905	90000	2150	120000
T042	42	890	42	890
T052	52	1100	52	1100
T072	72	1510	72	1510
T090	90	1900	90	1900

Table B-3 (Continued)
Lighting Fixture Wattage and Lumen Assumptions

Lighting Fixture Code	As-Built		Reference	
	Fixture Watts	Lamp lumens	Fixture Watts	Lamp lumens
T150	150	2700	150	2700
V040	50	1070	50	1070
V050	75	1276	75	1276
V075	95	2250	95	2250
V100	120	3200	120	3200
V10X	1075	47700	1075	47700
V175	205	7200	205	7200
V250	290	9800	290	9800
V400	455	18200	455	18200
V700	775	37600	700	37600
C056	58	3750	200	3900
Q10X	1000	35500	1000	35500
S1000	1100	126000	2730	120600

Table B-4
Exterior Lighting Operating Hours with Photocell Control

Month	Hours of Operation
January	16
February	14.4
March	12
April	10.5
May	8.8
June	8
July	8.1
August	9.5
September	12
October	13.2
November	15
December	16

Assumptions and Default Values

If a space was defined in the space database, but was not surveyed, then the lighting power for that space was set to the appropriate reference value. Operating hours were inferred from the occupancy schedule.

Equipment

Basic Equations

The following equations were used to calculate electricity consumption for miscellaneous equipment:

$$kWh = units \times kW_{conn} \times RLF \times FLH \qquad (E\text{-}1)$$

$$FLH = \sum_{j=1}^{3}\sum_{i=1}^{24}\frac{\%\ on_i}{100} \times n_j \qquad (E\text{-}2)$$

Variable Descriptions and Data Sources

Variable Name	Description	Source	Comments
kWh	Monthly equipment energy consumption	Equation E-1	These values were summed over all entries in the equipment inventories
units	Quantity of individual pieces of equipment at each site	Equipment inventory, Section 8 of survey and hospital space inventory, Section 13 of survey.	
kW_{conn}	Nameplate load (kW) of each unit of equipment	Equipment inventory, Section 8 of survey	
RLF	Rated load factor	Table B-5	Equal to the ratio of the actual running load to the nameplate load, varies with equipment type.
FLH	Equipment full-load hours	Equation E-2	
n_j	number of days per month corresponding to daytype j (weekday, saturday, sunday/holiday)	Table B-1	

Table B-5
Rated Load Factors

MECODE	Equipment Type	RLF
1	Office Equipment	0.3
2	Task Lighting	1.0
3	Computer Mainframe	0.3
4	Elevator, 2–5 Floors	0.5
5	Elevator, 6–10 Floors	0.5
6	Elevator, 11–20 Floors	0.5
7	Elevator, > 20 Floors	0.5
8	Escalator	0.5
9	Clothes Dryer	1.0
10	Sauna	1.0
11	Other, Appliance	0.5
12	Air Compressors	0.7
13	Welding	1.0
14	Battery Chargers	0.5
15	Machine Tools	0.7
16	Other, Motors and Fans	0.7
17	Other, Process Equipment	0.7
18	Other	0.7

Table B-6
Hospital Equipment Performance Characteristics (Source: AEC, 1989)

Space	Units	W/unit	RLF	hours per day
Clinical Lab	SF	4	0.5	24
Delivery Rm	Beds	3800	0.5	24
Diag Rad	SF	8	0.5	8
EEG	Stations	1900	0.5	8
Emerg. Rm	Beds	1400	0.5	24
Patient Rm	Beds	650	0.5	24
ICU	Beds	1430	0.5	24
MRI	machines		0.5	8
Nuclear Med	SF	10	0.5	8
Nursery	Beds	3800	0.5	24
Occ Therapy	SF	3.7	0.5	8
Pharmacy	SF	1.5	0.5	24
Phys Therapy	SF	1.5	0.5	8
Rad Therapy	machines	10000	0.5	8
Surgery	suites	7500	0.5	24

Assumptions and Default Values

If unit count missing, set to 1. Default values for other missing data were calculated by taking the average values for valid database entries, as shown in Table B-7.

Table B-7
Default Sizes and Operating Hours

MECODE	Equipment Type	Size (KW)	Weekday hours	Saturday hours	Sunday hours
1	Office Equipment	0.75	11.9	8.1	7.3
2	Task Lighting	0.075	7.4	4.2	3.6
3	Computer Mainframe	50.	24	24	24
4	Elevator, 2–5 Floors	20.	5.3	4.7	4
5	Elevator, 6–10 Floors	50.	10.7	7.2	7.2
6	Elevator, 11–20 Floors	N/A	10.7	7.2	7.2
7	Elevator, > 20 Floors	N/A	10.7	7.2	7.2
8	Escalator	96.	18	18	18
9	Clothes Dryer	7.	4.1	2.9	2.7
10	Sauna		8	8	8
11	Other, Appliance	11.	10.9	9.7	9.1
12	Air Compressors	8.6	4.9	1.6	1.3
13	Welding	18.	4.4	0.2	0.2
14	Battery Chargers	1.5	5.3	2.7	2.7
15	Machine Tools	5.5	4.3	1.8	0.9
16	Other, Motors and Fans	17.	10.3	7.4	7.1
17	Other, Process Equipment	26.	7.9	5.4	4.7
18	Other	6.4	12.4	9.6	10.1

HVAC

Basic Equations

Heating

$$kBtu_{heat} = \sum^{\text{all spaces}} \left[a_1 \frac{U_o A_t}{A_f} + a_2 \frac{L}{A_f} + a_3 \frac{E}{A_f} + a_4 \frac{OA}{A_f} + \sum_{i=1}^{N,S,E,W} \left(a_{4+i} \frac{A_{g,i} SC_i}{A_f} k_{o,i} \right) \right] \times A_f$$

$$kWh_{heat} = \frac{kBtu_{heat}}{COP \times 3.413 \times f_{heat}}$$

Cooling

$$kBtu_{cool} = \sum^{\text{all spaces}} \left[b_1 \frac{U_o A_t}{A_f} + b_2 \frac{L}{A_f} + b_3 \frac{E}{A_f} + b_4 \frac{OA}{A_f} + \sum_{i=1}^{N,S,E,W} \left(b_{4+i} \frac{A_{g,i} SC_i}{A_f} k_{o,i} \right) \right] \times A_f$$

$$kWh_{cool} = \frac{kBtu_{cool}}{EER \times f_{cool}}$$

Constant load, fixed schedule auxiliaries

$$kWh_{aux} = \frac{hp \times RLF \times .746 \times OH}{\eta_{motor}} \qquad \text{(A-1)}$$

Variable load auxiliaries

$$kWh_{aux} = \sum^{\text{all spaces}} \left[c_1 \frac{U_o A_t}{A_f} + c_2 \frac{L}{A_f} + c_3 \frac{E}{A_f} + c_4 \frac{OA}{A_f} + \sum_{i=1}^{N,S,E,W} \left(c_{4+i} \frac{A_{g,i} SC_i}{A_f} k_{o,i} \right) \right] \times A_f \times \frac{\eta_{ref}}{\eta_{motor}} \qquad \text{(A-2)}$$

Variable Descriptions and Data Sources

Variable Name	Description	Source	Comments
kWh	Monthly heating energy consumption.	Equation H-1	Used for core and perimeter spaces
U_o	Overall envelope thermal conductance, including walls, roof and glazing.	Building envelope information, Section 3 of survey	Area-weighted conductance considering wall and roof type, thermal short-circuits, insulation R-value, no. of panes, window treatment, and frame type
A_t	Total surface area of walls, roof and glazing corresponding to U_o	Building envelope information, Section 3 of survey	Set to zero for core spaces
$A_{g,i}$	Total glazing surface area per orientation i	Building envelope information, Section 3 of survey	Set to zero for core spaces
SC	Glazing shading coefficient, adjusted for interior shading	Building envelope information, Section 3 of survey	Considers no. of panes, window treatment, and interior shading
$k_{o,i}$	Exterior shading adjustment for orientation i	Building envelope information, Section 3 of survey	Considers exterior shading from trees, buildings and fixed overhangs
A_f	Floor area	Building envelope information, building space inventory	
L	Lighting energy consumption	From lighting end-use calculations.	
E	Equipment internal heat gains	From equipment end-use calculations	Considers miscellaneous equipment and cooking heat gains, and refrigeration room effect
OA	Outdoor air CFM	Building code recommended quantities according to space types listed in building space inventory, Section 2 of survey	CFM/person, occupant density (persons per kSF) from code. See Table B-8.
a	Regression coefficients for heating load	Table B-11	Varies by climate and heating system type
COP	Full-load heating efficiency at ARI rated conditions	From heating system inventory, Section 5 of survey	

Variable Name	Description	Source	Comments
f_{heat}	Heating seasonal adjustment factor	Table B-14.	Efficiency multipliers from DOE-2 analysis of prototypical buildings, used primarily for heat pumps.
b	Regression coefficients for cooling load	Table B-12.	Varies by climate and cooling system type
EER	Full-load cooling efficiency at ARI rated conditions	From air-conditioning system inventory, Section 6 of survey	
f_{cool}	Cooling seasonal adjustment factor	Table B-15.	Efficiency multipliers from DOE-2 analysis of prototypical buildings. Includes condenser (or cooling tower) pump and fan energy.
c	Regression coefficients for fan energy	Table B-13.	Varies by climate fan type
hp	Pump or fan nameplate hp	Air handling system inventory (Section 4), heating system inventory (Section 5), air conditioning system inventory (Section 6)	Constant load, constant schedule pumps and fans only (determined from control code).
RLF	Rated load factor	0.7	Equal to the ratio of the pump or fan running load to the nameplate power
η_{motor}	Pump or fan motor efficiency	Air handling system inventory (Section 4), heating system inventory (Section 5), air conditioning system inventory (Section 6)	Varies with motor size. If efficiency not listed, standard efficiency motor assumed.
OH	Pump or fan operating hours	Air handling system inventory (Section 4), heating system inventory (Section 5), air conditioning system inventory (Section 6)	

Table B-8
Outdoor Air Quantities by Space Type (Source: ASHRAE Standard 62-81)

OCCCODE	Occupancy	CFM/unit
1	Office	0.035/SF
2	Retail	0.10/SF
3	Grocery	0.05/SF
4	School	0.25/SF
5	College	0.25/SF
6	Fast Food	0.70/SF
7	Restaurant	0.50/SF
8	Kitchen	0.20/SF
9	Assembly	0.84/SF
10	Commons	0.15/SF
11	Hotel/Motel	15.0/Room
12	Mixed-Use	0.035/SF
13	Multi-Family	0.15/SF
14	Hospital	0.30/SF
15	Other Medical	0.30/SF
16	Laundry	0.60/SF
17	Warehouse	0.05/SF
18	Refrigerated	0.05/SF
19	Service	1.50/SF
20	Industrial	0.15/SF
21	Computer Center	0.035/SF
22	Mixed Use	0.035/SF
23	Other	0.035/SF
24	Not used	N/A
25	Parking Garage	1.5/SF
26	Mech/Equip Room	0.05/SF
27	Library	0.10/SF
28	Gymnasium	0.60/SF
29	Laboratory	0.30/SF
30	Greenhouse	0.05/SF
31	Storage	0.05/SF
32	Unfinished	0.0/SF

Table B-9
Thermal Properties of Opaque Wall and Roof Constructions

Wall or Roof Type Code	Description	Fixed R-value[1]	Notes
1	No exterior wall	0	
2	4 in face brick plus brick	2.07	
3	4 in face brick plus concrete	1.78	
4	4 in face brick plus block	2.39	
5	Poured concrete wall plus finish	1.35	
6	Concrete block plus finish	1.96	
7	Frame/curtain wall	$3.1-0.3 \times R_{insul}$	Wood stud construction assumed. Fixed R-value a function of insulation R-value.
8	No roof	0.0	
9	Sheet metal roof	1.78	
10	Wood deck with single ply membrane	2.26	
11	Wood deck with built-up roof	2.30	
12	Concrete with single ply membrane	1.57	
13	Concrete with built-up roof	1.61	

1 The overall building shell conductance was calculated from the wall or roof type indicated on the survey and the insulation R-value. Based on the wall type selected, a "fixed" R-value was added to the R-value of the insulation to account for the thermal resistance of the basic wall or roof section, including air film resistances.

Table B-10
Glazing Property Assumptions

Glass Type	Frame Type	Window Covering	No. of Panes	As-Built U-value	As-Built Shading Coef	Reference U-value	Reference Shading Coef
Clear	Metal	Drapes	2	0.72	0.52	0.72	0.52
Clear	Metal	Horiz, Dark	2	0.72	0.59	0.72	0.59
Clear	Metal	Horiz, Light	1	1.23	0.64	0.72	0.64
Clear	Metal	Horiz, Light	2	0.72	0.55	0.72	0.55
Clear	Metal	Horiz, Light	3	0.58	0.50	0.72	0.50
Clear	Metal	None	1	1.23	0.95	0.72	0.95
Clear	Metal	None	2	0.72	0.82	0.72	0.82
Clear	Metal	Opaque, Light	1	1.23	0.37	0.72	0.37
Clear	Metal	Opaque, Light	2	0.72	0.32	0.72	0.32
Clear	Metal	Translucent	1	1.23	0.42	0.72	0.42
Clear	Metal	Verti, Light	2	0.72	0.55	0.72	0.55
Clear	Thermal	Drapes	2	0.59	0.52	0.72	0.52
Clear	Thermal	Horiz, Dark	2	0.59	0.59	0.72	0.59
Clear	Thermal	Horiz, Dark	3	0.45	0.57	0.72	0.57
Clear	Thermal	Horiz, Light	1	1.10	0.64	0.72	0.64
Clear	Thermal	Horiz, Light	2	0.59	0.55	0.72	0.55
Clear	Thermal	None	2	0.59	0.82	0.72	0.82
Clear	Thermal	Opaque, Dark	2	0.59	0.67	0.72	0.67
Clear	Thermal	Translucent	2	0.59	0.38	0.72	0.38
Clear	Thermal	Verti, Light	2	0.59	0.55	0.72	0.55
Clear	Wood	Horiz, Dark	2	0.49	0.59	0.72	0.59
Clear	Wood	Horiz, Light	2	0.49	0.55	0.72	0.55
Clear	Wood	None	1	0.98	0.95	0.72	0.95
Clear	Wood	None	2	0.49	0.82	0.72	0.82
Clear	Wood	Opaque, Light	2	0.49	0.32	0.72	0.32
Clear	Wood	Translucent	2	0.49	0.38	0.72	0.38
Clear	Wood	Verti, Light	2	0.49	0.55	0.72	0.55
Clear Gas	Metal	Horiz, Light	2	0.69	0.55	0.72	0.55
Clear Gas	Metal	None	2	0.69	0.82	0.72	0.82

Table B-10 (Continued)
Glazing Property Assumptions

Glass Type	Frame Type	Window Covering	No. of Panes	As-Built U-value	As-Built Shading Coef	Reference U-value	Reference Shading Coef
Clear Gas	Wood	Horiz, Light	2	0.47	0.55	0.72	0.55
Clear Gas	Wood	None	2	0.47	0.82	0.72	0.82
Clear Low-E Gas	Metal	None	2	0.55	0.68	0.72	0.82
Low-E	Metal	Drapes	2	0.60	0.43	0.72	0.52
Low-E	Metal	Horiz, Light	2	0.60	0.45	0.72	0.55
Low-E	Metal	None	2	0.60	0.68	0.72	0.82
Low-E	Thermal	Horiz, Dark	2	0.46	0.49	0.72	0.59
Low-E	Thermal	Horiz, Light	2	0.46	0.45	0.72	0.55
Low-E	Thermal	None	2	0.46	0.68	0.72	0.82
Low-E	Thermal	Verti, Light	2	0.46	0.45	0.72	0.55
Low-E Gas	Metal	None	2	0.55	0.68	0.72	0.82
Reflect	Metal	Horiz, Dark	2	0.72	0.24	0.72	0.24
Reflect	Metal	Horiz, Light	2	0.72	0.23	0.72	0.23
Reflect	Metal	None	2	0.72	0.30	0.72	0.30
Reflect	Metal	Verti, Light	2	0.72	0.23	0.72	0.23
Reflect	Thermal	Horiz, Light	2	0.59	0.23	0.72	0.23
Reflect	Thermal	None	2	0.59	0.30	0.72	0.30
Reflect Clear	Metal	None	2	0.72	0.30	0.72	0.30
Tinted	Metal	Drapes	2	0.72	0.41	0.72	0.41
Tinted	Metal	Horiz, Dark	2	0.72	0.36	0.72	0.36
Tinted	Metal	Horiz, Light	2	0.72	0.34	0.72	0.34
Tinted	Metal	None	2	0.72	0.48	0.72	0.48
Tinted	Metal	Opaque, Dark	2	0.72	0.38	0.72	0.38
Tinted	Metal	Opaque, Light	2	0.72	0.20	0.72	0.20
Tinted	Metal	Translucent	2	0.72	0.29	0.72	0.29
Tinted	Metal	Verti, Light	2	0.72	0.34	0.72	0.34
Tinted	Thermal	Drapes	2	0.59	0.41	0.72	0.41
Tinted	Thermal	Drapes	3	0.45	0.40	0.72	0.40
Tinted	Thermal	Horiz, Dark	2	0.59	0.36	0.72	0.36

Table B-10 (Continued)
Glazing Property Assumptions

Glass Type	Frame Type	Window Covering	No. of Panes	As-Built U-value	As-Built Shading Coef	Reference U-value	Reference Shading Coef
Tinted	Thermal	Horiz, Light	2	0.59	0.34	0.72	0.34
Tinted	Thermal	None	2	0.59	0.48	0.72	0.48
Tinted	Thermal	Opaque, Light	2	0.59	0.20	0.72	0.20
Tinted	Thermal	Verti, Light	2	0.59	0.34	0.72	0.34
Tinted	Wood	Horiz, Light	2	0.49	0.34	0.72	0.34
Tinted	Wood	None	2	0.49	0.48	0.72	0.48
Tinted	Wood	Verti, Light	2	0.49	0.34	0.72	0.34
Tinted Low-E	Metal	Horiz, Light	2	0.60	0.28	0.72	0.34
Tinted Low-E	Metal	None	2	0.60	0.40	0.72	0.48
Tinted Low-E	Thermal	Horiz, Light	2	0.46	0.28	0.72	0.34

Table B-11
Heating Coefficients

City	Fan Type	Fan Sched.	Regression Coefficients a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8
Boise	CV	10hr	–55.204	1.021	1.137	–70.114	35.637	54.464	50.852	51.100
Boise	CYCLES	10hr	–51.140	0.498	0.538	–9.687	22.353	28.549	24.220	26.119
Boise	VAV	10hr	–67.378	1.144	1.282	–82.461	35.141	58.831	47.874	35.939
Boise	CV	24hr	–63.586	1.488	1.887	–191.823	59.459	102.687	98.668	101.298
Boise	CYCLES	24hr	–77.438	0.735	0.822	–15.986	24.613	25.107	24.775	25.403
Boise	VAV	24hr	–79.680	1.613	2.004	–234.873	47.228	92.743	61.343	61.439
Boise	CV	24sb	–45.528	1.304	1.591	–146.573	54.663	96.425	91.812	94.376
Boise	CYCLES	24sb	–54.767	0.517	0.550	–8.372	24.728	34.522	26.558	28.653
Boise	VAV	24sb	–59.445	1.401	1.681	–177.940	43.120	83.474	59.537	55.149
Pocatello	CV	10hr	–67.064	1.222	1.375	–95.013	40.300	74.509	68.798	62.755
Pocatello	CYCLES	10hr	–62.735	0.606	0.658	–14.538	33.929	39.200	39.631	32.590
Pocatello	VAV	10hr	–83.627	1.323	1.497	–103.818	39.154	67.161	30.343	55.749
Pocatello	CV	24hr	–71.109	1.614	2.084	–236.575	70.575	123.139	120.899	117.930
Pocatello	CYCLES	24hr	–89.846	0.847	0.949	–22.669	39.000	30.559	35.851	33.849
Pocatello	VAV	24hr	–92.652	1.711	2.140	–270.293	56.392	144.634	85.206	75.487

Table B-11 (Continued)
Heating Coefficients

City	Fan Type	Fan Sched.	Regression Coefficients							
			a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8
Pocatello	CV	24sb	–53.817	1.457	1.827	–188.549	61.896	120.796	116.305	109.896
Pocatello	CYCLES	24sb	–66.711	0.625	0.671	–12.985	36.997	42.766	41.599	35.305
Pocatello	VAV	24sb	–71.584	1.480	1.813	–210.578	46.391	126.033	73.283	68.086
Portland	CV	10hr	–40.542	0.846	0.935	–52.980	33.302	43.234	41.806	41.995
Portland	CYCLES	10hr	–37.034	0.360	0.380	–4.686	17.937	20.250	18.370	18.999
Portland	VAV	10hr	–52.474	1.079	1.204	–70.459	42.611	48.292	44.007	40.104
Portland	CV	24hr	–53.869	1.464	1.870	–160.453	61.353	92.533	90.713	90.577
Portland	CYCLES	24hr	–61.560	0.587	0.635	–8.172	22.993	23.535	22.712	22.753
Portland	VAV	24hr	–70.567	1.686	2.130	–209.877	54.647	67.958	54.432	56.990
Portland	CV	24sb	–34.290	1.144	1.387	–111.084	51.505	77.888	75.831	76.605
Portland	CYCLES	24sb	–39.104	0.368	0.384	–3.682	19.542	21.820	20.032	20.597
Portland	VAV	24sb	–48.476	1.426	1.713	–150.898	50.201	61.819	52.537	51.715
Seattle	CV	10hr	–47.266	1.011	1.117	–63.578	39.772	51.431	49.778	50.114
Seattle	CYCLES	10hr	–43.128	0.410	0.435	–4.953	22.528	24.517	22.737	23.409
Seattle	VAV	10hr	–61.602	1.232	1.373	–78.752	45.031	52.978	46.320	41.329
Seattle	CV	24hr	–62.295	1.680	2.149	–182.380	69.180	104.641	101.758	102.076
Seattle	CYCLES	24hr	–70.453	0.664	0.715	–8.681	28.607	28.705	27.729	27.979
Seattle	VAV	24hr	–82.290	1.766	2.244	–218.446	49.398	64.279	49.351	52.228
Seattle	CV	24sb	–40.280	1.336	1.622	–129.044	59.228	90.118	87.051	88.233
Seattle	CYCLES	24sb	–45.406	0.419	0.438	–3.826	24.287	26.112	24.529	25.045
Seattle	VAV	24sb	–58.020	1.517	1.839	–159.449	46.469	59.526	49.015	47.985
Yakima	CV	10hr	–52.098	0.978	1.101	–71.364	28.862	52.203	46.524	43.094
Yakima	CYCLES	10hr	–47.442	0.496	0.534	–12.210	20.760	26.821	24.854	20.562
Yakima	VAV	10hr	–72.877	1.176	1.331	–80.924	38.340	36.936	25.480	41.167
Yakima	CV	24hr	–58.780	1.482	1.934	–204.289	61.469	100.390	97.449	97.419
Yakima	CYCLES	24hr	–72.261	0.725	0.808	–19.322	26.570	22.794	25.958	23.403
Yakima	VAV	24hr	–90.845	1.696	2.144	–236.961	61.569	108.850	77.397	63.777
Yakima	CV	24sb	–41.820	1.259	1.590	–152.758	48.352	92.548	86.825	83.403
Yakima	CYCLES	24sb	–50.442	0.512	0.545	–11.070	23.166	27.241	26.851	22.980
Yakima	VAV	24sb	–65.794	1.443	1.775	–178.975	50.012	92.123	64.038	54.855

Note: 24sb denotes 24 hour operation with nighttime room temperature setback.

Table B-12
Cooling Coefficients

City	Fan Type	OA Type	Fan Sched.	Regression Coefficients b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8
Boise	CV	ECON	10hr	9.723	0.716	0.912	13.640	54.797	117.289	118.892	110.911
Boise	CV	FIXED	10hr	6.976	1.487	1.739	−6.206	65.606	292.287	231.700	215.135
Boise	CYCLES	ECON	10hr	7.842	0.934	1.067	12.562	63.262	136.266	135.502	124.910
Boise	CYCLES	FIXED	10hr	−1.543	1.966	2.123	−3.999	69.238	265.677	214.901	189.032
Boise	VAV	ECON	10hr	10.443	0.917	1.074	24.535	49.369	136.304	136.141	117.788
Boise	VAV	FIXED	10hr	5.124	1.175	1.366	16.846	35.290	178.678	149.621	112.655
Boise	CV	ECON	24hr	15.633	0.746	1.001	12.572	56.778	127.235	127.613	131.643
Boise	CV	FIXED	24hr	15.894	1.550	1.879	−12.134	70.367	342.171	267.276	269.759
Boise	CYCLES	ECON	24hr	11.633	1.127	1.277	11.057	67.115	148.185	146.818	151.252
Boise	CYCLES	FIXED	24hr	1.557	2.357	2.472	−7.443	78.080	298.450	234.905	224.535
Boise	VAV	ECON	24hr	16.299	0.831	0.963	52.509	40.685	148.045	144.338	150.745
Boise	VAV	FIXED	24hr	10.742	0.933	1.007	46.511	17.151	175.680	140.308	136.914
Boise	CV	ECON	24sb	13.316	0.735	0.963	6.668	54.571	122.434	123.700	116.963
Boise	CV	FIXED	24sb	13.396	1.331	1.634	−14.140	58.387	300.561	238.077	227.570
Boise	CYCLES	ECON	24sb	10.467	0.784	1.277	5.282	55.339	140.180	152.334	140.514
Boise	CYCLES	FIXED	24sb	4.121	1.586	2.036	−6.298	−65.501	287.372	207.039	232.585
Boise	VAV	ECON	24sb	14.032	0.716	0.843	55.818	29.427	128.676	127.233	119.931
Boise	VAV	FIXED	24sb	8.984	0.720	0.811	51.841	4.820	149.196	117.274	99.142
Pocatello	CV	ECON	10hr	5.716	0.648	0.836	12.283	47.038	68.496	74.467	109.404
Pocatello	CV	FIXED	10hr	5.067	1.216	1.471	−5.049	57.697	230.475	167.217	225.585
Pocatello	CYCLES	ECON	10hr	3.351	0.795	0.937	11.565	50.621	81.718	79.587	118.143
Pocatello	CYCLES	FIXED	10hr	−4.315	1.771	1.922	−6.534	56.285	216.675	150.964	205.874
Pocatello	VAV	ECON	10hr	7.527	0.729	0.889	24.144	38.560	85.467	75.278	120.844
Pocatello	VAV	FIXED	10hr	4.867	0.955	1.162	17.457	29.820	110.190	66.567	140.737
Pocatello	CV	ECON	24hr	8.713	0.631	0.869	9.046	40.000	66.916	70.361	107.610
Pocatello	CV	FIXED	24hr	12.394	1.237	1.584	−16.484	53.672	316.155	240.454	259.660
Pocatello	CYCLES	ECON	24hr	5.141	0.945	1.099	8.860	48.700	89.103	87.033	124.177
Pocatello	CYCLES	FIXED	24hr	−2.124	2.158	2.354	−15.359	63.243	293.147	220.421	226.000
Pocatello	VAV	ECON	24hr	12.076	0.628	0.795	44.632	20.509	86.297	81.684	124.470
Pocatello	VAV	FIXED	24hr	10.602	0.675	0.809	39.064	1.159	118.757	96.062	123.891

Table B-12 (Continued)
Cooling Coefficients

City	Fan Type	OA Type	Fan Sched.	Regression Coefficients							
				b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8
Pocatello	CV	ECON	24sb	8.059	0.644	0.851	4.937	45.117	67.339	66.597	109.385
Pocatello	CV	FIXED	24sb	10.002	1.057	1.367	–15.476	47.084	264.181	204.298	229.578
Pocatello	CYCLES	ECON	24sb	–2.836	0.845	1.127	7.275	28.902	48.441	62.991	134.922
Pocatello	CYCLES	FIXED	24sb	–4.733	0.231	1.922	3.482	75.702	194.571	231.534	225.470
Pocatello	VAV	ECON	24sb	11.463	0.576	0.747	45.565	17.360	81.301	76.173	115.489
Pocatello	VAV	FIXED	24sb	8.517	0.561	0.695	43.326	–0.858	91.042	69.098	109.004
Portland	CV	ECON	10hr	4.044	0.536	0.784	7.139	43.699	84.452	71.203	78.047
Portland	CV	FIXED	10hr	–0.040	1.686	1.995	–16.723	61.421	205.627	155.422	169.787
Portland	CYCLES	ECON	10hr	2.305	0.875	1.081	7.170	58.235	121.992	101.969	109.665
Portland	CYCLES	FIXED	10hr	–8.467	2.119	2.285	–9.243	69.201	188.934	141.305	150.551
Portland	VAV	ECON	10hr	5.422	0.792	0.956	25.192	33.385	103.579	84.192	88.492
Portland	VAV	FIXED	10hr	–1.027	1.181	1.386	16.119	14.655	107.390	70.188	67.365
Portland	CV	ECON	24hr	8.497	0.477	0.753	4.905	42.953	86.050	72.640	85.547
Portland	CV	FIXED	24hr	8.457	1.597	2.001	–24.689	61.831	241.635	182.662	210.534
Portland	CYCLES	ECON	24hr	4.731	1.009	1.249	5.153	61.781	132.803	110.551	127.955
Portland	CYCLES	FIXED	24hr	–6.479	2.458	2.621	–13.596	76.044	207.020	153.396	172.337
Portland	VAV	ECON	24hr	10.739	0.666	0.798	53.299	24.793	112.759	89.808	112.428
Portland	VAV	FIXED	24hr	4.095	0.806	0.862	48.328	–1.496	97.750	56.179	77.731
Portland	CV	ECON	24sb	7.311	0.498	0.765	0.584	41.137	85.294	72.562	78.789
Portland	CV	FIXED	24sb	7.265	1.368	1.721	–23.553	50.184	206.520	155.073	175.621
Portland	CYCLES	ECON	24sb	2.445	0.862	1.233	4.827	43.245	130.959	99.830	118.159
Portland	CYCLES	FIXED	24sb	–3.630	1.327	2.008	–5.551	77.716	208.738	169.477	168.634
Portland	VAV	ECON	24sb	9.633	0.561	0.697	56.047	14.385	97.310	76.924	90.540
Portland	VAV	FIXED	24sb	3.312	0.573	0.660	53.821	–11.677	77.419	39.648	51.934
Seattle	CV	ECON	10hr	0.968	0.345	0.531	2.970	26.549	55.791	42.904	50.875
Seattle	CV	FIXED	10hr	–3.293	1.453	1.751	–22.330	42.757	184.338	133.611	145.184
Seattle	CYCLES	ECON	10hr	–0.172	0.625	0.801	3.978	40.713	91.959	74.936	81.746
Seattle	CYCLES	FIXED	10hr	–11.538	1.968	2.136	–15.316	54.378	172.550	125.253	130.769
Seattle	VAV	ECON	10hr	3.750	0.580	0.719	17.436	22.120	83.160	64.707	70.163
Seattle	VAV	FIXED	10hr	–1.874	0.987	1.177	7.697	3.840	93.310	56.784	53.291
Seattle	CV	ECON	24hr	3.964	0.288	0.486	1.601	24.730	55.728	42.779	54.752

Table B-12 (Continued)
Cooling Coefficients

City	Fan Type	OA Type	Fan Sched.	Regression Coefficients							
				b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8
Seattle	CV	FIXED	24hr	3.861	1.270	1.614	–26.797	42.106	217.837	158.005	182.895
Seattle	CYCLES	ECON	24hr	1.408	0.713	0.905	2.884	42.416	97.850	79.632	93.102
Seattle	CYCLES	FIXED	24hr	–10.394	2.266	2.438	–19.407	60.076	190.414	137.039	151.943
Seattle	VAV	ECON	24hr	8.591	0.500	0.625	36.917	18.139	95.970	74.901	92.451
Seattle	VAV	FIXED	24hr	3.599	0.664	0.715	31.547	–6.029	88.945	49.201	64.360
Seattle	CV	ECON	24sb	3.373	0.307	0.504	–1.490	23.969	56.474	43.562	51.297
Seattle	CV	FIXED	24sb	3.416	1.086	1.394	–25.007	32.691	184.133	132.012	148.366
Seattle	CYCLES	ECON	24sb	–0.116	0.592	0.892	2.849	33.250	91.208	77.662	86.310
Seattle	CYCLES	FIXED	24sb	–8.257	1.215	1.997	–10.117	44.777	165.630	141.164	132.157
Seattle	VAV	ECON	24sb	8.056	0.423	0.551	38.831	10.012	84.626	65.553	76.685
Seattle	VAV	FIXED	24sb	3.073	0.457	0.533	36.599	–13.807	71.744	34.803	43.116
Yakima	CV	ECON	10hr	2.925	0.710	0.957	12.270	46.441	80.666	67.552	100.568
Yakima	CV	FIXED	10hr	1.740	1.398	1.694	–5.236	57.478	209.287	142.978	188.496
Yakima	CYCLES	ECON	10hr	0.266	0.915	1.096	11.579	52.188	95.390	78.562	113.200
Yakima	CYCLES	FIXED	10hr	–6.602	1.869	2.048	–5.394	57.389	192.182	128.958	167.847
Yakima	VAV	ECON	10hr	8.723	0.791	0.980	29.148	30.252	84.712	61.518	107.624
Yakima	VAV	FIXED	10hr	9.577	0.998	1.232	22.171	16.276	90.344	40.399	103.425
Yakima	CV	ECON	24hr	7.479	0.651	0.940	8.687	38.428	75.633	63.660	96.938
Yakima	CV	FIXED	24hr	9.784	1.351	1.733	–16.076	49.816	279.678	195.729	216.219
Yakima	CYCLES	ECON	24hr	3.194	1.027	1.213	9.273	49.474	96.985	80.770	116.913
Yakima	CYCLES	FIXED	24hr	–4.083	2.231	2.436	–13.589	61.951	255.037	179.519	185.079
Yakima	VAV	ECON	24hr	15.315	0.632	0.820	49.884	8.502	84.253	61.762	107.332
Yakima	VAV	FIXED	24hr	21.533	0.642	0.781	43.024	–16.796	101.161	53.086	80.494
Yakima	CV	ECON	24sb	6.579	0.682	0.954	2.694	41.881	77.031	63.170	100.184
Yakima	CV	FIXED	24sb	7.731	1.178	1.522	–16.574	45.284	236.493	164.313	190.533
Yakima	CYCLES	ECON	24sb	–2.007	0.964	1.204	11.667	25.297	75.034	57.735	128.023
Yakima	CYCLES	FIXED	24sb	–7.304	1.136	2.259	–0.142	39.331	215.110	147.618	206.633
Yakima	VAV	ECON	24sb	14.504	0.552	0.748	51.564	4.440	80.056	58.207	99.622
Yakima	VAV	FIXED	24sb	18.020	0.499	0.641	48.734	–17.239	72.095	31.604	68.555

Table B-13
Auxiliary Energy Coefficients

City	Fan Type	Fan Sched.	Regression Coefficients c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8
Boise	VAV-ASD	10hr	–0.297	0.034	0.061	2.146	–0.905	6.311	4.640	5.224
Boise	VAV-INLET	10hr	2.411	0.064	0.113	0.729	3.603	22.491	18.128	22.607
Boise	VAV-DISCH	10hr	3.819	0.088	0.156	1.243	6.185	35.498	28.243	34.640
Boise	VAV-ASD	24hr	–0.364	–0.005	0.004	6.276	–5.474	–0.370	–1.861	–1.420
Boise	VAV-INLET	24hr	3.962	0.072	0.132	4.033	6.005	30.533	26.811	29.434
Boise	VAV-DISCH	24hr	5.943	0.107	0.197	6.500	9.797	46.617	40.890	44.075
Boise	VAV-ASD	24sb	–0.383	–0.011	0.000	6.302	–6.082	–0.574	–2.049	–2.014
Boise	VAV-INLET	24sb	3.957	0.069	0.130	4.027	5.774	30.485	26.781	29.225
Boise	VAV-DISCH	24sb	5.921	0.102	0.194	6.565	9.318	46.375	40.609	43.509
Boise	CYCLES	10hr	0.640	0.051	0.071	0.001	1.887	7.590	6.410	5.821
Boise	CYCLES	24hr	1.369	0.049	0.063	0.073	2.106	8.060	6.532	6.361
Boise	CYCLES	24sb	0.854	0.040	0.062	–0.108	1.554	7.045	6.321	5.455
Pocatello	VAV-ASD	10hr	–0.449	0.024	0.044	3.051	–2.039	0.333	–0.780	2.394
Pocatello	VAV-INLET	10hr	1.981	0.047	0.089	1.236	2.041	18.371	16.962	18.401
Pocatello	VAV-DISCH	10hr	3.233	0.068	0.126	1.565	4.645	30.169	27.682	28.898
Pocatello	VAV-ASD	24hr	–0.986	–0.016	–0.017	7.892	–6.518	–4.958	–6.143	–5.115
Pocatello	VAV-INLET	24hr	2.946	0.046	0.099	4.742	4.412	27.056	24.548	27.086
Pocatello	VAV-DISCH	24hr	4.687	0.084	0.158	6.621	10.167	42.806	38.628	41.868
Pocatello	VAV-ASD	24sb	–1.035	–0.019	–0.019	7.950	–6.643	–5.926	–7.128	–5.004
Pocatello	VAV-INLET	24sb	2.931	0.045	0.099	4.747	4.361	26.711	24.194	27.133
Pocatello	VAV-DISCH	24sb	4.637	0.081	0.155	6.718	10.097	41.806	37.711	41.939
Pocatello	CYCLES	10hr	0.730	0.043	0.062	–0.009	1.219	6.716	4.318	5.823
Pocatello	CYCLES	24hr	1.425	0.043	0.056	0.046	1.513	6.943	5.447	5.789
Pocatello	CYCLES	24sb	0.634	0.040	0.057	–0.036	0.669	4.894	3.914	5.603
Portland	VAV-ASD	10hr	–0.521	0.024	0.039	2.670	–1.939	0.720	–1.084	0.271
Portland	VAV-INLET	10hr	1.740	0.051	0.091	1.227	2.132	14.041	11.159	15.392
Portland	VAV-DISCH	10hr	2.750	0.079	0.138	1.700	4.584	22.552	17.950	23.992
Portland	VAV-ASD	24hr	–0.889	–0.015	–0.010	7.443	–5.729	–4.584	–6.166	–5.168
Portland	VAV-INLET	24hr	3.115	0.064	0.122	4.631	4.738	23.417	21.001	23.355
Portland	VAV-DISCH	24hr	4.780	0.104	0.189	6.917	9.763	36.076	32.288	35.464

Table B-13 (Continued)
Auxiliary Energy Coefficients

City	Fan Type	Fan Sched.	Regression Coefficients							
			c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8
Portland	VAV-ASD	24sb	–0.895	–0.021	–0.015	7.535	–6.175	–4.914	–6.433	–5.600
Portland	VAV-INLET	24sb	3.113	0.061	0.120	4.659	4.553	23.303	20.926	23.201
Portland	VAV-DISCH	24sb	4.774	0.099	0.185	7.012	9.474	35.777	31.972	35.042
Portland	CYCLES	10hr	0.228	0.052	0.070	–0.140	1.466	5.122	3.675	4.149
Portland	CYCLES	24hr	0.798	0.054	0.069	–0.118	1.579	5.369	3.816	4.466
Portland	CYCLES	24sb	0.297	0.049	0.067	–0.135	1.152	5.113	3.458	3.954
Seattle	VAV-ASD	10hr	–0.606	0.016	0.027	3.089	–2.509	–0.403	–2.144	–1.169
Seattle	VAV-INLET	10hr	1.493	0.043	0.078	1.520	1.769	13.338	10.568	14.166
Seattle	VAV-DISCH	10hr	2.399	0.069	0.122	1.976	4.346	21.651	17.180	22.456
Seattle	VAV-ASD	24hr	–1.142	–0.019	–0.020	8.088	–6.165	–5.768	–7.410	–6.572
Seattle	VAV-INLET	24hr	2.483	0.058	0.114	4.903	4.483	23.586	20.858	23.102
Seattle	VAV-DISCH	24hr	3.924	0.100	0.180	6.951	10.339	36.882	32.587	35.662
Seattle	VAV-ASD	24sb	–1.139	–0.025	–0.025	8.188	–6.524	–6.083	–7.683	–6.982
Seattle	VAV-INLET	24sb	2.485	0.055	0.112	4.935	4.332	23.480	20.784	22.960
Seattle	VAV-DISCH	24sb	3.923	0.096	0.176	7.049	10.114	36.595	32.266	35.254
Seattle	CYCLES	10hr	0.222	0.048	0.064	–0.189	1.005	4.476	3.072	3.415
Seattle	CYCLES	24hr	0.822	0.049	0.063	–0.190	1.096	4.738	3.240	3.747
Seattle	CYCLES	24sb	0.283	0.045	0.063	–0.189	0.780	4.287	3.042	3.257
Yakima	VAV-ASD	10hr	–0.031	0.023	0.040	3.187	–2.506	–1.016	–2.699	–0.443
Yakima	VAV-INLET	10hr	1.555	0.047	0.088	1.509	1.605	15.462	12.591	14.427
Yakima	VAV-DISCH	10hr	2.917	0.072	0.127	1.481	4.559	26.215	21.538	23.258
Yakima	VAV-ASD	24hr	–0.178	–0.023	–0.027	8.425	–7.655	–7.782	–9.527	–8.924
Yakima	VAV–INLET	24hr	2.483	0.044	0.095	5.274	2.941	21.693	17.990	22.030
Yakima	VAV-DISCH	24hr	4.677	0.087	0.159	6.424	9.480	35.958	30.081	35.306
Yakima	VAV-ASD	24sb	–0.211	–0.028	–0.031	8.542	–7.768	–9.052	–10.488	–9.036
Yakima	VAV-INLET	24sb	2.468	0.042	0.094	5.304	2.891	21.239	17.646	22.004
Yakima	VAV-DISCH	24sb	4.659	0.084	0.155	6.546	9.416	34.772	29.164	35.109
Yakima	CYCLES	10hr	0.426	0.047	0.068	–0.007	1.365	5.610	3.796	4.843
Yakima	CYCLES	24hr	1.032	0.048	0.064	0.013	1.507	6.349	4.584	4.962
Yakima	CYCLES	24sb	0.418	0.045	0.062	0.063	0.576	4.961	3.274	4.904

Table B-14
Heat Pump COP Seasonal Adjustment Factors

City	SYSTYPE	COP Adjustment
Boise	Air Source Heat Pump	0.557
Boise	Water Source Heat Pump, Gas Boiler	0.825
Boise	Dual Fuel Heat Pump	0.693
Boise	Water Source Heat Pump, Elec. Boiler	0.269
Pocatello	Air Source Heat Pump	0.485
Pocatello	Water Source Heat Pump, Gas Boiler	0.931
Pocatello	Dual Fuel Heat Pump	0.991
Pocatello	Water Source Heat Pump, Elec. Boiler	0.263
Portland	Air Source Heat Pump	0.645
Portland	Water Source Heat Pump, Gas Boiler	0.717
Portland	Dual Fuel Heat Pump	0.684
Portland	Water Source Heat Pump, Elec. Boiler	0.272
Seattle	Air Source Heat Pump	0.654
Seattle	Water Source Heat Pump, Gas Boiler	0.761
Seattle	Dual Fuel Heat Pump	0.721
Seattle	Water Source Heat Pump, Elec. Boiler	0.270
Yakima	Air Source Heat Pump	0.548
Yakima	Water Source Heat Pump, Gas Boiler	0.890
Yakima	Dual Fuel Heat Pump	0.869
Yakima	Water Source Heat Pump, Elec. Boiler	0.263

Table B-15
Cooling System EER Seasonal Multipliers

City	Condenser Type	Fan Type, Outdoor Air Control	EER Multiplier
Boise	Air Cooled	Constant Volume, Economizer	1.054
Boise	Air Cooled	Constant Volume, Fixed OA	1.103
Boise	Air Cooled	VAV, Economizer	0.910
Boise	Air Cooled	VAV, Fixed OA	0.957
Boise	Water Cooled	Constant Volume, Economizer	0.728
Boise	Water Cooled	Constant Volume, Fixed OA	0.687
Boise	Water Cooled	VAV, Economizer	0.773
Boise	Water Cooled	VAV, Fixed OA	0.808
Boise	Evap Cooled	Constant Volume, Economizer	0.728
Boise	Evap Cooled	Constant Volume, Fixed OA	0.687
Boise	Evap Cooled	Fan Cycles, Economizer	0.728
Boise	Evap Cooled	Fan Cycles, Fixed OA	0.687
Boise	Evap Cooled	VAV, Economizer	0.996
Boise	Evap Cooled	VAV, Fixed OA	1.028
Pocatello	Air Cooled	Constant Volume, Economizer	1.077
Pocatello	Air Cooled	Constant Volume, Fixed OA	1.119
Pocatello	Air Cooled	Fan Cycles, Economizer	1.077
Pocatello	Air Cooled	Fan Cycles, Fixed OA	1.119
Pocatello	Air Cooled	VAV, Economizer	0.956
Pocatello	Air Cooled	VAV, Fixed OA	0.977
Pocatello	Water Cooled	Constant Volume, Economizer	0.735
Pocatello	Water Cooled	Constant Volume, Fixed OA	0.702
Pocatello	Water Cooled	Fan Cycles, Economizer	0.735
Pocatello	Water Cooled	Fan Cycles, Fixed OA	0.702
Pocatello	Water Cooled	VAV, Economizer	0.806
Pocatello	Water Cooled	VAV, Fixed OA	0.825
Pocatello	Evap Cooled	Constant Volume, Economizer	0.735
Pocatello	Evap Cooled	Constant Volume, Fixed OA	0.702
Pocatello	Evap Cooled	Fan Cycles, Economizer	0.735
Pocatello	Evap Cooled	Fan Cycles, Fixed OA	0.702
Pocatello	Evap Cooled	VAV, Economizer	1.026

Table B-15 (Continued)
Cooling System EER Seasonal Multipliers

City	Condenser Type	Fan Type, Outdoor Air Control	EER Multiplier
Pocatello	Evap Cooled	VAV, Fixed OA	1.029
Portland	Air Cooled	Constant Volume, Economizer	1.095
Portland	Air Cooled	Constant Volume, Fixed OA	1.136
Portland	Air Cooled	VAV, Economizer	0.772
Portland	Air Cooled	VAV, Fixed OA	0.923
Portland	Water Cooled	Constant Volume, Economizer	0.717
Portland	Water Cooled	Constant Volume, Fixed OA	0.654
Portland	Water Cooled	VAV, Economizer	0.623
Portland	Water Cooled	VAV, Fixed OA	0.743
Portland	Evap Cooled	Constant Volume, Economizer	0.717
Portland	Evap Cooled	Constant Volume, Fixed OA	0.654
Portland	Evap Cooled	VAV, Economizer	0.784
Portland	Evap Cooled	VAV, Fixed OA	0.927
Seattle	Air Cooled	Constant Volume, Economizer	1.124
Seattle	Air Cooled	Constant Volume, Fixed OA	1.158
Seattle	Air Cooled	VAV, Economizer	0.750
Seattle	Air Cooled	VAV, Fixed OA	0.928
Seattle	Water Cooled	Constant Volume, Economizer	0.715
Seattle	Water Cooled	Constant Volume, Fixed OA	0.652
Seattle	Water Cooled	VAV, Economizer	0.599
Seattle	Water Cooled	VAV, Fixed OA	0.749
Seattle	Evap Cooled	Constant Volume, Economizer	0.715
Seattle	Evap Cooled	Constant Volume, Fixed OA	0.652
Seattle	Evap Cooled	VAV, Economizer	0.762
Seattle	Evap Cooled	VAV, Fixed OA	0.929
Yakima	Air Cooled	Constant Volume, Economizer	1.079
Yakima	Air Cooled	Constant Volume, Fixed OA	1.125
Yakima	Air Cooled	VAV, Economizer	0.932
Yakima	Air Cooled	VAV, Fixed OA	0.994
Yakima	Water Cooled	Constant Volume, Economizer	0.730
Yakima	Water Cooled	Constant Volume, Fixed OA	0.701

Table B-15 (Continued)
Cooling System EER Seasonal Multipliers

City	Condenser Type	Fan Type, Outdoor Air Control	EER Multiplier
Yakima	Water Cooled	VAV, Economizer	0.794
Yakima	Water Cooled	VAV, Fixed OA	0.841
Yakima	Evap Cooled	Constant Volume, Economizer	0.730
Yakima	Evap Cooled	Constant Volume, Fixed OA	0.701
Yakima	Evap Cooled	VAV, Economizer	0.991
Yakima	Evap Cooled	VAV, Fixed OA	1.042

Assumptions and Default Values

Default values for missing data are shown in Tables B-16 to B-19.

Table B-16
HVAC Auxiliary Calculation Default Values

Variable	Default
Number of air handlers	1
Supply fan type	Constant volume
Supply fan hp	Calculated from volts, phase and amps, or set to 1.2 W/SF
Return fan type	No return fan
Air handler schedule	24 hour operation
Chilled water pump hp	Calculated from volts, phase and amps, or set to 0.
Hot water pump hp	Calculated from volts, phase and amps, or set to 0.
Motor efficiency	Set at reference value (Table 19).

Table B-17
Heating and Cooling System Default Values

Variable	Default
Condenser type	Air-cooled
Outdoor air economizer	Yes
Cooling system EER	Set at reference level (Tables 21, 22, 24 or 25 as applicable)
Heating system COP	Set at reference level (Tables 20 or 23 as applicable)

Table B-18
Building Envelope Default Values

Variable	Default
Wall or Roof Orientation	Interior
Wall type	Frame/curtain wall
Roof type	Wood deck with built-up roof
Wall R-value	R-11
Roof R-value	R-30
Window type	Fixed
Frame type	Metal
Number of panes	2
Glass type	Standard clear (not low-e)
Interior shading	Light horizontal louver
Exterior shading	None

Table B-19
Reference Motor Efficiency

Motor hp	Reference Efficiency
1	77.6
1.5	79.2
2	80.8
3	82
5	84
7.5	85.8
10	86.6
15	87
20	88.7
25	89.6
30	90.1
40	90.4
50	91.4
60	91.8
75	92.1
100	92.3
125	92.6
150	93.2
200	94
250	93.6
300	93.6
350	93
400	93
450	93.5
500	93.5
600	93.5

Note: Based on TPU data for 1800 RPM enclosed motors. Full-load efficiency used.

Table B-20
Heat Pump Efficiency—Heating Mode: All Sites Except Idaho

	Reference Spec.		
Equipment Type	**COP**	**HSPF (Btuh/W)**	**Source**
Air Source - Split System	3.0 @ 47°F EDB	6.8	WSEC
Air Source - Single Package	3.0 @ 47°F EDB	6.8	WSEC
Water Source	3.8 @ 70°F EWT	—	WSEC
Ground Source	3.0 @ 50°F EWT	—	WSEC

Table B-21
Packaged Cooling Equipment Efficiency: All Sites Except Idaho

	Reference Specification			
	Condenser Type			
	Air-Cooled		Evap/ water-cooled	
Size/Type	**SEER**	**EER**	**EER**	**Source**
Split System - < 65000 Btuh	10.0	—	—	WSEC
Single Package - ≤ 65000 Btuh	9.7	—	9.3	WSEC
CAP > 65000 Btuh	—	8.9	10.5	WSEC

Table B-22
Water Chilling Equipment Specifications: All Sites Except Idaho

	Reference Specification						
	Condenser Type						
	Air		Water		Evaporative		
Equipment	EER	COP	EER	COP	EER	COP	Source
Centrifugal or Rotary Compressor, including condenser	8.00	2.34	13.80	4.04	—	—	WSEC
Reciprocating Compressor, including condenser	8.40	2.36	12.00	3.51	—	—	WSEC
Reciprocating Compressor, not including condenser	9.90	2.90	12.00	3.51	—	—	WSEC
Positive displacement compressor and condenser units ≥ 65,000 Btuh	9.50	2.78	12.50	3.66	12.50	3.66	WSEC
Water Source Hydronic Heat Pump, centrifugal or rotary < 65000 Btuh	—	—	9.00	2.64	—	—	WSEC
Water Source Hydronic Heat Pump, centrifugal or rotary ≥ 65000 Btuh	—	—	9.40	2.75	—	—	WSEC

Table B-23
Heat Pump Efficiency: Heating Mode —Idaho

	Reference Specification	
Equipment Type	COP	Source
Air Source - Split System	2.7 @ 47°F EDB	MEC
Air Source - Single Package	2.7 @ 47°F EDB	MEC
Water Source	3.0 @ 70°F EWT	MEC

Table B-24
Packaged Cooling Equipment Efficiency —Idaho

	Reference Specification			
	Condenser Type			
	Air-Cooled		Evap/ Water-Cooled	
Size/Type	SEER	EER	EER	Source
Split System - < 65000 Btuh	8	7.8	7.8	MEC
Single Package - ≤ 65000 Btuh	8	7.8	7.8	MEC
CAP > 65000 Btuh	—	8.2	8.2	MEC

Table B-25
Water Chilling Equipment Efficiency—Idaho

	Reference Specification						
	Condenser Type						
	Air		Water		Evaporative		
Equipment	EER	COP	EER	COP	EER	COP	Source
Centrifugal or Rotary Compressor, including condenser	8.00	2.34	13.80	4.04	—	—	MEC
Reciprocating Compressor, including condenser	8.40	2.36	12.00	3.51	—	—	MEC
Reciprocating Compressor, not including condenser	9.90	2.90	12.00	3.51	—	—	MEC
Positive displacement compressor and condenser units ≥ 65,000 Btuh	9.50	2.78	12.50	3.66	12.50	3.66	MEC
Water Source Hydronic Heat Pump, centrifugal or rotary < 65000 Btuh	—	—	7.8	2.3	—	—	MEC
Water Source Hydronic Heat Pump, centrifugal or rotary ≥ 65000 Btuh	—	—	8.2	2.4	—	—	MEC

Water Heating

Basic Equations

The following equation was used to calculate electricity consumption for water heaters and service hot water circulation pumps:

$$kWh = \frac{UA(T_{set} - T_{room}) \times t}{\eta_{WH} \times 3413} + \sum_{j=1}^{3} \frac{GPD_j \times 8.3 \times (T_{use} - T_{cold})}{\eta_{WH}} \times n_j + \frac{hp \times RLF \times .746 \times OH}{\eta_{motor}} \qquad \text{WH-1}$$

Variable Descriptions and Data Sources

Variable Name	Description	Source	Comments
kWh	Monthly water heating energy consumption.	Equation WH-1	These values will be summed over all entries in the water heating inventory
UA	Overall water heating system heat loss coefficient (Btu/hr-°F)	Table B-26	Based on water heater type and size (kW) from water heating inventory, Section 7 of survey.
T_{set}	Water heater setpoint temperature	Temperature code, from water heating inventory, Section 7 of survey. See Table B-27.	
T_{room}	Average temperature of water heater and circulation pipe surroundings		Set at 70°F
t	hours per month		
η_{WH}	Water heater efficiency	Table B-28	Conversion efficiency only, not including tank losses.
GPD	Monthly average daily hot water consumption (gal/day)	Table B-32	
T_{use}	Hot water use temperature	Table B-27	
T_{cold}	Entering cold water temperature	Table B-29	
n_j	number of days per month corresponding to daytype j (weekday, saturday, sunday/holiday)	Table B-1	
OH	Recirculation pump operating hours	Recirculation pump schedule, from water heating inventory, Section 7 of survey.	

Variable Name	Description	Source	Comments
hp	Recirculation pump nameplate horsepower	Table B-30	
RLF	Rated load factor	0.7	Equal to the ratio of the pump running load to the nameplate power
η_{motor}	Pump motor efficiency	Table B-19	Varies with motor size

Table B-26
Water Heater UA

WHTYPE	Size (kW)	UA (Btu/hr-°F)
1,3	≤ 2.5	2.8
1,3	2.5^{+}–12	3.8
1,3	12^{+}–80	6.4
1,3	80^{+}–145	8.0
1,3	145^{+}–700	27.2
2	all	8.0
4,5	all	0.0
6	all	8.0

Table B-27
Water Heater Set Temperature

TEMP	T_{set}
1	180
2	165
3	140
4	120
5	100

Table B-28
Water Heater Efficiency

WHTYPE	Water Heater Type	η_{WH}
1	Self-Contained	1.0
2	Storage off Boiler	1.0
3	Heat Pump	2.0
4	Tankless	1.0
5	Point-of-use	1.0
6	Heat Recovery	set kwh to zero

Table B-29
Cold Water Temperature

Month	Boise	Pocatello	Portland	Seattle	Yakima
J	38	34	39	33	38
F	36	32	42	35	36
M	40	36	42	38	40
A	41	37	48	42	41
M	44	40	47	49	44
J	52	48	55	45	52
J	55	51	62	44	55
A	58	54	68	48	58
S	54	50	64	46	54
O	50	46	56	40	50
N	41	37	50	39	41
D	35	31	46	34	35

Table B-30
Hot Water Recirculation Pump Size and Efficiency

Building Height	hp	η_{motor}
≤ 25	1	0.768
25–50	2	0.811
50–75	3	0.814
75–100	5	0.839
≥ 100	10	0.864

Table B-31
Recirculation Pump Operating Hours

PUMPCONT	Pump Controls	OH
NA or no entry	No Controls	0
1	Temperature	hr_m
2	Timer	sum (hour1..hour24), if UNITS = 2, else hr_m
3	EMCS	sum (hour1..hour24), if UNITS = 2, else hr_m
4	Continuous operation	hr_m

Table B-32
GPD Estimates

OCCCODE	Occupancy	GPD/Unit	Units
1	Office	1 per person	150 SF/person × AREA
2	Retail	0.5 per person	33 SF/person × AREA
3	Grocery	0.5 per person	125 SF/person × AREA
4	School	1.8 per person	50 SF/person × AREA
5	College	0.6 per person	50 SF/person × AREA
6	Fast Food	0.7 per meal	MEALSWD, MEALSAT, MEALSUN
7	Restaurant	2.4 per meal	MEALSWD, MEALSAT, MEALSUN
8	Kitchen	0	
9	Assembly	0.1 per person	7 SF/person × AREA

Table B-32 (Continued)
GPD Estimates

OCCCODE	Occupancy	GPD/Unit	Units
10	Commons	0	
11	Hotel/Motel (≤ 20 units)	20 gal per unit	NUMROOMS
	(21–99 units)	14 gal per unit	
	(≥ 100 units)	10 gal per unit	
12	Mixed-Use	0	
13	Multi-Family	0	
14	Hospital	18 per bed	1000 SF/BED × AREA
15	Other Medical	1.0 per person	150 SF/person × AREA
16	Laundry	0	
17	Warehouse	1 per person	200 SF/person × AREA
18	Refrigerated	1 per person	200 SF/person × AREA
19	Service	1 per person	150 SF/person × AREA
20	Industrial (w/ shower)	1.0 per person	150 SF/person × AREA
	(w/o shower)	1.8 per person	
21	Computer Center	1 per person	150 SF/person × AREA
22	Mixed-Use	0	
23	Other	0	
Additional Occupancy Codes:			
25	Garage	0	
26	Equipment room	0	
27	Library	0.1 per person	50 SF/person × AREA
28	Gymnasium and Pool room	1.8 per person	33 SF/person × AREA
29	Laboratory	1.0 per person	33 SF/person × AREA
30	Greenhouse	0.1 per person	125 SF/person × AREA
31	Storage	0	
32	Unfinished	0	

Cooking

Basic Equations

The following equations were used to calculate electricity consumption for cooking equipment and calculate heat gains to space from cooking equipment:

$$kWh = units \times \sum_{j=1}^{3}\left[\frac{kWh_{warmup}}{unit} + \left(\frac{kWh_{idle}}{unit} \times t_{idle}\right) + \left(\frac{kWh_{cooking}}{unit} \times t_{cooking,j}\right)\right] \times n_j \qquad \text{K-1}$$

$$KHG = units \times \sum_{j=1}^{3}\left[\frac{Q_{kit}}{1000} \times (t_{idle,j} + t_{cooking,j})\right] \times n_j \qquad \text{K-2}$$

Variable Descriptions and Data Sources

Variable Name	Description	Source	Comments
kWh	Monthly cooking energy consumption.	Equation K-1	These values were summed over all entries in the cooking equipment inventory, Section 10 of the survey
KHG	Monthly space heat gains from cooking equipment (kBtu/mo).	Equation K-2	These values were summed over all entries in the cooking equipment inventory, Section 10 of the survey. They are added to the miscellaneous equipment heat gains.
units	Size of each piece of cooking equipment (lineal feet, square feet, etc.).	Cooking equipment inventory, Section 10 of survey.	
kW/unit	Nameplate load (kW) of each unit of cooking equipment, or industry average connected load per unit of measure	Cooking equipment inventory, Section 10 of survey.	
$kWh_{warm-up}$	Warm-up energy	Tables B-33, B-34	Varies by equipment type
kW_{idle}	Equipment demand at idle	Tables B-33, B-34	Varies by equipment type
$kW_{cooking}$	Equipment demand while cooking	Tables B-33, B-34	Medium loading assumed
Q_{kit}	Unit heat gains to space	Tables B-36, B-37	Depends on fuel type and exhaust hood.

Variable Name	Description	Source	Comments
$t_{idle,j}$	Time spent idling (hr/day) for daytype j	Table B-35	
$t_{cooking,j}$	Time spent cooking (hr/day) for daytype j	Table B-35	
n_j	number of days per month corresponding to daytype j (weekday, saturday, sunday/holiday)		

Table B-33
Performance of Counter Appliances —(Source: PG&E, Kitchen Monitor)

Appliance	Description	f_{warmup}	t_{warmup}	f_{idle}	$f_{cooking}$
1	Broiler/Griddle	1	.3	.17	.30
2	Deep Fat Fryer	1	.1	.06	.3
3	Dry Food Warmer	0	0	0	.7
4	Short Order Stove	1	.3	0	.5
5	Toaster, Continuous	1	.1	0	.7
6	Coffee Urn	1	.1	.2	.7
7	Steam Table	1	.25	.3	.3
8	Reach-in Refrigerator	0	0	0	0
9	MISC	1	.1	.3	.3
10	Carbonator	0	0	.7	.7
11	Convection Oven	.85	.25	.15	.30
12	Non-cooking	0	0	0	0
13	Microwave Oven	0	0	0	.3
14	Dishwasher	0	0	0	0
15	Ice Maker	0	0	.7	.7

Table B-34
Performance of Floor Appliances (Source: PG&E, Kitchen Monitor)

Item	Description	f_{warmup}	t_{warmup}	f_{idle}	$f_{cooking}$
1	Broiler/Griddle	1	.3	.17	.3
2	Deep Fat Fryer	1	.1	.06	.3
3	Range, top section	1	.3	0	.5
4	Range, oven	.7	.25	.26	.4
5	Oven, baking	.9	.25	.12	.4
6	Oven, roasting	.9	.25	.12	.4
7	Fryer	1	.1	.06	.3
8	Charbroiler	1	.3	.67	.67
9	Convection Oven	.85	.25	.15	.3
10	Self-Contained Refrig.	0	0	0	0
11	Food Warmer	0	0	0	.7
12	Non-Food	0	0	0	0
13	Miscellaneous	1	.1	.3	.3
14	Kettle	1	.1	.3	.3
15	Soup	1	.1	.3	.3
16	Ice Maker	0	0	.7	.7
17	Dishwasher	0	0	0	0

Table B-35
Idle and Cooking Times by MEALCODE

MEALCODE	Meal	t_{idle}	t_{cook}
1	Breakfast	1	2
2	Lunch	1	2
3	Dinner	1	3

Table B-36
Kitchen Heat Gains from Counter Appliances (Source: ASHRAE, 1993)

		Electric		Gas		
Appliance	Description	Heat Gain (hooded)	Heat Gain (no hood)	Heat Gain (hooded)	Heat Gain (no hood)	Notes
1	Broiler/Griddle	3060	8640	10980	73530	9 SF
2	Deep Fat Fryer	700	—	8000	—	50 lb
3	Dry Food Warmer	5100	5100	—	—	6 lamp
4	Short Order Stove	6240	13240	6590	—	
5	Toaster, Continuous	—	5800	—	—	
6	Coffee Urn	20400	66900	—	—	30 qt
7	Steam Table	990	3060	—	—	3 cf
8	Reach-in Refrigerator	—	—	—	—	
9	MISC	0	0	0	0	
10	Carbonator	0	0	0	0	
11	Convection Oven	1800	—	—		10 cf
12	Non-cooking	—	—	—	—	$= kW_{input}$
13	Microwave Oven	—	8970	—	—	
14	Dishwasher	1700	5400	2300	7100	1000 dish/hr
15	Ice Maker	—	—	—	—	$= kW_{input}$

Table B-37
Kitchen Heat Gains from Floor Appliances (Source: ASHRAE, 1993)

		Electric		Gas		
Appliance	Description	Heat Gain (hooded)	Heat Gain (no hood)	Heat Gain (hooded)	Heat Gain (no hood)	Notes
1	Broiler/Griddle	3060	8640	10980	73530	9 SF
2	Deep Fat Fryer	700	—	8000	—	50 lb
3	Range, top section	7980	—	19770	—	
4	Range, oven	1800	—	2500	—	10 cf
5	Oven, baking	1800	—	2500	—	10 cf
6	Oven, roasting	1800	—	2500	—	10 cf
7	Fryer	700	—	8000	—	50 lb
8	Charbroiler	29790	—	66905	—	9 sf
9	Convection Oven	1800	—	2500	—	10 cf
10	Self-Contained Refrig.	—	—	—	—	$= kW_{input}$
11	Food Warmer	1450	4525			2.5 cf
12	Non-Food	—	—	—	—	$= kW_{input}$
13	Miscellaneous	0	0	0	0	
14	Kettle	1560	4800			120 qt
15	Soup	1560	4800			120 qt
16	Ice Maker	—	—	—	—	$= kW_{input}$
17	Dishwasher	1700	5400	2300	7100	1000 dish/hr

Refrigeration

Basic Equations

The following equations were used to calculate electricity consumption for refrigeration equipment and calculate heat losses from the space to open refrigeration cases:

$$\text{kWh} = \text{units} \times \left[\left(\frac{\text{Case Load / unit}}{\overline{\text{EER}} \times 1000} \times \text{FLH} \right) + \left(\frac{W_{aux}/\text{ unit}}{1000} \times t \right) + \left(\frac{\text{kWh}_{def}}{\text{unit}} \right) \right] \quad \text{R-1}$$

$$\text{RHL} = \text{units} \times \left[\frac{\text{RE}}{1000} \times t \right] \quad \text{R-2}$$

Variable Descriptions and Data Sources

Variable Name	Description	Source	Comments
kWh	Monthly refrigeration energy consumption.	Equation R-1	These values were summed over all entries in the refrigeration equipment inventory, Section 11 of survey.
RHL	Monthly room heat loss from open refrigeration cases (kBtu/mo)	Equation R-2	These values were summed over all entries in the refrigeration equipment inventory, Section 11 of survey. The total room heat loss is subtracted from the miscellaneous equipment heat gains.
units	Size of each case (lineal feet, square feet, cubic feet, etc.).	Refrigeration equipment inventory, Section 11 of survey.	
Case load/ unit	Design case load (Btu/hr) per unit of case size	Table B-38	
RE	Room effect - space heat loss per unit of case (Btu/hr)	Table B-38	
$\overline{\text{EER}}$	Monthly average compressor energy efficiency ratio (Btu/Wh)	Table B-40	Varies with compressor type, condenser type, and location.
W_{aux}/unit	Refrigeration case auxiliary energy requirements per unit of case dimension	Table B-38	Typical values for case lighting, evaporator fans, and anti-sweat heaters.
FLH	Monthly compressor full-load hours	Table B-39	
t	hours per month	Table B-39	
kWh_{def}/unit	Defrost energy per unit of case dimension	Table B-38	Varies by case and defrost mechanism used

Table B-38
Refrigerator Temperature Readings

Case Type Code	Case Description	Temp Code	Temperature Code Description	LOAD (Btu/ hr-unit)	Room Effect (Btu/ hr-unit)	AUX (ANT-COND-HT = 1)	AUX (ANT-COND-HT = 2)	DEF (DEF-CODE = 1)	DEF (DEF-CODE = 2)	Unit
1	Open Coffin (Tub)	1	Ice Cream	150	107	10	6	.016	.014	SF
1	Open Coffin (Tub)	2	Frozen Food	150	107	10	6	.016	.012	SF
1	Open Coffin (Tub)	3	Fresh Meat and Deli	106	74	4	4	0	0	SF
1	Open Coffin (Tub)	4	Dairy/Produce	106	74	4	4	0	0	SF
1	Open Coffin (Tub)	5	Beverage	106	74	4	4	0	0	SF
2	Closed Coffin (Tub)	1	Ice Cream	90	0	10	4	.012	.010	SF
2	Closed Coffin (Tub)	2	Frozen Food	90	0	10	4	.012	.009	SF
2	Closed Coffin (Tub)	3	Fresh Meat and Deli	64	0	3	3	0	0	SF
2	Closed Coffin (Tub)	4	Dairy/Produce	64	0	3	3	0	0	SF
2	Closed Coffin (Tub)	5	Beverage	64	0	3	3	0	0	SF
3	Open Multideck	1	Ice Cream	1400	1095	112	99	.76	.64	LF
3	Open Multideck	2	Frozen Food	1400	1095	112	99	.76	.55	LF
3	Open Multideck	3	Fresh Meat and Deli	1400	1095	41	41	0	0	LF
3	Open Multideck	4	Dairy/Produce	1275	980	41	41	0	0	LF
3	Open Multideck	5	Beverage	1275	980	41	41	0	0	LF
4	Closed Multideck	1	Ice Cream	560	0	73	48	.40	.34	LF
4	Closed Multideck	2	Frozen Food	560	0	73	48	.40	.29	LF
4	Closed Multideck	3	Fresh Meat and Deli	550	0	72	49	0	0	LF
4	Closed Multideck	4	Dairy/Produce	550	0	72	49	0	0	LF
4	Closed Multideck	5	Beverage	550	0	72	49	0	0	LF
5	Self-Contained Cabinet	1	Ice Cream	67.5	0	6	3	.025	.025	CF
5	Self-Contained Cabinet	2	Frozen Food	67.5	0	6	3	.025	.025	CF
5	Self-Contained Cabinet	3	Fresh Meat and Deli	23.0	0	0.8	0	0	0	CF

Table B-38 (Continued)
Refrigerator Temperature Readings

Case Type Code	Case Description	Temp Code	Temperature Code Description	LOAD (Btu/ hr-unit)	Room Effect (Btu/ hr-unit)	AUX (ANT-COND-HT = 1)	AUX (ANT-COND-HT = 2)	DEF (DEF-CODE = 1)	DEF (DEF-CODE = 2)	Unit
5	Self-Contained Cabinet	4	Dairy/Produce	23.0	0	0.8	0	0	0	CF
5	Self-Contained Cabinet	5	Beverage	23.0	0	0.8	0	0	0	CF
6	Walk-in	1	Ice Cream	90	0	2	2	.1	.1	SF
6	Walk-in	2	Frozen Food	90	0	2	2	.1	.1	SF
6	Walk-in	3	Fresh Meat and Deli	55	0	2	2	0	0	SF
6	Walk-in	4	Dairy/Produce	55	0	2	2	0	0	SF
6	Walk-in	5	Beverage	55	0	2	2	0	0	SF
7	Walk-in/Reach-in	1	Ice Cream	180	0	14	10	.1	.1	SF
7	Walk-in/Reach-in	2	Frozen Food	180	0	14	10	.1	.1	SF
7	Walk-in/Reach-in	3	Fresh Meat and Deli	150	0	14	10	0	0	SF
7	Walk-in/Reach-in	4	Dairy/Produce	150	0	14	10	0	0	SF
7	Walk-in/Reach-in	5	Beverage	150	0	14	10	0	0	SF
8	Produce	1	Ice Cream	kick out						
8	Produce	2	Frozen Food	kick out						
8	Produce	3	Fresh Meat and Deli	kick out						
8	Produce	4	Dairy/Produce	425	240	41	41	0	0	LF
8	Produce	5	Beverage	kick out						

Table B-39
Monthly Refrigeration Full-load Hours

Month	FLH	t	day
January	558	744	31
February	504	672	28
March	558	744	31
April	540	720	30
May	558	744	31
June	540	720	30
July	558	744	31
August	558	744	31
September	540	720	30
October	558	744	31
November	540	720	30
December	558	744	31

Table B-40
Monthly Refrigeration Compressor EER

City	Comp Type	Cond Type	Case Temp	EER Month Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BOISE	1	1	1	4.37	4.37	4.36	4.33	4.25	4.15	3.9	3.95	4.18	4.31	4.36	4.37
BOISE	1	1	2	5.03	5.03	5.02	4.97	4.87	4.75	4.44	4.51	4.78	4.95	5.01	5.04
BOISE	1	1	3	12	12	11.9	11.8	11.4	11	10.1	10.3	11.1	11.7	11.9	12
BOISE	1	1	4	14.3	14.3	14.3	14	13.5	13	11.8	12.1	13.1	13.9	14.2	14.4
BOISE	1	1	5	14.3	14.3	14.3	14	13.5	13	11.8	12.1	13.1	13.9	14.2	14.4
BOISE	2	1	1	7.06	7.07	6.99	6.6	5.99	5.47	4.7	4.85	5.61	6.48	6.95	7.1
BOISE	2	1	2	7.57	7.59	7.49	7.06	6.39	5.82	5	5.15	5.97	6.93	7.45	7.62
BOISE	2	1	3	18.1	18.1	17.7	16.3	14.5	13.1	11.3	11.7	13.5	15.9	17.5	18.3
BOISE	2	1	4	21.4	21.5	20.9	19.2	17.1	15.5	13.3	13.7	15.9	18.7	20.7	21.6
BOISE	2	1	5	21.4	21.5	20.9	19.2	17.1	15.5	13.3	13.7	15.9	18.7	20.7	21.6
BOISE	2	2	1	7.3	7.3	7.28	7.24	7.18	7.08	6.83	6.93	7.1	7.23	7.27	7.31
BOISE	2	2	2	7.85	7.86	7.84	7.79	7.71	7.6	7.31	7.43	7.62	7.77	7.82	7.86
BOISE	2	2	3	19.4	19.4	19.3	19.1	18.7	18.2	17.1	17.6	18.3	19	19.2	19.4
BOISE	2	2	4	23	23.1	22.9	22.6	22	21.3	19.8	20.5	21.5	22.4	22.8	23.1
BOISE	2	2	5	23	23.1	22.9	22.6	22	21.3	19.8	20.5	21.5	22.4	22.8	23.1
POCATELLO	1	1	1	4.38	4.37	4.37	4.34	4.28	4.17	3.96	4.02	4.21	4.32	4.37	4.38
POCATELLO	1	1	2	5.04	5.04	5.03	4.99	4.92	4.77	4.51	4.59	4.82	4.96	5.02	5.04
POCATELLO	1	1	3	12	12	12	11.8	11.5	11	10.3	10.5	11.2	11.7	12	12
POCATELLO	1	1	4	14.4	14.4	14.3	14.1	13.7	13	12	12.3	13.3	13.9	14.3	14.4
POCATELLO	1	1	5	14.4	14.4	14.3	14.1	13.7	13	12	12.3	13.3	13.9	14.3	14.4
POCATELLO	2	1	1	7.12	7.09	7.04	6.74	6.23	5.57	4.83	5.02	5.76	6.5	7.02	7.11
POCATELLO	2	1	2	7.64	7.61	7.55	7.21	6.64	5.93	5.14	5.33	6.13	6.95	7.53	7.63

Table B-40 (Continued)
Monthly Refrigeration Compressor EER

				EER											
				Month											
City	Comp Type	Cond Type	Case Temp	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
POCATELLO	2	1	3	18.4	18.2	18	16.8	15.2	13.4	11.7	12.1	13.9	16.1	17.9	18.4
POCATELLO	2	1	4	21.8	21.6	21.3	19.8	17.9	15.8	13.7	14.2	16.4	18.9	21.1	21.7
POCATELLO	2	1	5	21.8	21.6	21.3	19.8	17.9	15.8	13.7	14.2	16.4	18.9	21.1	21.7
POCATELLO	2	2	1	7.31	7.31	7.3	7.27	7.21	7.13	7	7.05	7.17	7.25	7.3	7.31
POCATELLO	2	2	2	7.87	7.87	7.86	7.82	7.75	7.66	7.51	7.57	7.71	7.8	7.85	7.87
POCATELLO	2	2	3	19.5	19.5	19.4	19.2	18.9	18.5	17.8	18	18.7	19.1	19.4	19.5
POCATELLO	2	2	4	23.2	23.1	23.1	22.8	22.3	21.7	20.7	21.1	22	22.6	23	23.2
POCATELLO	2	2	5	23.2	23.1	23.1	22.8	22.3	21.7	20.7	21.1	22	22.6	23	23.2
PORTLAND	1	1	1	4.36	4.36	4.35	4.33	4.29	4.25	4.17	4.19	4.24	4.31	4.35	4.36
PORTLAND	1	1	2	5.02	5.01	5	4.97	4.93	4.87	4.77	4.79	4.86	4.95	5	5.02
PORTLAND	1	1	3	12	11.9	11.9	11.8	11.6	11.4	11	11.1	11.3	11.7	11.9	11.9
PORTLAND	1	1	4	14.3	14.2	14.2	14	13.7	13.5	13	13.1	13.4	13.9	14.2	14.3
PORTLAND	1	1	5	14.3	14.2	14.2	14	13.7	13.5	13	13.1	13.4	13.9	14.2	14.3
PORTLAND	2	1	1	7.02	6.96	6.9	6.65	6.31	5.93	5.46	5.52	5.85	6.49	6.91	7
PORTLAND	2	1	2	7.53	7.46	7.4	7.11	6.72	6.31	5.8	5.86	6.22	6.92	7.4	7.5
PORTLAND	2	1	3	17.9	17.6	17.3	16.4	15.2	14.1	13	13.1	14	15.7	17.3	17.8
PORTLAND	2	1	4	21.1	20.7	20.4	19.2	17.9	16.6	15.3	15.5	16.4	18.4	20.3	20.9
PORTLAND	2	1	5	21.1	20.7	20.4	19.2	17.9	16.6	15.3	15.5	16.4	18.4	20.3	20.9
PORTLAND	2	2	1	7.27	7.26	7.25	7.2	7.12	7	6.82	6.85	6.98	7.12	7.23	7.26
PORTLAND	2	2	2	7.82	7.81	7.8	7.74	7.64	7.51	7.3	7.33	7.48	7.65	7.77	7.81
PORTLAND	2	2	3	19.2	19.2	19.1	18.9	18.4	17.8	17.1	17.2	17.7	18.4	19	19.2
PORTLAND	2	2	4	22.8	22.7	22.6	22.3	21.6	20.8	19.8	19.9	20.6	21.6	22.5	22.8
PORTLAND	2	2	5	22.8	22.7	22.6	22.3	21.6	20.8	19.8	19.9	20.6	21.6	22.5	22.8

Table B-40 (Continued)
Monthly Refrigeration Compressor EER

				EER											
				Month											
City	Comp Type	Cond Type	Case Temp	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SEATTLE	1	1	1	4.36	4.35	4.35	4.33	4.30	4.26	4.20	4.22	4.22	4.32	4.35	4.36
SEATTLE	1	1	2	5.02	5.01	5.00	4.98	4.94	4.88	4.81	4.83	4.83	4.96	5.00	5.01
SEATTLE	1	1	3	11.95	11.91	11.89	11.80	11.60	11.40	11.14	11.21	11.20	11.71	11.87	11.92
SEATTLE	1	1	4	14.27	14.21	14.18	14.06	13.80	13.52	13.17	13.26	13.24	13.94	14.16	14.23
SEATTLE	1	1	5	14.27	14.21	14.18	14.06	13.80	13.52	13.17	13.26	13.24	13.94	14.16	14.23
SEATTLE	2	1	1	7.01	6.95	6.91	6.74	6.36	5.97	5.58	5.64	5.57	6.58	6.90	6.98
SEATTLE	2	1	2	7.52	7.45	7.40	7.21	6.78	6.35	5.92	5.99	5.91	7.03	7.39	7.48
SEATTLE	2	1	3	17.81	17.54	17.35	16.65	15.36	14.20	13.26	13.37	13.22	15.95	17.27	17.66
SEATTLE	2	1	4	21.00	20.65	20.41	19.53	18.02	16.69	15.62	15.77	15.62	18.66	20.28	20.79
SEATTLE	2	1	5	21.00	20.65	20.41	19.53	18.02	16.69	15.62	15.77	15.62	18.66	20.28	20.79
SEATTLE	2	2	1	7.26	7.25	7.24	7.21	7.11	6.98	6.81	6.84	6.86	7.13	7.22	7.25
SEATTLE	2	2	2	7.81	7.80	7.79	7.75	7.64	7.49	7.30	7.32	7.35	7.65	7.77	7.80
SEATTLE	2	2	3	19.20	19.12	19.09	18.89	18.38	17.75	17.09	17.11	17.21	18.45	18.98	19.13
SEATTLE	2	2	4	22.77	22.66	22.60	22.31	21.57	20.67	19.80	19.80	19.92	21.66	22.44	22.66
SEATTLE	2	2	5	22.77	22.66	22.60	22.31	21.57	20.67	19.80	19.80	19.92	21.66	22.44	22.66
YAKIMA	1	1	1	4.37	4.36	4.35	4.32	4.27	4.15	3.92	4.14	4.19	4.31	4.36	4.37
YAKIMA	1	1	2	5.03	5.02	5.01	4.97	4.89	4.74	4.47	4.74	4.79	4.96	5.01	5.03
YAKIMA	1	1	3	12	12	11.9	11.7	11.4	10.9	10.2	10.9	11.1	11.7	11.9	12
YAKIMA	1	1	4	14.3	14.3	14.2	14	13.6	12.9	11.9	12.9	13.1	13.9	14.2	14.3
YAKIMA	1	1	5	14.3	14.3	14.2	14	13.6	12.9	11.9	12.9	13.1	13.9	14.2	14.3
YAKIMA	2	1	1	7.05	7	6.91	6.59	6.08	5.44	4.76	5.4	5.6	6.5	6.96	7.05
YAKIMA	2	1	2	7.57	7.51	7.4	7.04	6.48	5.79	5.06	5.73	5.95	6.94	7.46	7.56
YAKIMA	2	1	3	18	17.8	17.4	16.2	14.7	13.1	11.5	12.9	13.4	15.9	17.6	18

Table B-40 (Continued)
Monthly Refrigeration Compressor EER

City	Comp Type	Cond Type	Case Temp	EER Month Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
YAKIMA	2	1	4	21.3	21	20.5	19	17.3	15.4	13.5	15.2	15.8	18.6	20.7	21.3
YAKIMA	2	1	5	21.3	21	20.5	19	17.3	15.4	13.5	15.2	15.8	18.6	20.7	21.3
YAKIMA	2	2	1	7.29	7.29	7.27	7.23	7.14	7.05	6.93	6.98	7.1	7.2	7.27	7.29
YAKIMA	2	2	2	7.85	7.84	7.82	7.77	7.67	7.56	7.43	7.48	7.62	7.73	7.82	7.85
YAKIMA	2	2	3	19.4	19.3	19.2	19	18.5	18	17.5	17.7	18.3	18.8	19.2	19.4
YAKIMA	2	2	4	23	22.9	22.8	22.5	21.8	21.1	20.4	20.6	21.4	22.2	22.8	23
YAKIMA	2	2	5	23	22.9	22.8	22.5	21.8	21.1	20.4	20.6	21.4	22.2	22.8	23

Notes: 1) Comp Type 1 = Standalone, 2 = Multiplex
2) Cond Type 1 = Air cooled, 2 = Water cooled
3) Case Temp 1= Ice cream, 2 = Frozen food, 3 = Fresh Meat and Deli, 4 = Dairy/Produce, 5 = Beverage

Assumptions and Default Values

1. Closed coffin case load is 60% of open case load
2. Coffin case width is 4 ft.; its depth, 2 ft.
3. Closed coffin cases have no lights
4. No floating head pressure control on stand-alone compressors
5. Hot gas defrost kWh = Electric kWh/COP/.9
6. Self-contained cabinet 10 CF/LF
7. Walk-in height = 8 ft.
8. Default values for missing data are shown in Tables B-41 and B-42.

Table B-41
Default Values for Case Temperature

Case Type Code	Temp Code
1	2
2	2
3	3
4	2
5	3
6	5
7	5
8	4

Table B-42
Other Miscellaneous Default Values

Variable	Default
Compressor Type	Stand-alone
Anti-condensate Heaters	Yes
Defrost Type	Electric Resistance
Condenser Type	Air Cooled

Pools and Spas

Basic Equations

The following equation was used to calculate electricity consumption for pool and spa heaters and circulation pumps:

$$kWh = SF \times \left[\frac{(Q / A \times t)_{cov} + (Q / A \times t)_{uncov}}{\eta_{boiler} \times 3413} \right] + \frac{hp_{pump} \times RLF \times .748}{\eta_{motor}} \times t_{pump} \quad \text{P-1}$$

Variable Descriptions and Data Sources

Variable Name	Description	Source	Comments
kWh	Monthly pool/spa energy consumption.	Equation P-1	These values were summed over all entries in the pool and spa inventory, Section 12 of survey.
SF	Pool or spa surface area (ft^2)	Pool and spa inventory, Section 12 of survey.	
$(Q/A)_{uncov}$	Monthly average pool or spa heat loss per square foot when uncovered.	FCHART program	Function of pool temperature, outdoor or pool room temperature, relative humidity, surface velocity.
$(Q/A)_{cov}$	Monthly average pool or spa heat loss per square foot when covered.	FCHART program	Function of pool temperature, outdoor or pool room temperature, surface velocity.
hr_{uncov}	Monthly average hours per day pool/spa uncovered	Cover schedule, from pool and spa inventory, Section 12 of survey.	Varies by season
hr_{cov}	Monthly average hours per day pool/spa covered	Cover schedule, from pool and spa inventory, Section 12 of survey.	Varies by season
η_{boiler}	Pool/spa boiler efficiency	Equal to 1 for electric resistance boilers	
hp_{pump}	Pool/spa pump nameplate horsepower	From pool and spa inventory, Section 12 of survey.	
RLF	Rated load factor	0.7	Equal to the ratio of the pump running load to the nameplate power
η_{motor}	Pump motor efficiency	Table B-19	Varies with motor size
t_{pump}	Pump operating hours	Pool/spa pump schedule, from pool/spa inventory, Section 12 of survey.	Varies by season

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C

FINAL SURVEY INSTRUMENT

This appendix contains the final survey instrument used in this performance impact project.

NW Commercial Evaluation Project – On-Site Data-Collection Form

Site Number	Survey Number		Utility ID Number
Auditor's Name	Audit Date	Start Time	Finish Time

1. General Building Information

Building Name:		Building Number:	
Address:		Serving Utility:	
City:	Fax #:	Elec. Account #:	
Primary Contact:	Title:	Secondary Contact:	Title:
Phone Number:	Pager #:	Phone Number:	Pager #:

Number of KWH Meters		Primary KWH Meter #:	
No. of Conditioned Floors (above / below)	/	Other KWH Meter #s	Area Served (if ECM) OR Meter #s
Building Square Footage		1.	
Typical Floor to Floor Distance		2.	
Occupancy Type Code		3.	
Building Development Status Code		4.	
Number of Tenants		5.	
Date of Initial Occupancy		6.	
No. of Rooms (if hotel/motel)		7.	
		8.	

% Occupied SQFT	**Date (Mo/Yr)**	**HVAC & Equipment**	**Date (Mo/Yr)**

Occupancy Type Codes	
1	Owner - Chain or Franchise
2	Owner - Private
3	Owner - Public or Non-Profit
4	Single Tenant - Private
5	Single Tenant - Public or Non-Profit
6	Multi-Tenant
Bldg. Dev. Codes	
1	Build to Suit
2	Owner Occupied
3	Speculation

Notes:

2. Building Space Inventory

Code	Occ. Code	Total Floor Area per Space	Occ. Sch. Code WD	Sat	Sun	YR	Stat Type	Cool Setpoint Sch. WD	Sat	Sun	Heat Setpoint Sch. WD	Sat	Sun
primary						*							
S2													
S3													
S4													
S5													
S6													
S7													
S8													
S9													
S10													

* Use schedule S-G or enter 'A' for all months.

Sch. Code	Units	1	2	3	4	5	6	7	8	9	10	11	N	1	2	3	4	5	6	7	8	9	10	11	M
S - A	□°F / □%																								
S - B	□°F / □%																								
S - C	□°F / □%																								
S - D	□°F / □%																								
S - E	□°F / □%																								
S - F	□°F / □%																								

(Hr ending at: 1–M)

Sch. Code	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
S - G	□%												

(Month)

Occupancy Codes					T-Type Control Codes
1 Office	6 Fast Food	11 Hotel/Motel	16 Laundry	21 Computer Ctr.	1 EMCS
2 Retail	7 Restaurant	12 Mixed-Use	17 Warehouse	22 Mixed-Use	2 Single Setpoint
3 Grocery	8 Kitchen	13 Multi-Family	18 Refrigerated	23 Other (note)	3 Dual Setpoint
4 School	9 Assembly	14 Hospital	19 Service	24	4 Setback T-stat
5 College	10 Commons	15 Other Medical	20 Industrial	25	5 7-day Setback T-stat

Notes:

3. Whole Building Envelope Information

	BE1	BE2	BE3	BE4	BE5	BE6	BE7	BE8
Actual Orientation (NNE, NE, Roof, etc.)								
Wall/ Roof Type Code (or footnote)								
Wall/Roof R-value (insulation only)								
Wall/Roof Color Code								
Gross Envelope Area, SF (including windows)								
Percent Window Area								
Window Type Code								
Number of Panes								
Window Treatment Code								
Window Frame Type Code								
Interior Shading Code								
Ext. Shading (% window area, + S for seasonal)								

Wall Type Codes	Window & Frame Type Codes	Interior Shading Codes
1 No Exterior Wall	1 Fixed	1 None
2 4" Face Brick + Brick	2 Double Hung	2 Hor'l Louver, Light
3 4" Face Brick + Poured Concrete	3 Casement	3 Hor'l Louver, Medium
4 4" Face Brick + Concrete Block	4 Sliding Pane	4 Vert. louvers, light
5 Poured Concrete Wall + Finish	5 Other (describe)	5 Roll-down, opaque, light
6 Concrete block + Finish	1 Wood Frame	6 Roll-down, opaque, dark
7 Frame/Curtain Wall	2 Metal Frame	7 Roll-down, translucent
	3 Thermal Break	8 Drapes

Roof Type Codes	Window Treatment Codes	Wall/Roof Color Codes
8 No Roof	1 Plain Clear Glass	1 Dark
9 Sheet Metal	2 Tinted Glass	2 Medium
10 Wood Deck with Single-ply Membrane	3 Reflective Glass/Film	3 Light
11 Wood Deck with Built-Up Roof	4 Low-E	4 Reflective
12 Concrete with Single-ply Membrane	5 Unknown	
13 Concrete with Built-Up Roof	6 + Gas-Filled	

Sketch Floor Plan (include north arrow, dimensions, space use):

Notes:

4. Air-Handling System Inventory

Air Handler Code:	AHU1		AHU2		AHU3	
Primary Space Code Serviced						
Air-handling System Type Code						
Number of Units						
	SF	RF	SF	RF	SF	RF
Fan Type Code						
Fan data horsepower						
Efficiency (%)						
Volts / Phase / Amps	/ /	/ /	/ /	/ /	/ /	/ /
Outside Air Type Code						
Return Air Path Code						
Optimum Start Control (Yes/No)						
AH Schedule Code Weekdays						
Saturday						
Sunday						

Sch. Code: AH - A	☐°F / ☐%																								
	Hr ending at:	1	2	3	4	5	6	7	8	9	10	11	N	1	2	3	4	5	6	7	8	9	10	11	M

Sch. Code: AH - B	☐°F / ☐%																								
	Hr ending at:	1	2	3	4	5	6	7	8	9	10	11	N	1	2	3	4	5	6	7	8	9	10	11	M

System Type Codes

1 Air Handler
2 Packaged Unit
3 Split System
4 Unit Vent./Unit Heat/Fan-coil/HP Units
5 Packaged Multi-zone
6 Packaged Dual Duct
7 Packaged VAV
8 Built-Up Multi-zone
9 Built-Up Dual Duct
10 Built-Up VAV
11 VAV with Induction units
12 Furnace
13 Window Unit
14 Other (describe)

Fan Type Codes

1 Constant Volume
2 Two-Speed
3 Fan Cycles
4 VAV-Inlet
5 VAV-ASD

Outside Air Type

1 None
2 Fixed Damper
3 Fixed Damper Adj. Seasonally
4 Mixed air control
5 Dry-bulb economizer
6 Wet-bulb economizer

Return Air Path Codes

1 Plenum
2 Duct
3 Exhausted

Additional systems are described on another page? ☐Yes / ☐No

Notes:

5. Heating System Inventory

Heating System Code:	HS1	HS2	HS3
Primary Space Code Serviced			
System Type Code			
Fuel Code			
If electric, then: Size (kW)			
Number of Units			
Morning Warm-Up Cycle (Yes/No)			
COP, Efficiency, or HSPF			
Reference Temp for COP & HSPF			
OR Make/Manufacturer			
Model Name/Number			
Hot Water Pump (or hp loop pump) horsepower			
Efficiency (%) OR			
Volts / Phase / Amps	/ /	/ /	/ /
ASD? (Y/N)			

System Type Codes			Fuel Codes
1 Steam Boiler	5 Unit Heater/Ventilator	9 Heat pump, water source	1 Electricity
2 Hot-water Boiler	6 Baseboard	10 Heat pump, ground source	2 Natural Gas
3 Warm-air Furnace	7 Radiant Heater	11 Elec. Storage Heater	3 Fuel Oil
4 Duct Heater	8 Heat pump, air-source	12 Other (describe)	4 LPG 5 Steam

Additional systems are described on another page? ☐Yes / ☐No

Record pumps and fans only if ≥ 2 horsepower, unless predominant system type.

Notes:

6. Air-Conditioning System Inventory

AC System Code:	AC1	AC2	AC3
Primary AHU Code Serviced			
Compressor Type Code			
CFC Refrigerant? (Yes/No)			
Fuel Code			
IF electric: **Nominal Tons (output)**			
Number of Units			
Volts / Phase / FL Amps OR	/ /	/ /	/ /
kW (input)			
EER (rated)			
OR Make/Manufacturer			
Model Name/Number			
Condenser Type Code			
Control Code			
Chilled Water Pump horsepower			
Efficiency (%) OR			
Volts / Phase / Amps	/ /	/ /	/ /
ASD? (Y/N)			
Condenser Water Pump horsepower			
Efficiency (%) OR			
Volts / Phase / Amps	/ /	/ /	/ /
ASD? (Y/N)			
Cooling Tower Fan horsepower			
Efficiency (%) OR			
Volts / Phase / Amps	/ /	/ /	/ /
Fan Control Code			

Note: Record pumps and fans only if ≥ 2 horsepower, unless predominant system type.

Compressor Type Codes		Condenser Type Codes	Fuel Codes
1 Centrifugal Chiller	9 Evaporative	1 Air-Cooled	1 Electricity
2 Screw Chiller	10 Other	2 Cooling Tower	2 Natural Gas
3 Reciprocating Chiller	11 + Cool Storage	3 Evaporative Tower	3 Fuel Oil
4 Packaged DX	**Tower Fan Control**	**Control Codes**	4 LPG
5 Split DX	1 ASD	1 Chilled-Water Reset	5 Steam
6 Heat Pump	2 Two-Speed Motor	2 Condenser Water Reset	
7 Window or Wall Unit	3 Pony Motor	3 Building Purge (describe)	
8 Absorption Chiller	4 Other	4 Other (describe)	

Additional systems are described on another page? ☐Yes / ☐No

Describe compressor sequencing:

7. Water Heating Inventory

Water Heater Code:	WH1	WH2	WH3
Water heater Type Code			
Pump Control Code (NA if no pump)			
Fuel Code			
If electric, then: Size (kW)			
Number of Units			
Temperature Code			
Use Code			
Temperature Control Code			
WH Schedule Code Weekdays			
Saturday			
Sunday			

WH Type Codes	
1	Self-Contained
2	Storage off boiler
3	Heat Pump
4	Tank-less
5	Point-of-use
6	Heat Rcvry. (note)

Control Codes	
1	Temperature
2	Timer
3	EMCS
4	Continuous Op.

Temperature Codes	
1	180°F or higher
2	150–179°F
3	130–149°F
4	110–129°F
5	Less than 110°F

WH Use Codes	
1	Domestic/cleanup
2	Dishwashing
3	Lavatories
4	Showers
5	Central System

Sch. Code:		1	2	3	4	5	6	7	8	9	10	11	N	1	2	3	4	5	6	7	8	9	10	11	M
WH - A	☐°F / ☐%																								
WH - B	☐°F / ☐%																								

(Hr ending at: 1–11, N, 1–11, M)

Notes:

8. Miscellaneous Electrical Equipment

Miscellaneous Equipment Code:	ME1	ME2	ME3	ME4	ME5	ME6	ME7	ME8
Item Code								
Number of Units								
Size (per number of units, kW)								
Spaces Served/Floor Area Affected								
Operating Schedule Weekdays								
Saturday								
Sunday								

Sch. Code:		1	2	3	4	5	6	7	8	9	10	11	N	1	2	3	4	5	6	7	8	9	10	11	M
EE - A	☐°F / ☐%																								
EE - B	☐°F / ☐%																								
EE - C	☐°F / ☐%																								
EE - D	☐°F / ☐%																								
EE - E	☐°F / ☐%																								
EE - F	☐°F / ☐%																								
EE - G	☐°F / ☐%																								

(Hr ending at: 1–11, N, 1–11, M)

Miscellaneous Equipment Codes			Fuel Codes
1 Office Equipment (see note)	8 Escalator	15 Machine tools	1 Electricity
2 Task Lighting	9 Clothes Dryers (electric)	16 Other, Motors or Fans	2 Natural Gas
3 Computer Mainframe	10 Saunas	17 Other, process equip.	3 Fuel Oil
4 Elevator, 2–5 floors	11 Other, Appliance	18 Other	4 LPG
5 Elevator, 6–10 floors	12 Air Compressors		5 Steam
6 Elevator, 11–20 floors	13 Welding		6 Heat Recovery (describe)
7 Elevator, >20 floors	14 Battery Chargers		7 Other (describe)

Office equipment includes computers, terminals, printers, typewriters, copiers, fax machines, coffee makers, room fans, refrigerators, etc.

Notes:

9. Lighting Space Inventory

Code	Space Type	Floor Area	Fixt. Code	Quantity	Ctrl. Code	Ctrl. Qty.	Schedule Codes Week	Sat	Sun
LS1									
LS2									
LS3									
LS4									
LS5									
LS6									
LS7									
LS8									
LS9									
LS10									
LS11									
LS12									
LS13									
LS14									
LS15									
LS16									
LS17									
LS18									
LS19									
LS20									
LS21									
LS22									
LS23									
LS24									
LS25									
LS26									
LS27									
LS28									
LS29									
LS30									
LS31	Exterior								
LS32									
LS33									
LS34									
LS35									

Occupancy Codes

1 Office
2 Retail
3 Grocery
4 School
5 College
6 Fast Food
7 Restaurant
8 Kitchen
9 Assembly
10 Commons
11 Hotel/Motel
12 Mixed-Use
13 Multi-Family
14 Hospital
15 Other Medical
16 Laundry
17 Warehouse
18 Refrigerated
19 Service
20 Industrial
21 Computer Ctr.
22 Mixed-Use
23 Other (describe)

Control Codes

1 Single Switch
2 Double Switch
3 Mixed Switching
4 Step Daylighting
5 Cont. Daylighting
6 EMCS
7 Occupancy / Motion
8 Timer
9 Manual Dimmer
10 Photo Cell
11 Other (describe)

Sch. Code	☐°F / ☐% Hr ending at:	1	2	3	4	5	6	7	8	9	10	11	N	1	2	3	4	5	6	7	8	9	10	11	M
LS - A																									
LS - B																									
LS - C																									
LS - D																									
LS - E																									
LS - F																									

Lighting maintenance as a percent of lamps burnt-out: ________% out.

Notes:

10. Cooking

Restaurant Type

- ☐ 1 Full-Service
- ☐ 2 Fast Food
- ☐ 3 Take-Out Only
- ☐ 4 Cafeteria
- ☐ 5 Tavern + Meal Service
- ☐ 6 Bakery/Donut
- ☐ 7 Pizza Rest.
- ☐ 8 Deli
- ☐ 9 Other

Meals per day

	Qty.	% B	% L	% D
WD				
Sat				
Sun				

Dishwashing

- ☐ 1 None/disposable
- ☐ 2 Manual
- ☐ 3 Single-Tank
- ☐ 4 Conveyor
- ☐ 5 Low-Temp, _____°F

Appliance Inventory

	Counter Appliances	Fuel Code	Total Size (kW, LF, SF, burners, Btuh)	Hood Code		Floor Appliances	Fuel Code	Total Size (kW, LF, SF, burners, Btuh)	Hood Code
1	Broiler/Griddle				1	Broiler/Griddle			
2	Deep-fat Fryer				2	Deep-Fat Fryer			
3	Dry Food Warmer				3	Range, top section			
4	Short-Order Stove				4	Range, oven			
5	Toaster, Continuous				5	Oven, baking			
6	Coffee Urn				6	Oven, Roasting			
7	Steam Table				7	Fryer			
8	Reach-In Refrig'r				8	Charbroiler			
9					9	Convection Oven			
10					10	Self-Contained Refg			

Hood Inventory

	Hood Type	Size (LF, CFM, other)	Make-Up Air Source Code
H-1			
H-2			
H-3			
H-4			
H-5			
H-6			
H-7			

Hood Type Codes	
1	Std. Wall Awning
2	Std. Island Awning
3	Std. Back Shelf
4	Compensating Wall Awning
5	Compensating Island Awning
6	U.L. (Eng.) Wall Awning
7	U.L. (Eng.) Island Awning

Make-Up Air Codes	
1	Conditioned Air
2	AC Cooled
3	Evaporative Cooled
4	Unconditioned
Fuel Codes	
1	Electric
2	Gas

Notes:

11. Refrigeration

Caution: Be sure to exclude refrigerators accounted for under Appliance Inventory, above.

Refrigeration Equipment Code:	R1	R2	R3	R4	R5	R6
Location (space code from form 2)						
Case Type Code						
Temperature Code						
Number of Cases						
Size (see units under case type codes)						
Manufacturer						
CFC Refrigerant? (Y/N)						
Compressor Type Code						
Anti-Condensate Heaters (Y/N)						
Defrost Type Code						
Condenser Type Code						

Case Type Codes

1	Coffin, open (SF)
2	Coffin, closed (SF)
3	Multideck, open (LF)
4	Multideck, closed (LF)
5	Self-contained cabinet (CF)
6	Walk-in (SF)
7	Walk-in/Reach-in (SF)
8	Produce (LF)

Defrost Type

1	Electric
2	Hot-gas
3	Ambient

Temperature Code

1	Ice cream	below 10 °F
2	Frozen food	-10–25°F
3	Fresh Meat & Del	25–36°F
4	Dairy/Produce	36–45°F
5	Beverage	40–65°F

Condenser Type

1	Air-cooled
2	Water-cooled
3	Evaporative cooled

Compressor Type

1	Stand-alone
2	Multiplex

Notes:

12. Pools and Spas

Pool/Spa Code:		P1	P2	P3	P4	P5	P6
Type (pool or spa)							
If inside: Ambient Temperature (Deg. F)							
Fan horsepower or CFM (give units)							
Ventilation Sch.	Typ. Summer						
	Typ. Winter						
Pump Horsepower							
Pump Schedule	Typ. Summer						
	Typ. Winter						
Fuel Code							
If electric: Pool Surface Area							
Surface Water Temperature							
Heater Type Code							
Cover Schedule	Typ. Summer						
	Typ. Winter						

Sch. Code																									
VS - A	☐°F / ☐%																								
	Hr ending at:	1	2	3	4	5	6	7	8	9	10	11	N	1	2	3	4	5	6	7	8	9	10	11	M
VS - B	☐°F / ☐%																								
	Hr ending at:	1	2	3	4	5	6	7	8	9	10	11	N	1	2	3	4	5	6	7	8	9	10	11	M
PS - A	☐°F / ☐%																								
	Hr ending at:	1	2	3	4	5	6	7	8	9	10	11	N	1	2	3	4	5	6	7	8	9	10	11	M
PS - B	☐°F / ☐%																								
	Hr ending at:	1	2	3	4	5	6	7	8	9	10	11	N	1	2	3	4	5	6	7	8	9	10	11	M
CS - A	☐°F / ☐%																								
	Hr ending at:	1	2	3	4	5	6	7	8	9	10	11	N	1	2	3	4	5	6	7	8	9	10	11	M
CS - B	☐°F / ☐%																								
	Hr ending at:	1	2	3	4	5	6	7	8	9	10	11	N	1	2	3	4	5	6	7	8	9	10	11	M

Fuel Codes		Heater Type Codes
1 Electricity	4 LPG	1 Boiler
2 Natural Gas	5 Steam	2 Heat pump
3 Fuel Oil		3 Heat Recovery

Notes:

13. Measure Verification

	Utility Code	Measure Description	Qty. Exp.	ECM Area	Qty. Inst.	Conf. Code	Op. Code	Conf. Code	Apparent Operating Condition (*)
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									

* If ECM absent, describe what is present, if anything.

Confidence Codes	Apparent Operation Codes / Describe
1 No Confidence 2 Low 3 Moderate 4 High 5 Complete	1 Measure is Disabled 2 Measure Unverifiable 3 Poor Operation 4 Fair Operation 5 Good Operation

Notes:

14. Hospital Spaces

Space Type	Units	No. of Units	Notes
Clinical Laboratory	square feet		
Delivery Room	beds		
Diagnostic Radiology	square feet		
EEG	stations		
Emergency Room	beds		
General Patient Rooms	beds		
Intensive Care	beds		
MRI	machines		
Nuclear Medicine	square feet		
Nursery	beds		
Nurses Stations	stations		
Occupational Therapy	square feet		
Pharmacy	square feet		
Physical Therapy	square feet		
Radiation Therapy	machines		
Surgery	suites		

Notes:

Supplementary Schedules

Sch. Code:		Hr ending at:	1	2	3	4	5	6	7	8	9	10	11	N	1	2	3	4	5	6	7	8	9	10	11	M
Sch. Code:	□°F / □%																									
Sch. Code:	□°F / □%																									
Sch. Code:	□°F / □%																									
Sch. Code:	□°F / □%																									
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Sch. Code:	□°F / □%																									
Sch. Code:	□°F / □%																									

Sch. Code:		Month:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sch. Code:	□%													

Sch. Code:		Month:	Jan	Feb	Mar	Apr	Macy	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sch. Code:	□%													

Sch. Code:		Month:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sch. Code:	□%													

Notes:

D

GLOSSARY

Glossary of Selected Terms

As-built Usage: The energy use of a building or end use. The as-built usage may be different from the billing data due to adjustments for occupancy and weather effects.

Billing Analysis: A method used to estimate program impacts that relies on analysis of customers' energy bills. Billing analyses range from simple bill comparisons to complex econometric models.

Baseline: An concept used to describe behavior or state of being in absence of a DSM program. The baseline is generally unobservable and must be inferred through models.

DOE-2: An engineering analysis software program developed by the Department of Energy to simulate the hourly energy use of buildings.

Efficiency Choice Model: A statistical model used to explain variation in efficiency levels across different buildings. The models can estimate the change in efficiency levels associated with characteristics, such as different building types, and program participation. The models used in this project involved the estimation of two equations to estimate the impact on efficiency levels due to program participation while controlling for potential self-selection bias.

Efficiency Level Index: A measure of the efficiency level for each building and end use. The index is equal to the reference case energy use divided by the as-built energy use.

EUI: Energy Use Index: The energy use per square foot of floor space in a commercial building. An end-use EUI represents the energy use per square foot of a given end use.

Expected Measure Life: The predicted average life of a DSM measure.

Free Driver: A customer who installs DSM measures or changes their energy use because of a program but is not a program participant.

Free Rider: A program participant who would have installed the DSM measures covered by the program even if the program was not offered.

GLSME: Generalize Least Squares Mixed Estimation: A statistical regression technique that can be used to calibrate engineering estimates to billing data. Similar to the SAE and realization rate models.

Gross Impacts: The energy savings that result from the adoption of DSM measures. Gross savings depend on how the DSM measures are defined. In this study, the gross impact is defined as the difference between the as-built electric usage and what the electric usage would have been if the building were built with "reference case" equipment and building shell characteristics.

Incremental Measure Cost: The difference in price between that of an efficient technology or measure and the alternative standard technology.

Levelized Cost: An equal payment per unit over the life of the resource, taking into account assumed discount or interest rates; a mortgage payment is an example of a levelized cost.

Market Transformation: The changing of long-term behavior through various market interventions.

Net-to-Gross Ratio: A ratio of net impacts divided by gross impacts.

Net Impacts: The total change in energy use caused by the offering of the program in a given time frame.

Realization Rate Model: A statistical regression technique that can be used to calibrate engineering estimates to billing data. Similar to the SAE and GLSME models.

Reference Case: A defined set of building shell characteristics and equipment efficiencies that is used for reference purposes. The reference case is used to create the efficiency level index for each building and end use.

Reference Case Usage: The estimated energy use of a building or end use that has been built using reference case characteristics and equipment. The reference case usage is used with the as-built usage to create the efficiency level index for each building and end use.

SAE: Statistically-adjusted Engineering: A statistical regression technique that can be used to calibrate engineering estimates to billing data. Similar to the realization rate and GLSME models.

Self-selection Bias: A bias that can occur in a quasi-experimental design where customer select themselves to be either participants (treatment group) or nonparticipants (control group).

Spillover: Net program impacts that are not directly attributable to the measures installed as part of the program.

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